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# MEMOIRS OF THE GEOLOGICAL SURVEY

OF THE

# UNITED KINGDOM.

THE

# JURASSIC ROCKS

OF

# BRITAIN.

## VOL. IV.

## THE LOWER OOLITIC ROCKS OF ENGLAND (YORKSHIRE EXCEPTED).

BY

HORACE B. WOODWARD, F.G.S.

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# PREFACE.

The present work, forming the fourth volume of the Monograph on the Jurassic Rocks of Britain, contains an account by Mr. H. B. Woodward of the Lower Oolitic Rocks of England lying to the south of the Yorkshire district already described in the first volume.

The same general plan of treatment has been continued as was adopted in describing the Lias. Each sub-division of the Lower Oolitic series is first sketched in regard to its leading stratigraphical and palæontological characters, and then local details are given to illustrate the variations which the strata present as they are followed along the strike across the country. A general description follows of the influence of the Lower Oolitic rocks upon the scenery and the soils of the districts where they occur; their economic products are then enumerated, and an account is added of their relation to the question of water-supply.

In the Preface to Volume III. attention was called to various early geological maps of the Jurassic areas of England, and likewise to the maps of the Geological Survey. In regard to the Memoirs of the Survey much assistance has been derived from them by Mr. Woodward in the preparation of the present volume, especially from those dealing with the Lower Oolitic rocks, by Prof. Hull, Prof. Green, Prof. Judd, Mr. Ussher, and Mr. Jukes-Browne.

Besides the large number of stratigraphical sub-divisions generally recognised in the series of formations described in the following chapters, many more have been based by palæontological writers upon the local horizons of species. The number and real value of such palæontological zones and horizons must obviously depend a good deal upon individual views concerning species. In adopting broad palæontological sub-divisions rather than minutely defined and often merely local zones, Mr. Woodward has been guided by the evidence he has been able himself to gather from a careful study of the sections in the field, together with the aid supplied by the palæontological determinations made for him by his colleagues, Messrs. G. Sharman and E. T. Newton. In this general Memoir, which is intended to present a broad but detailed picture of the subject of which it treats, it would obviously be impossible to enter into such minute particulars as are mainly of local interest, or belong rather to the domain of the specialist in some restricted field of palæontological research.

The literature of the subject, probably more extensive than that of the Lias, has so far as is possible been attentively studied. It is intended that a full bibliography shall appear in the next volume which, treating of the Middle and Upper Oolites, will conclude the account of the Jurassic rocks of England and Wales.



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Amidst the work of the older observers, the original labours of William Smith, which must always hold the foremost place, are commemorated in the names given by him to many of the chief sub-divisions of the Oolites. He was followed by Conybeare, Buckland, Lonsdale, John Phillips, and Murchison. The writings of these geologists on the Oolites were largely stratigraphical. To a succeeding generation we owe the determination of the chief palæontological horizons, and among those no longer living we are indebted mainly to James Buckman, Thomas Wright, John Lycett, John Morris, Samuel Sharp, and Edwin Witchell. Among living geologists who have largely added to our knowledge of the Jurassic rocks, the names of Mr. W. H. Hudleston and of Mr. S. S. Buckman, who have done so much in the Inferior Oolite, should be specially mentioned.

In the field Mr. Woodward has received much friendly personal assistance from the Rev. H. H. Winwood of Bath, Mr. S. S. Buckman of Stonehouse, Mr. W. C. Lucy of Gloucester, Mr. E. Wethered of Cheltenham, Prof. Allen Harker of Cirencester, Mr. T. J. Slatter of Evesham, Mr. E. A. Walford of Banbury, and Mr. Beeby Thompson of Northampton. From their published papers great help has likewise been derived, as will be seen from the references to these throughout the volume.

The fossils collected by the author, excepting only such forms as could be safely identified in the field, have been named by Messrs. Sharman and Newton; who now perform the duties which were formerly discharged so well by Mr. Etheridge for the earlier Jurassic Memoirs.

Mr. Teall has examined and reported upon a large number of microscopic sections of Oolitic rocks, and we are under obligations to Mr. J. H. Player for some analyses of Fuller's Earth.

For some of the illustrations in this volume, as will be seen from the list in the Table of Contents, we have to acknowledge the courtesy of the Council of the Geological Society in permitting the use of blocks from the Quarterly Journal of the Society, and of Dr. Henry Woodward in supplying others from the Official Guides to the Department of Geology in the British Museum. A few clichés appear from my text book of Geology, and some of the cuts are reproduced from former Survey Memoirs. But most of the figures of fossils have been engraved for this work, the sources from which the drawings were made being acknowledged in the List of Illustrations.

ARCH. GEIKIE,
Director-General.

Geological Survey Office,
28, Jermyn Street, London,
17th January 1894.

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THE

# LOWER OOLITIC ROCKS

OF

# ENGLAND

(YORKSHIRE EXCEPTED).

## CHAPTER I.

## INTRODUCTION.

*The term Oolitic—General Character and Thickness of the Rocks—Physical Conditions of the Period—Sequence of Strata and Extent of the Formations.*

THE Oolitic rocks form a series far more interesting and diversified than the Lias upon which they rest. Over parts of the area the two divisions occur in uninterrupted sequence, but there is a broad difference between the essentially argillaceous formation of the Lias, and the alternating series of limestones, sands, and thick beds of clay, of which the Oolitic group is composed.

Most of the limestones are characterized by a structure resembling the roe of a fish, such as the cod: hence the name "roestone" came to be applied by the quarrymen, and this has been translated, in the language of science, into Oolite. Rocks of this character were described by Pliny,* but the term *Oolithus* appears to have been first introduced as a petrological name in 1727 by F. E. Bruckmann.† It was not until 1803 that the name Oolite was applied in a stratigraphical sense, and then it was used by A. J. M. Brochant de Villiers.‡ Eventually through the labours of William Smith, followed by those of Conybeare,

* See J. Morton, Nat. Hist. Northamptonshire, 1712, pp. 99, 248.

† The name is mentioned in Bruckmann's Historia Naturalis curiosa Lapidis, 1727, p. 7. See Da Costa, Nat. Hist. Fossils, 1757, p. 130; also J. Kidd, Outlines of Mineralogy, vol. i., 1809, p. 26; and Jameson, System of Mineralogy, vol. i. p. 504.

‡ Minéral. elem., vol. i. pp. 523, 529.

Buckland, and others, the names Inferior and Great Oolite, Coralline or Oxford Oolite, and Portland Oolite, came to be applied to different beds of limestone in the Oolitic Series.

The general sequence that has been established in the Jurassic rocks of this country, has been mentioned in the previous volume on the Lias. In that formation the main divisions can be followed across the country from Dorsetshire to Yorkshire; while in regard to the Oolites distinct stratigraphical divisions are necessary in different parts of the area, owing to the inconstant character of some of the subdivisions, and more especially those of a calcareous and arenaceous nature. The limestones characterized by oolitic structure are as a rule conspicuously current-bedded, and they, together with the sandy sediments, were evidently deposited in comparatively shallow water; while the clays, as a rule, indicate the sediments of deeper water that were further removed from the land.

We have thus to deal with a series that exhibits marked changes in the thickness and character of its numerous divisions; for the total thickness varies from about 1,500 to nearly 3,000 feet. Evidences of terrestrial conditions are afforded in the Northampton Sand and in the Purbeck Beds; but the only direct evidence of an old land-area (probably of an island) is met with in the Mendip Hills, where conglomeratic beds of Inferior Oolite rest on the Carboniferous Limestone. Indirect evidence is otherwise afforded of the nearness of land, whether of islets or portions of a continent it is difficult to say. This evidence is gathered partly from the pebbly character of the Lower Calcareous Grit and Portlandian Beds, and partly from the estuarine nature of other strata, a character which becomes developed in portions of the Lower Oolitic Series as we proceed from the south-west of England in a north-easterly direction into Yorkshire. The evidence of the proximity of land and of estuarine conditions, is derived from the occurrence of much lignite and of certain Mollusca: while the occurrence, as at Stonesfield, of plants and terrestrial animals, is indicative perhaps of an island. In the Northampton Sand we have layers penetrated by rootlets; and in the highest of the Jurassic Rocks, the Purbeck Beds, we find remains of the growth *in situ* of Cycads and Conifers, as well as beds of distinctly freshwater origin. It should be noted, however, that the presence of lignite, or even of leaves, seeds, and fruits, affords no indication of the depth of water in which beds may have been deposited, as such remains have been dredged from a depth of over 1,500 fathoms off the West Indies.*

The Oolitic Series, so far as our area is concerned, is broken only by the local absence of one or more of its members, an absence that may in some cases be attributed to contemporaneous erosion and in others to cessation of sediment. There are no facts to tell of any great and wide-spread discordance such as would be produced by considerable upheaval and erosion.

* A. Agassiz, Nature, January 21, 1892, p. 281.

Eastwards of the Cotteswolds we have higher members of the Inferior Oolite overlapping lower members (from W. to E.); and in this Midland region we have evidence of unconformable overlap of the Great Oolite Series, which traced from Lincolnshire into Northamptonshire (from N.E. to S.W.), rests in places on lower and lower portions of the Inferior Oolite Series. Again in the eastern part of Northamptonshire and in Bedfordshire, the Great Oolite Series rests on attenuated beds of the Inferior Oolite Series, and finally overlaps them, so as to rest directly on the Lias. In some localities there is more marked evidence of local disturbance and erosion between members of the Great and Inferior Oolite. (See Fig. 51, p. 188.) Again in the area extending from Bath to Dorsetshire, we find a considerable overlap of the Forest Marble where it stretches across the Great Oolite on to the Fuller's Earth, and this overlap was probably attended by local erosion. (See Fig. 80, p. 255.)

With regard to the former extent of the Oolites, we have no evidence whatever for marking the limits of their formation west of the main outcrop. Eastwards and south-eastwards, we know that Oolitic rocks are absent beneath the Cretaceous and Tertiary coverings at Harwich and Ware; but some members of the series have been proved in deep borings at Richmond, under London, at Streatham, Chatham, and Dover. In this subterranean area, as in the Boulonnais, the Great Oolite is found to have overlapped the lower members of the Oolitic Series and the Lias, so as to rest directly on the Palæozoic floor: and it is not unreasonable to conclude that land existed in the area during some portions of the Jurassic period. (See p. 360.) We cannot tell for certain how far the absence of Jurassic beds in the eastern portions of England (Harwich, Ware, &c.) may be due to denudation prior to the Upper Cretaceous period; but we know that much destruction took place locally in Lower Cretaceous times, from the unconformable overlap of the Lower Greensand, and from the occurrence of derived Jurassic fossils in that formation in Bedfordshire and other parts.

The general relationship of the leading sub-divisions of the Oolitic Series is shown in the Table on page 4; and the principal local breaks are indicated by wavy lines.

The several subdivisions of this Series are all more or less intimately linked together: thus the Midford Sand links the Lias with the Inferior Oolite; and the Fuller's Earth (which is intimately connected with the Stonesfield Slate) links the Inferior Oolite with the Great Oolite. It appears likely that the uppermost portion of the Inferior Oolite in Oxfordshire, locally known as the Chipping Norton Limestone, is coeval with portions of the Fullers Earth Clay elsewhere. Again, the Cornbrash and Kellaways Rock, and the succeeding beds of the Middle and Upper Oolites are all closely bound together, and locally pass up into the Wealden Beds without any evidence of a break in the succession. In Lincolnshire, as pointed out by Mr. A. Strahan, there is evidence of unconformable overlap between the Kimeridge Clay

## TABLE SHOWING THE SUBDIVISIONS OF THE OOLITIC SERIES.

| | Dorsetshire to Frome. | Vale of Wardour, Bradford-on-Avon, to Bath. | Swindon, Stroud, Cheltenham, to Stonesfield. | Aylesbury, Oxford, Brackley, Towcester, Northampton. | Lynn, Ely, Peterborough, Kettering, Stamford. | Market Rasen, Ancaster, Lincoln. |
|---|---|---|---|---|---|---|
| Upper Oolites. | Purbeck Beds. | Purbeck Beds. | Purbeck Beds. | Purbeck Beds. | (Not known). | Spilsby Sandstone. |
| | Portland Beds. | Portland Beds. | Portland Beds. | Portland Beds. | (Not known). | |
| | Kimeridge Clay. | Kimeridge Clay. | Kimeridge Clay. | Kimeridge Clay. | Kimeridge Clay. | Kimeridge Clay. |
| Middle Oolites. | Corallian Beds. | Corallian Beds. | Corallian Beds. | Corallian Beds. | Ampthill Clay, &c. | Corallian Clay. |
| | Oxford Clay and Kellaways Rock. | Oxford Clay and Kellaways Rock. | Oxford Clay and Kellaways Rock. | Oxford Clay and Kellaways Rock. | Oxford Clay and Kellaways Rock. | Oxford Clay and Kellaways Rock. |
| Lower Oolites. | Cornbrash. | Cornbrash. | Cornbrash. | Cornbrash. | Cornbrash. | Cornbrash. |
| | Forest Marble and Bradford Clay. | Forest Marble and Bradford Clay. | Forest Marble and Bradford Clay. | Forest Marble and Great Oolite Clay - | Great Oolite Clay (Blisworth Clay). | Great Oolite Clay. |
| | | Great Oolite. | Great Oolite. | Great Oolite. | Great Oolite Limestone. | Great Oolite Limestone. |
| | | | Stonesfield Slate. | Upper Estuarine Series. | Upper Estuarine Series. | Upper Estuarine Series. |
| | Fullonian or Fuller's Earth. | Fuller's Earth. | Fuller's Earth. | | | |
| | Inferior Oolite. | Inferior Oolite. | Inferior Oolite. | | Lincolnshire Limestone. Collyweston Slate. | Lincolnshire Limestone. |
| | Midford Sand (Passage Beds). | Midford Sand. | Midford Sand. | Lower Estuarine Series and Northampton Sand. | Lower Estuarine Series and Northampton Sand. | Lower Estuarine Series and Northampton Sand (Dogger). |

and Spilsby Sandstone, and although the latter contains Portlandian fossils, yet these bear evidence of having been derived; and the most that can be said on behalf of the Jurassic age of the Spilsby Sandstone, is that it may include representatives in time of the Purbeck Beds.

The divisions into Upper, Middle, and Lower Oolites, adopted by the Geological Survey, are practically the same as those employed by Conybeare in 1822; they are simply divisions that are convenient for purposes of local description.

In upward sequence we have to deal therefore with deposits that represent an alternating series of sedimentary conditions; and although a comparatively small part of each formation is opened to view, yet the general characters of the chief subdivisions are maintained along the line of strike northwards from Dorsetshire to the northern end of the Cotteswolds. The general strike turns in an easterly direction from the Cotteswold region to Northampton, and there we find evidence of the more important changes in the nature of the calcareous and arenaceous beds. The great clay-formations, on the other hand, while varying in thickness, maintain fairly uniform lithological characters across England; and even in the far north of Scotland, some of the Oxfordian clays and Kimeridgian shales are identical in character with equivalent beds in the south of England.

### "*Tripartite*" *Series.*

In subdividing the strata, Conybeare and Phillips remarked on the apparent regularity of the sequence of clay, sand, and limestone that characterizes the larger divisions; and the subject has been more fully discussed by John Phillips and others.

Phillips explains the matter "on the simple and sure basis of interrupted depression of the sea-bed." He says, "In the cases before us the liassic sea-bed first receives only the finest sediments which can fall in deep water; by degrees these sediments accumulate so as to bring the sea-bed near enough to the surface for the drift and settlement of the fine sand of Midford and Frocester: on this sandbank flourish colonies of coral and shells, and constitute the basis of the Inferior oolite. Depression follows; the deposit again becomes argillaceous 'fuller's earth'; shallow water succeeds, and the Stonesfield banks of sand and shells appear, followed by the Great oolite rock. Less distinctly the same things occur and recur; and the cornbrash ends this series."

"Next we have a long depression marked by 600 feet of Oxford clay, followed by the fine sandbank of calcareous grit, on which corals and oysters and many forms of life grew in profusion."

"Again the same things are repeated for the Kimeridge clay, Portland sands, and Portland oolite."

"It deserves remark that the three orders of deposits, clays, sands, limestones, are so much alike in the several groups as to be in fact hardly distinguishable by hand specimens; they seem all to have been derived from similar sources—from neighbouring shores and lands, with no importations from afar." *

* Geology of Oxford, &c., pp. 393, 394. See also Seeley, Physical Geology and Palæontology, 1885, p. 54.

The following Table shows the varying nature of the supposed Tripartite series :—

| Formations. | Leading Lithological Characters. | Grouping of John Phillips.* | Grouping of Conybeare and W. Phillips.† |
|---|---|---|---|
| Purbeck Beds | Limestones and clays. | | |
| Portland Beds | Limestone<br>Sand | Calcareous<br>Arenaceous | Limestone.<br>Sand. |
| Kimeridge Clay | Clay | Argillaceous | Clay. |
| Corallian Beds | Limestone<br>Sand | Calcareous<br>Arenaceous | Limestone.<br>Sand. |
| Oxford Clay | Clay | Argillaceous | Clay. |
| Kellaways Rock | Sand. | | |
| Cornbrash | Limestone | Calcareous | |
| Forest Marble | Clay and sand<br>Limestone<br>Clay | Arenaceous<br>Argillaceous | |
| Great Oolite | Limestone | Calcareous | Limestone. |
| Stonesfield Slate | Sand and limestone | Arenaceous | |
| Fuller's Earth | Clay<br>Limestone<br>Clay | Argillaceous | |
| Inferior Oolite | Limestone | Calcareous | |
| Midford Sand | Sand | Arenaceous | Sand. |
| Upper Lias | Clay | Argillaceous | |
| Middle Lias | Limestone.<br>Sand.<br>Clay. | | Clay. |
| Lower Lias | Clay.<br>Limestone. | | |
| Rhætic Beds | Limestone.<br>Clay. | | |

It will thus be seen that the so-called "tripartite series" is by no means constant, and that the exceptions are almost as frequent as the rule. Especially is this the case when we come to trace the divisions from the south of England through the Midland counties into Yorkshire. Nevertheless considering the matter in its local aspects it is deserving of some attention. As a rule we are taught that the sands were formed near shore, the clays further off, and the limestones in the deeper water. In the case of the oolites, however, the evidence tends to show that most if not all of them must have been accumulated as shore-formations in shallow water ;‡ and it is desirable to consider their origin before proceeding further.

### *Oolitic Rocks.*

The term oolite in a petrographical sense is usually restricted to rocks that contain small roe-like grains having a concentric and radiate, or simply a concentric or radiate structure, formed

* Geol. Oxford, p. 393.

† Outlines of Geol. England and Wales, pp. 165–167.

‡ See also Duncan, Quart. Journ. Geol. Soc., vol. xxxix. p. 196.

usually of crystalline layers of carbonate of lime, mostly calcite but sometimes aragonite. These grains are often replaced by ferruginous compounds and rarely by silica. The grains though small are variable in size, and are usually spherical but sometimes oval; and in other instances the shape bears relation to the nucleus around which the calcareous coating has been deposited.

Many rocks however that present an oolitic appearance, prove on microscopic examination to be very largely composed of structureless grains or pellets; and some, like those of the Coral Sands of the West Indies, are composed largely of tiny rounded and spherical fragments, with or without a thin envelope of calcareous matter.

Fig. 1.

*Microscopic Structure of Oolitic Limestone* (after Sorby).
*Magnified* 30 *Diameters.*

Examination in the field, and with the aid of a hand magnifying glass, is insufficient to enable a discrimination to be made between the rocks chiefly formed of true oolitic grains, and those more largely composed of pellets or rounded fragments of organisms. Thus some of the Lower Purbeck beds are composed of granular limestone in which true oolitic grains form but a subordinate portion.

In some instances we find three or four oolitic grains in the midst of a pellet, as in the Inferior Oolite of Sleaford. Compound oolitic grains also occur, and occasionally we find mechanical additions amid the encircling oolitic growths, as in the Corallian limestone of Keevil. Some of the mud-pellets in the Great Oolite of Burford, as noticed by Mr. Teall, look as if they had been slightly pressed together when in a soft state. (See p. 19.)

Among the Jurassic rocks, oolitic grains occur in the Lias, Inferior Oolite, Great Oolite, Forest Marble, Corallian Beds, Portland Beds, and Purbeck Beds.

In the Lower and Middle Lias they occur mainly in the ironstone; but, both in those formations and in the Inferior Oolite, we often find tiny spheroidal grains of oxide of iron (limonite), or "iron-shot" grains, that as a rule exhibit no structure. In these cases, as in some of the Lower Lias limestones, it does not follow that the particles replaced were originally oolitic granules: they may have been pellets of limestone or rolled fragments of organic remains.

In a yellow and blue-hearted oolite which I obtained from the Lincolnshire Limestone of Castle Bytham, Mr. A. B. Dick found the grains in the blue rock to be coated with a thin film of pyrites, and the grains in the exterior yellow portion to be coated with a film of limonite, evidently produced by the oxidation of the pyrites. The division between the blue and yellow oolite was very sharply defined, and cut through individual grains of oolite. By the action of weak acids, the grains were dissolved and the coatings left intact, forming beautiful objects for examination under the microscope. In both cases the matrix itself was colourless and transparent. (See Plate I., p. 26, fig. 4.)

In the Corallian Beds again we have the oolites that are locally replaced by iron-ore, as at Westbury and Abbotsbury. (See Plate II., p. 29.)

Sometimes the grains occur in a calcareo-arenaceous paste, as in certain layers of the Stonesfield Slate, and in sandy beds of Corallian age. In the Forest Marble we have the oolitic grains disseminated amid comminuted fragments of shell, furnishing evidence of some reconstruction or reassortment of material.

### *Petrological Notes on the Oolitic Rocks. By J. J. H. Teall, F.R.S.*

#### *The Limestones.*

These rocks exhibit considerable variations in colour and texture. Some are nearly pure white, others bluish-grey, others again cream colour, buff, yellow, or brown. Yellow and brown tints are especially characteristic of surface-rocks, and are evidently due to the oxidation of the iron present in bluish-grey varieties, such as are found in deep well-borings (*e.g.*, Great Oolite of Streatham), and in the interior of blocks from deep quarries. Having regard to texture, and the character of the recognizable constituents of the rocks, we may distinguish three principal types; compact, shelly and oolitic. The compact varieties are seen, by the aid of the microscope, to consist essentially of extremely minute granules of calcareous matter, and may be regarded without fear of error as resulting from the accumulation of excessively fine calcareous mud (*e.g.*, Fuller's Earth Rock and some beds of Great Oolite Limestone). By the coming in of shell fragments and oolitic grains the compact type passes into the shelly or oolitic type. In fact no hard and fast line can be drawn between the different rocks.

The shelly limestones consist mainly of shell-fragments, and the oolitic limestones of spherical or ellipsoidal grains of calcareous matter—the so-called oolitic grains. The matrix in which the shell-fragments or oolitic grains are embedded, may consist of fine-grained calcareous mud similar to that of which the compact limestones are mainly composed, or of clear crystalline calcite, or of mixtures of these substances. The shelly and oolitic types are of course connected together by intermediate varieties. In a few cases there is no matrix at all; the oolitic grains having been merely soldered together at their points of contact by minute crystals of calcite (*e.g.*, Inferior Oolite freestones of Weldon and Stamford).

There is a variable amount of what may be termed ordinary non-calcareous detrital material, the nature of which is best studied by the microscopic examination of the residues left after treating the rock with acid.

By an increase in the amount of excessively fine-grained argillaceous material, the compact limestones are connected with the clays; and by an increase in the amount of coarser arenaceous material the shelly and oolitic limestones pass into sandstones.

I will now consider the constituents of these rocks in greater detail dealing with them in the following order:—I. Oolitic Grains; II. Organic Fragments; III. Non-calcareous Detrital Material; IV. Matrix.

### I. *Oolitic Grains.*

Spherical or ellipsoidal grains ("rice-grains") which vary in size from that of small shot to that of peas, and which consist for the most part of carbonate of lime, enter largely into the composition of the rocks under consideration. These grains may be classified as follows:—

(1.) Rolled fragments of organic bodies.
(2.) Amorphous pellets without any recognizable structure.
(3.) Grains showing a rude concentric arrangement, *e.g.*, the pisolites, in which Girvanella-structure is common.*
(4.) Grains showing both concentric and radial structures with reference to one or more nuclei.
(5.) Compound grains made up of oolitic grains, shell-fragments, &c.

The investigation of the more minute structures of these grains under the microscope is attended with considerable difficulty, in consequence of the want of transparency in the grains. Extremely thin sections are required, and even then the structures are often very indistinct.

The typical oolitic grain is one which shows both radial and concentric structure. In a very thin section such a grain will give an ill-defined black cross in polarized light. It is made up largely of minute particles or fibres of calcite, which have their principal axes roughly arranged in a radial manner with reference to the centre of the grain. The surfaces of some of these grains are seen to be rough in consequence of the projection of excessively minute crystals of dog-tooth spar. The indefiniteness of the black cross proves that the radial arrangement of the axes of the crystalline particles is only approximately realized.

That the typical oolitic grain, above referred to, is the result of growth by accretion appears certain. It is probable, however, as Dr. Sorby has pointed out,† that this growth is not a simple chemical process but a combination of chemical and mechanical processes, such as the crystallization of carbonate of lime and the mechanical picking up of foreign matter. There does not appear to be satisfactory proof that the growth of organisms of the

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* More particular accounts of "*Girvanella*," are given on pp. 15, 16.

† Address to Geol. Soc. 1879; Quart. Journ. Geol. Soc., vol. xxxv. (Proc.), pp. 74, &c. See also Zirkel, Lehrbuch der Petrographie, Ed. 2, vol. i., 1893, pp. 484–489; and Bleicher, Comptes Rendus, vol. cxiv., 1892, p. 1138.

Girvanella type, has played an important part in the formation of the concentric and radiate portions of oolitic grains; but the growth of minute Algæ, as suggested by Dr. Rothpletz, may have influenced the formation of the grains.

Oolitic grains vary considerably in the character of their nuclei. These may consist of quartz grains, amorphous pellets, pellets with Girvanella-structure, fragments of oolitic grains, organic fragments (Foraminifera, and fragments of Mollusca, Corals, and Echinoderms), complete oolitic grains with amorphous material, &c.

The structure of the pisolitic grains differs from that of the typical oolitic grains, for they exhibit a rude kind of concentric structure, and radial structure is absent. It is in these grains that the Girvanella-structure is best seen. Assuming Girvanella to have been an incrusting organism, the feature of these grains may be explained by supposing the interstices between the Girvanellæ-tubes to have become filled up with calcareous mud. That the pisolites have picked up foreign matter is proved by the occasional occurrence of sand-grains in them.

So far reference has been made only to calcareous oolitic grains. In some rocks the oolitic grains are formed of concentric layers of deep brown ferric oxide. In these oolites the nuclei often consist of broken oolitic grains. In other ferruginous oolites (*e.g.*, Cleveland) rhombs of carbonate of iron are present and the true structure of the interior portions of the grain has been lost.

An example of silicified oolite has also been obtained by Mr. Woodward from the cherty Portland Beds of Dorsetshire.

### II. *Organic Fragments.*

The Organic remains that have been found in the Oolitic rocks include Calcareous Algæ, Foraminifera, Ostracods, and fragments of Corals, Echinoderms, Annelides, Polyzoa, Brachiopods, and Mollusca.* Such remains have been observed by Dr. Sorby and Mr. E. T. Newton. In some cases the original structure of the organic remains is preserved; in others it has been destroyed by re-crystallization.

### III. *Non-calcareous Detrital Material.*

Among the residues of the Oolitic rocks, in addition to Quartz, I have found Oligoclase, Plagioclase, Rutile, Tourmaline, Garnet, and Zircon. The insoluble residues of the Inferior Oolite of the Cotteswold Hills have been studied by Mr. E. Wethered; and he shows that the beds, from the Pea Grit Series to the Ragstones, contain from 1 to 5 per cent. He notes mica, and silicate of alumina, as well as some of the minerals above noted.†

### IV. *Matrix.*

Reference has already been made to the general characters of the matrix; one feature, however, deserves special mention.

* For illustrations, see Carpenter, Rep. Brit. Assoc. for 1844, p. 1; 1848, p. 93.

† Quart. Journ. Geol. Soc., vol. xlvii. p. 559.

The phenomenon known as "lustre-mottling" is shown in some of the oolitic freestones of Barnack, Ketton, and Ancaster, and in the sandy limestone of Dene Mill, Great Weldon. It occurs also in calcareous grits associated with the Kimeridgian rocks in Sutherlandshire and near Cromarty. Attention was first called to such appearances in calcareous grit by Sedgwick, who referred to it as "chatoyant lustre."*

These appearances are seen on a fractured surface of a rock when the lustre from the cleavage of a mineral is broken, and as it were "mottled," by the occurrence of inclusions. In the case of the oolites, the mottling is produced by the oolite grains that are included in the matrix of calcite; and in calcareous sandstones the grains of quartz act in the same way. In the freestone associated with the Barnack Rag the oolite grains, showing concentric and radial structure, are embedded in a matrix of clear crystalline calcite. The individuals of calcite are of immense size, far more than sufficient to fill the field of view of a 1¼ inch object glass. The oolite grains lie in the crystalline individuals of the matrix, as do the grains of sand in the Fontainebleau Sandstone.

### *Origin of Oolitic Grains.*

The first question of importance is whether the oolitic structure is original or secondary. I have seen no evidence in the slides to suggest that it is secondary. The occurrence of oolitic rocks without any matrix, and the presence of broken oolitic grains, are facts which point strongly to the conclusion that the structure is original. Assuming then that the structure is original we have to consider the causes which may have given rise to it. Rounded fragments of organic bodies are easily accounted for by the ordinary process of mechanical attrition. The origin of pisolitic grains is more complex; Girvanella-growth and mechanical picking up of foreign bodies have both operated. An important question arises as to whether this picking up is purely a mechanical process or whether it may not have been facilitated by the simultaneous precipitation of carbonate of lime from solution. In the case of the typical pisolitic grains it is not easy to answer this question. The oolitic grains showing concentric and radial structure certainly appear to have grown by deposition of the kind referred to. Minute crystals and granules were deposited on the surfaces of the grains. Nevertheless it is probable that even in the case of these grains the growth was not solely due to this cause; but that it was supplemented by the picking up of extraneous particles. If the grains had resulted solely from crystalline deposition we should expect to find them more transparent and the individual grains of a simpler and more uniform character than is actually the case.

As regards the amorphous pellets so common in many rocks and which frequently constitute the nuclei of oolitic grains;

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* Trans. Geol. Soc., ser. 2, vol. iii. p. 464.

these appear to be rolled fragments of the calcareous mud which was accumulating under the influences of the decomposition and attrition of calcareous organisms, combined it may be with Girvanella-growth and the precipitation of minute calcareous particles from solution.

There may be recognized then in the formation of oolitic grains the operation of a variety of causes:—

(*a.*) Mechanical movements.
(*b.*) Organic growth, *e.g.*, Girvanella.
(*c.*) Deposition of carbonate of lime from solution.

The interstices may have been filled up at the time by calcareous mud, or subsequently by the deposition of calcite. In a few rare cases the rock is made up of the larger fragments of oolitic grains, and rolled organic fragments without any cement at all. Thus, in an example of oolite (Lincolnshire Limestone) from Weldon, there was no matrix. The oolite grains were joined together at the points of contact, and their external surfaces were rough in consequence of the projection of excessively minute crystals of calcite.*

As regards those oolites which contain a large amount of carbonate of iron of the type of the Cleveland ironstone, and the blue varieties of Northamptonshire ironstone, there seems no reason to doubt that they have originated, as Dr. Sorby has maintained, by the subsequent replacement of carbonate of lime by carbonate of iron.

The calcareous rocks with detached oolitic grains, composed mainly of ferric oxide, are difficult to account for on the hypothesis of replacement subsequent to formation.—J. J. H. T.

### *Sandstones.*

The sandstones, of which examples are found in the Inferior Oolite, Stonesfield Series, Forest Marble, Corallian Beds, Kellaways Beds, Portland and Purbeck Beds, consist of angular and sub-angular grains of quartz, cemented by a matrix of crystalline or granular calcite.

In a fine-grained sand (Midford Sand) from Seizincote near Stow-on-the-Wold, J. A. Phillips noted the occurrence of grains of sand, which are generally angular, but in some instances "their more acute angles appear to be slightly rounded." He observed also numerous fragmentary crystals of schorl and garnet.† The ferruginous sandstone of Duston, which was examined by Mr. Teall, showed angular quartz grains, occasionally also flakes of white mica, and probably some felspar, cemented by ferric oxide, and with some carbonates in places.

Concretionary masses of Sandstone or Doggers occur in the Midford and Northampton Sands, in the Collyweston and Stonesfield Slate series, in the Forest Marble (Hinton Sand), in the

* See also A. Harker, Naturalist, 1890, p. 302.
† Quart. Journ. Geol. Soc., vol. xxxvii. p. 16.

Kellaways Rock, Lower Calcareous Grit and Portland Sands. These appear in all cases to be cemented by calcareous matter, and hence the Doggers when exposed are liable to rapid decay. That the masses were hardened *in situ* is shown by the occurrence of laminæ of bedding and false-bedding in some of the spheroidal doggers; and when split up the upper and lower portions often present the aspect of "pot lids."* They furnish as it were one stage in the formation of sandstone, evidence of which is well shown in some of the quarries in the Lower Calcareous Grit of Berkshire, and in the sands associated with the Collyweston Slate.

### *Colour of Rocks.*

The limestones and clays, which at the surface present various shades of buff and brown, are usually bluish-grey at a depth—the difference being due generally to the peroxidation of the protosalt of iron. (See p. 8.)

The blue or grey colour of strata, especially of clays, may be due to the presence of carbonaceous matter; it is also due in some cases to carbonate of protoxide of iron;† and in others to sulphide of iron.‡ Six or seven per cent of iron-ore is commonly found in the Jurassic clays. Analyses of Kimeridge Clay show in some cases carbonate of iron and bisulphide of iron in quantities of not more than 1 to 2 per cent.

Silicate of iron gives a green colour to the cores of some ironstones; and in the form of Glauconite it gives a similar colour to many sands and sometimes to calcareous rocks, of which examples occur in the Portland Beds.

Of pure white earthy limestones like some varieties of Chalk, we have examples in the Purbeck Beds, Portland Beds, Kimeridge Clay (occasional bands), and Great Oolite; in the same beds the layers are sometimes compact like the White Lias, which occurs in the upper part of the Rhætic Beds.

The Inferior Oolite is blue-hearted in places in Dorsetshire, but not as a rule markedly so when quarried in the west of England. Nor do we find that the Great Oolite in the country near Bath presents these bluish tinges; in fact where quarried at a depth near Corsham it comes out as a buff or yellow freestone. Under London, however, the rock is bluish-grey, and contains 2·40 per cent. of sulphide of iron in the form of pyrites.§ (See p. 7.)

In the Midland counties we find more distinct evidence of bluish-limestones even when the beds are quarried near the surface. In this region there are protecting clays in the Upper Estuarine Series, in the Great Oolite Clay, and in the Boulder

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* See also De la Beche, Researches in Theoretical Geology, p. 95.

† G. Maw, Quart. Journ. Geol. Soc., vol. xxiv. pp. 356, 357, 366; Judd, Geol. Rutland, p. 176, and Quart. Journ. Geol. Soc., vol. xl. p. 741.

‡ See also paper by Ebelmen (quoted by Judd), Bull. Soc. Géol. France, ser. 2, tome ix. p. 221; and A. H. Church, Quart. Journ. Chem. Soc., ser. 2, vol. ii., p. 379.

§ C. Homersham, Quart. Journ. Geol. Soc., vol. xl. p. 726.

Clay. Some layers in the Lincolnshire Limestone, especially those near the clay-covering, are stained various shades of red.

The Forest Marble is very generally of a bluish colour as the stone-beds are interstratified with clays.

### *Stratigraphical characters of Oolitic rocks.*

The stratigraphical evidence shows that the rocks now under consideration, which are mainly composed of oolitic grains, are all more or less false-bedded, and sometimes minutely current-bedded: hence the grains must have been formed before they were drifted and accumulated in their present positions.

Comminuted shells occur in some of the oolitic limestones, and we find gradations from beds composed of oolitic grains to those mainly formed of shell-fragments.

The tranquilly-deposited strata, that are associated with these false-bedded oolites, are white more or less earthy limestones and marls, that contain in places scattered oolitic grains or clusters of them; they also yield occasional quartz grains.

Of such beds we have instances in the Oolite Marl of the Inferior Oolite of the Cotteswolds, in the Lincolnshire Limestone near Lincoln, in the Fuller's Earth Rock, and in the White Limestones of the Great Oolite.

Sandy sediments containing oolitic grains are also met with, in the Great Oolite and Corallian Series.

In some of these beds we have evidence of Coral-growths. They occur not *in situ* in the false-bedded freestones, but in the earthy limestones and marls that are developed at different horizons in the series of more or less oolitic limestones: in the Oolite Marl of the Inferior Oolite, in the white limestones of the Great Oolite, in the Coral Rag above the Coralline Oolite.

It may be said that the occurrence of masses of oolitic freestone is thus associated with Coral-growths, and that the formation of the granules is more or less dependent on nuclei, and on the disturbed condition of the waters in which they were formed.

That oolite granules are formed under other conditions, is well known; and further reference will be made to this matter. In the case also of the oolitic ironstone of the Middle Lias, there is no particular evidence of current-bedding to point to a disturbed condition of the waters.

### *Pisolite.*

Of the little concretions known as Pisolite, the best known examples occur in the "Pea Grit" at the base of the Inferior Oolite of the Cotteswold Hills. There are however equally important layers in the Corallian Beds near Sturminster Newton and elsewhere. More particular reference to these will be given in the chapters that refer to the several formations.

It should however be mentioned that Mr. E. Wethered in 1889* announced the discovery in the Pisolites, both of the

* Geol. Mag., 1889, p. 196.

Inferior Oolite and Coralian Rocks, of a minute tubular organism similar to that previously described from the Lower Silurian (Ordovician) Rocks of Ayrshire, under the name of *Girvanella problematica* by Dr. H. A. Nicholson and Mr. R. Etheridge, jun.*

The *Girvanella* has been compared with certain forms of Foraminifera described by Dr. H. B. Brady under the names of *Syringammina fragilissima* and *Hyperammina vagans*; branching organisms, the latter of which is found "spreading in irregular tortuous lines over the surface of shells or stones, or, in the absence of foreign bodies, growing coiled upon itself in irregular masses."†

It is interesting to note that forms provisionally identified with *Girvanella*, occur in the oldest fossiliferous rocks, for Mr. C. D. Walcott recognizes an organism of similar character in the *Olenellus*-zone.‡ Whether the form is a Sponge, a Rhizopod, or an Alga, is at present uncertain.

It is interesting to note that in his account of the Bahamas (1852), Captain R. J. Nelson remarks that "The marshy lands, that are gradually taking the place of the creeks and brackish lakes, abound with, and may be said at some points to consist largely of a highly calciferous moss-like Conferva"; and he further describes this accumulation "as a spongy mass of laterally aggregated and much-interwoven *fasciculi* of tubes, perhaps $\frac{1}{100}''$ in diameter."§

In 1890 Mr. Wethered brought forward evidence to show that *Girvanella*-tubes occurred in the true oolitic granules of the Inferior Oolite (freestone) at Chedworth, and also in the Coralline Oolite; and he maintained that the spherules in question were not concretions, but due to a variety of *Girvanella*—the so-called pisolitic granules being in his opinion "really formed by the growth of an organism around a nucleus."||

It is admitted that the shape of the pisolites depends upon the form of the nucleus, but the tubes of *Girvanella* appear to be plastered around the nuclei and often to be twisted about in a very irregular manner; so that it occurred to both Mr. Teall and myself that the *Girvanella* might have been derived mechanically from the calcareous mud of the sea-bed.¶ (See p. 10.)

Resemblances to "*Girvanella*"-structure were noticed by Mr. Teall in the nucleus of oolitic grains in the Osmington oolite, and in the margin as well as in the centre of some of the pisolitic concretions from Stower. (See Plate I., p. 26, fig. 1.) "*Girvanella*"-structure was well shown in the pisolite of Sturminster Newton, and, in his opinion, mechanical picking up of foreign matter must also have played a part in the growth of the pisolite, because the grains contain quartz-fragments. The same structure appears in the nuclei of some grains from the Great Oolite of Farley Down, in pellets in the "Scallett Bed" (Great Oolite) of Box, and in the Great Oolite of Calmsden and Rodmarton. Obscure "*Girvanella*"-structure was seen in pisolitic grains from the Inferior Oolite of Ancaster.

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* Monograph of the Silurian Fossils of the Girvan District in Ayrshire, vol. i., 1880, pp. 23, 24, Plate ix., fig. 24; and Nicholson, Geol. Mag., 1888, p. 22.

† "Challenger" Reports, vol. ix. p. 242, fig. 9.

‡ Tenth Ann. Rep. U. S. Geol. Survey, Part 1, p. 598.

§ Quart. Journ. Geol. Soc., vol. ix. p. 210.

|| Quart. Journ. Geol. Soc., vol. xlvi. pp. 275, 276, and 282; and vol. xlvii. p. 553.

¶ *Ibid.*, vol. xlvii. p. 570.

Some of the granular limestones in the Lower Purbeck Beds contain organic fragments, with a thin coating that shows concentric and radiate structure; and they also comprise more or less rounded pellets, often similarly coated, and showing obscure resemblances to "*Girvanella*"-structure.

In some instances, as pointed out by Lycett, Polyzoa are found adhering to the pisolites;* and I have found Serpulæ and small Oysters attached to them at Crickley.

Witchell has remarked that "The passage of fragments of shell, and other particles of which the nuclei consist, along a sea bottom covered with a calcareous muddy deposit, portions of which became attached to the moving fragments as they were carried onward, might account for the concentric layers which compose the pisolites."† He notes also the occurrence of oolite grains, as well as rounded fragments of limestone and organic remains in the Pea Grit.

Again Messrs. Blake and Hudleston, in referring to the Corallian pisolite of North Dorsetshire, remark that the beds "seem to indicate that they are the result of irregular currents bringing material that had been rolled about for some time in a calcareous ooze."‡

The facts favour this general explanation of the formation of the pisolitic limestones; while the influence of incrusting organisms may have played a part in their production. It is, however, not unlikely, as lately suggested by Mr. C. Reid, that the filaments of Algæ, attached to tiny pebbles, assisted in the deposition of calcareous matter, and to the subsequent decay of these filaments may be due the tiny tubes of the so-called *Girvanella.*§

*Origin of Oolite and of strata associated with Oolitic limestones.*

In considering the origin of oolite we have first to inquire whether similar accumulations are now in process of formation.

Fitton in 1835 remarked on the many points of resemblance between the top beds of the Portland series and the recent agglomerated limestones of Bermuda and the shores of Australia.‖ As pointed out previously, the resemblances between such limestones and the characteristic oolites are mostly superficial.

Specimens of recent limestones from St. Helena, Bermuda, and Bahama, as remarked by Dr. Sorby, consist largely of rounded grains of Corallines, Corals, Balani, and Mollusca, together with Foraminifera; while others show the organic structure but imperfectly preserved or so crystallized with the mud that their structure and outline have been lost.¶

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* Cotteswold Hills, p. 38.

† Geology of Stroud, p. 44; Proc. Cottesw. Club, vol. viii. p. 35.

‡ Quart. Journ. Geol. Soc., vol. xxxiii. p. 278.

§ See remarks at meeting of Geol. Soc., Mar. 8, 1893; Quart. Journ. Geol. Soc., vol. xlix. (Proc.), p. 143.

‖ Proc. Geol. Soc., vol. ii. p. 186. See also R. J. Nelson, Trans. Geol. Soc., ser. 2, vol. v. p. 103.

¶ Address to Geol. Soc., 1879; Quart. Journ. Geol. Soc., vol. xxxv. (Proc.), p. 74.

On some of the islets connected with the Australian barrier, there are beach-deposits that contain true oolitic grains, as described by Jukes.

He mentions a stone "made up of small round grains, some of them apparently rolled bits of coral and shell, but many of them evidently concretionary, having concentric coats. It was not unlike some varieties of oolite in texture and appearance . . . Some parts of it made a very fair building-stone, but it got softer below, till it passed downwards into a coarser coral sand, unconsolidated and falling to pieces on being touched . . . many recent shells, more or less perfect, were found compacted in the stone, and one or two nests of turtle eggs were discovered . . . It is evident from the fossil turtle eggs, that the consolidation of the stone had taken place after it was raised above the sea. It was due, probably to the infiltration of the rain water percolating through the calcareous sand, that had been gradually piled above high-water mark by the combined action of the winds and waves."*

These facts are of especial interest when we note the occurrence of Reptilian eggs in the Great Oolite of Cirencester.

Moreover it is stated that while the beach is often composed of coarse fragments of worn corals and shells, hardened beds not infrequently stand out above high-water mark to a height of 6 or 8 feet, and at angles of 6° or 8°.†

Dana mentions that the "sand-rock" is sometimes drifted into hillocks or ridges by the winds, and afterwards consolidated, and this rock is more or less friable, and frequently oolitic.‡ Captain R. J. Nelson observed the same features in the Bahamas, where the "calcareous sand" is heaped up irregularly by the wind, so as to produce false-bedding.§ Dana remarked that some of the beach-deposits become cemented by being alternately moistened and dried, through the action of the recurring tides and the wash of the sea on the shores. "The waters take up some carbonate of lime, and this is deposited and hardens among the particles on the evaporation of the moisture at the retreat of the tides. In some places the grains are loosely coherent, and seem to be united only by the few points in contact; and with a little care the calcareous coating which caused the union may be distinctly traced out. In other cases, the sand has been consolidated into a solid limestone rock, the interstices having been filled till a compact mass was formed. Generally even the most solid varieties show evidence of a sand origin, and in this they differ from the reef rock . . . In most localities the rock is an oolite or oolitic limestone. The grains become coated by the agglutinating carbonate of lime, and each enlarges thus into a minute sphere—a spherical concretion; and the aggregation of these concretions makes the oolite . . . At certain localities the beach sand-rock has been washed away after it was formed; and occasionally large masses or slabs have been uplifted by the sea and thrown high up on the beach . . . Deposits of the same kind sometimes include detritus from the hills."||

It is a study of these sedimentary and other accumulations, due to the destruction of Coral-reefs, that will help to explain the origin of our oolitic deposits. The reefs themselves forming fringes or barriers along the coast are more or less solid beds of limestone, presenting an unstratified appearance, attaining in places a con-

* Voyage of the "Fly," vol. i. pp. 127, 128, 340.
† Jukes, *op. cit.* pp. 1–3.
‡ Corals and Coral Islands, 1872, pp. 154–156.
§ Quart. Journ. Geol. Soc., vol. ix. p. 206.
|| Dana, Corals and Coral Islands, pp. 152, 153, 348.

siderable thickness, and being made up of Corals and partly of Mollusca, Polyzoa, Echinoderms, Annelides, Sponges, Calcareous Algæ, and Foraminifera, cemented and compacted by infiltration of carbonate of lime. Dr. H. B. Guppy says that Coral-rock in the Solomon Group is from 70 to 100 feet thick, rarely 150, and at most 200 feet.* It corresponds with the limit of depth at which corals appear to thrive.

Among the oolitic rocks we have no reef of any magnitude. We have bands made up almost entirely of Corals in the Inferior Oolite, in the Great Oolite, and in the Corallian rocks; but they do not extend over large areas, nor are they of great thickness, seldom attaining more than 10 feet. Moreover the Coral-beds are often more or less earthy, with bands of marls, whereas Coral-rock is comparatively pure. Prof. J. F. Blake has remarked that the rarity of corals in the Portland rocks may account for the scarcity of oolitic beds.†

Dana remarks that in Coral-reefs "The rock of the outer reef, wherever broken, exhibits usually a compact texture. In some parts it consists of coral fragments, rounded or angular, of quite large size, firmly cemented. Other portions are a finer coral breccia or conglomerate. Still others, more common, are solid white limestones, as impalpable and homogeneous in texture as the old limestones of our continents. There are also other regions where the corals in the rock retain the original position of growth." Dr. Guppy also speaks of chalky coral-limestone, like the Chalk formation, made up of decomposed coral and calcareous algæ. Sometimes the rock is magnesian.

Dana also says that "The deposits of sand or coral mud over the bottom of the seas outside of barrier reefs are sometimes of great extent. These sands are the fine detritus which the return flow of the breakers bears seaward; and, in still deeper water, the deposits should be of the finest calcareous sand or mud—fit material for impalpable compact limestones. The waters outside of the reef, especially when moved by heavy tidal currents or storms, are often milky with the coral sand; and while the coarser sand is dropped near the shores, the finer may be carried for miles and distributed far out to sea."‡ The formation of oolitic coral-limestone, and the deposition of chalky silt over wide areas, has been observed, by Prof. A. Agassiz, in his studies of the Tortugas and Florida Reefs.§

In very many respects therefore we find that the chief features of our oolitic rocks are repeated in the accumulations connected with Coral-reefs. We have the granular and oolitic limestones, the pure white limestones, the pebbles or rolled masses of oolite, the coral conglomerate or coral rag, &c.; while the false-bedded character of so many of the oolites is seen also in the shelving banks of coral-sand and oolitic mud that fringe the Coral-reefs and islands.

Dr. Guppy has noted the presence in the Solomon group of beds largely made up of Rhynchonellas, forming a *Rhynchonella*-limestone, such as may be compared with the Brachiopoda-beds in the Lower Oolites. Capt. R. J. Nelson observed the occurrence

* Trans. R. Soc. Edin., vol. xxxii. p. 545.

† Quart. Journ. Geol. Soc., vol. xxxvi. p. 191.

‡ Dana, Corals and Coral Islands, pp. 138, 142, 351; and John Murray, Nature, Feb. 28, 1889, p. 424.

§ Mem. Amer. Acad. Arts & Sci., vol. xi. 1885, pp. 115, 125, 128, &c.

in the Bermudas and Bahamas of thick Serpuline reefs, made up largely of *Serpulæ;* and of such layers we have examples in the Inferior Oolite, and in the Portland Beds.

The formation of oolite has been discussed by Mr. Hudleston, who, basing his conclusions on the observations of Dana, remarks that oolite is for the most part *granulated coral mud.** Thus the fine calcareous mud, or chalky silt, that is worn from the reefs may be carried away great distances and deposited as ordinary sediment. Nearer to the reefs the matter that subsides "encounters an acid stratum of water, due to the quantity of carbonic acid generated by the decomposition of organic matter and the respiration of animals." The same acid is also conveyed to sea water from the atmosphere by rain. By the aid of this acid the soluble bicarbonate of lime is formed from the calcareous sediment as it subsides, but in its downward passage the excess of carbonic acid is no longer found, and the calcic carbonate is precipitated amongst the interspaces or on particles of the slowly settling mud.

Sorby stated his opinion that the normal oolitic grains "indicate the original deposition of calcite round nuclei gently drifted along by currents of the ordinary temperature."† It would thus seem that the grains were formed in agitated water in which were present minute particles of quartz, Foraminifera, and fragments of other organic remains; and that the water was charged with much carbonate of lime in solution. The mechanical impurities acted as nuclei around which the carbonate of lime was deposited, while the grains were kept in motion, so that all sides would be encrusted. (See also p. 14.)

This explanation is not inconsistent with that applied long ago by Werner to the "Sprudelstein," of Carlsbad. There "particles of sand are raised in the water by means of air-bubbles, and become covered with calcareous earth, which is deposited around them in lamellar concretions."‡ When the particles become too heavy to be thus supported they subside. The opinion has also been expressed that thin films of carbonate of lime have sometimes been formed around the air-bubbles, from which the globules of oolite have been formed by further accretions.

Among the Oolitic rocks that have been examined under the microscope, there are some that show granules with but a thin coating of calcareous matter. Where the nuclei were very heavy they were rolled over and plastered with layers of mud and *Girvanella*, as in the case of the Pisolites.

Other grains of oolite come closely in contact and appear to be welded together and partially indented. It is remarkable that these features are represented in calculi, which show both the radial and concentric structure of ordinary oolite grains.§

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* Proc. Geol. Assoc., vol. v. p. 431, and Gasteropoda of Inf. Oolite, p. 22. See also Phillips, Geol. Oxford, p. 396; Wright, Proc. Cotteswold Club, vol. iv. p. 97; vi. p. 136; and Fox-Strangways, Jurassic Rocks of Yorkshire, vol. i. pp. 398, &c.

† Address to Geol. Soc. 1879, Quart. Journ. Geol. Soc., vol. xxxv. (Proc.), p. 75.

‡ Jameson's Mineralogy, ed. 3, vol. ii. p. 540.

§ See Figs. 3 and 4, pp. 11 and 12, of G. Rainey's Mode of Formation of Shells of Animals, of Bone, and of several other structures. 8vo. London, 1858. See also Sorby, Address to Geol. Soc., 1879; reprint with plates, Plate XVI., fig. 1.

The association of algous growth with the deposition of travertine, in connection with the warm mineral waters of Carlsbad, has been shown by Dr. F. Cohn, and the subject has been discussed at some length by Mr. W. H. Weed.*

The connection between calcareous algæ and oolitic granules has been suggested by several authorities.† Such algæ often enter largely into the composition of recent Coral-rock.

The oolitic granules in our Jurassic rocks would appear to have been in most, if not in all cases, of inorganic origin; but the chemical deposition of calcareous matter may have been influenced by the presence of algous growths, as they abstract carbonic acid from the water.

The modern formation of "oolitic sand" on the shores of Lake Bonneville, in Utah, has been noticed by Mr. G. K. Gilbert. It constitutes the materials of a beach and is drifted shoreward in dunes. In one locality its formation is near the mouth of a stream, and in another it is connected with hot calcareous springs.‡ Here again we have the formation of oolitic granules in waters subject to commotion. Mr. I. C. Russell states that oolite is now forming on the borders of Pyramid Lake, Lahontan, Nevada: it occurs near warm springs, and some of the granules are an inch in diameter. The nuclei are sand-particles, &c.§

Mr. C. Reid informs me that oolitic concretions, that exceed the size of hazel-nuts, have been formed by a calcareous spring that issues from the Oligocene limestone at Totland Bay, in the Isle of Wight.‖

It is interesting to note that the soundings marked over the sea-bed in the northern area of the Great Barrier reefs, show in different places coral sand, coral fragments, mud, mud and sand, and sand.¶ Such varying accumulations are taking place in some places near the reefs; and in others near the mainland where no reefs occur and where river borne sediments may be distributed. While such facts indicate the variable nature of the sea-bed, the general conditions of a Coral-region may help to account for some of the local successions of clay, sand, and shallow-water limestone to which attention has been drawn. Dana has given particulars of borings in Coral-regions that show alternations of sand, coral-rock, and clay to depths of 700 and 1,000 feet.**

Clays form what has been termed the "normal" (that is the more prevalent) type of sediment during the Jurassic period;†† and they were deposited over certain areas until gradually the increase of sediment, or changes in physical conditions affecting currents, brought about the deposition of sands. Finally the freedom from muddy sediments furnished conditions favourable to the growth of Corals, and the old lands were bordered in places by reefs. Such reefs, whether Fringing or Barrier reefs, afford protection to the land, as pointed out by Jukes, so that the rarity or absence, in deposits associated with them, of detrital material from the land is accounted for. Thus fine calcareous sediment may be deposited

* Ninth Ann. Rep. U.S. Geol. Survey, 1889, pp. 631, 642, &c.

† H. G. Seeley, Rep. Brit. Assoc. for 1888 (1889), p. 675. Dr. A. Rothpletz, Botanisches Centralblatt, No. 35, 1892 (Amer. Geol., vol. x. p. 279).

‡ Lake Bonneville, Monogr. U.S. Geol. Survey, vol. i. p. 169.

§ Monogr. U. S. Geol. Survey, vol. xi. pp. 61, 168.

‖ Geol. I. of Wight (Geol. Survey), ed. 2, p. 299.

¶ Chart attached to Jukes' Voyage of the "Fly," vol. i.; see also W. Saville-Kent, Great Barrier Reef of Australia, 1893.

** Amer. Journ. Science, ser. 3. vol. xxxvii. p. 96.

†† See J. F. Blake, Rep. Brit. Assoc. for 1879, p. 335; and Nature, 1879, p. 470.

along the coast-line, for the heavy surf is confined to the outer reefs. On this outer side were accumulated the sediments due to the wear and tear of the reefs, and the oolitic granules that were formed by chemical agency. In drawing these conclusions we cannot however argue that reefs of similar character and magnitude existed in Oolitic times: we can only infer that the general conditions were similar.*

Hence, although Coral-reefs played an important part in the history of the Oolites, the larger reefs that may have existed must have been destroyed by the agents that laid down the successive deposits. These notions receive support when we notice in the Oolites themselves, evidences of reconstruction, and the occurrence of small rolled masses of previously formed oolite in later accumulations.

The growth of reef-building Corals at the present day is dependent on the temperature of the surface-waters, and the presence of currents that keep up the food-supply, as well as on the purity of the water. They flourish only in comparatively shallow water. As Dana has remarked, the "Facts seem to indicate—though perhaps not sufficient to demonstrate—that the Gulf Stream has had, from the Jurassic period in Geological history onward, the same kind of influence on the temperature of the North Atlantic Ocean which it now has."†

While many of the Jurassic Mollusca belong to genera that have a wide range, most of their living representatives taken together suggest a warm if not tropical character, and very many of them are such as now exist in association with coral-reefs. Among these are *Nautilus*, *Anomia*, *Arca*, *Astarte*, *Avicula*, *Cardium*, *Cucullæa*, *Cypricardia*, *Lima*, *Modiola*, *Ostrea*, *Pecten*, *Bulla*, *Cerithium*, *Delphinula*, *Natica*, *Nerita*, *Patella*, '*Phasianella*,' *Pleurotomaria*, *Pterocera*, *Rostellaria*, *Solarium*, *Trochus*, and *Turbo*. Polyzoa, Serpulæ, Echinoderms, Foraminifera, and Sponges are likewise abundant in the neighbourhood of reefs.

### *Fossils of the Oolitic Series.*

The assemblages of fossils met with in each division are found to vary according to the sedimentary conditions. Thus the organic remains of the purer false-bedded oolites or "freestones" differ from those of the more earthy and more slowly deposited "ragstones."‡ In successive deposits of similar nature there is some repetition in the forms of life. Thus *Terebratula maxillata* abundant in the purer marly limestone of the Inferior Oolite (Oolite Marl) occurs plentifully in rocks of similar lithological character in the Great Oolite; in the Collyweston Slate and Stonesfield Slate there are some identical species; and long ago Prof. Buckman compared the fauna of the ragstones of the

* See descriptions by Jukes, Voyage of the "Fly," vol. i. pp. 332, 333, 343. In early geological times, reefs of more extensive character may have existed. See Dana, *op. cit.* p. 353. See also Tomes, Quart. Journ. Geol. Soc., vol. xl. p. 354.

† Dana, *op. cit.* p. 362; Duncan, Rep. Brit. Assoc. for 1869, p. 166.

‡ Hull, Geol. Cheltenham, p. 61 Quart. Journ. Geol. Soc., vol. xvi. p. 72; see also Judd, Geol. Rutland, &c., p. 49.

Inferior Oolite with that of the very similar sediments of the Cornbrash: in both are some identical or closely allied species of *Echinobrissus* and *Clypeus*, of *Arca*, *Astarte*, *Cardium*, *Ceromya*, *Cypricardia*, *Gervillia*, *Goniomya*, *Gresslya*, *Hinnites*, *Lima*, *Modiola*, *Myacites*, *Pholadomya*, &c. In comparing the successive formations of clay, like the Oxford and Kimeridge Clay, we do not find any marked repetition of specific forms. Some species of *Astarte*, *Goniomya*, *Modiola*, *Pecten* and *Thracia* are however common to the two formations. Cephalopoda are abundant in both, but the species are with few exceptions distinct.

General remarks on the fauna and flora of the Jurassic rocks have been given in the introductory portion of the Memoir on the Lias of England and Wales (Yorkshire excepted).

In the Oolitic rocks one of the most noteworthy facts is the preservation of Mammalian remains in the Stonesfield Slate and Purbeck Beds.

Among the Reptiles some winged forms occur, but the Dinosaurians are more prominent. Some of the bones of the *Cetiosaurus* are of gigantic size, one femur measuring upwards of 5 feet in length. Remains of *Megalosaurus* and *Omosaurus* are likewise characteristic; while of the Crocodilians, *Teleosaurus* and *Steneosaurus* are the more abundant forms. Turtles are preserved in the Stonesfield Slate, Portland and Purbeck Beds, and occasionally remains of them are found in other formations.

Fishes are abundant, more particularly species of *Lepidotus*, *Mesodon* ("*Pycnodus*"), *Strophodus*, and *Asteracanthus*.*

Ammonites and Belemnites are most abundant in the clays, and in some of the earthy limestones. They are rare in the false-bedded oolites. In these oolites we find occasional bands of Corals; and, as remarked by Prof. Duncan, Cephalopods and Saurians are rarely found in relation with them.

Among the Gasteropods, *Nerinæa* and *Purpuroidea* make their appearance, and other forms such as *Amberleya*, *Alaria*, *Cerithium*, *Pleurotomaria*, and *Pseudomelania* are fairly abundant. Of Lamellibranchs *Astarte*, *Avicula*, *Lima*, *Pecten*, *Cardium*, *Ceromya*, *Isocardia*, *Trigonia*, *Pholadomya*, *Myacites*, and *Ostrea* are the more conspicuous forms.

Brachiopods occur in the oolitic limestones, in rich fossil-beds. Polyzoa have been found in abundance in the Inferior Oolite and Great Oolite Series; but few traces have at present been recorded from the Corallian rocks where they might have been expected. Echinodermata are plentiful in the limestones; and some being of a gregarious nature, large numbers of one species of Echinoid such as *Acrosalenia* and *Hemicidaris* are occasionally met with at a particular locality. Among the Crinoids, such forms as *Apiocrinus* and *Millericrinus* furnish characteristic species; and there are also *Comatulæ* or Feather Stars of the genus *Antedon*.†

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* See A. S. Woodward, Proc. Geol. Assoc., vol. xi. p. 285; vol. xii. p. 238.

† Portions of *Antedon* have been described under the name *Solanocrinus*. See Moore, Geol. Mag. 1875, p. 627.

Plant-remains occur conspicuously in the Lower Purbeck Beds, and occasionally at other horizons, as in the Stonesfield Slate.

The collector must bear in mind that many localities regarded as specially fossiliferous, owe their celebrity to the energy of resident geologists. Thus Minchinhampton, which furnished Dr. Lycett with so many treasures from the Great Oolite, yielded them only after much toil and time and money had been expended.

Attention has already been drawn to the subject of Zones, so that a more particular consideration of them may be reserved for discussion in connection with the several stratigraphical divisions.

Strictly speaking, Zones must be named from forms that are wide-spread, and only an extended knowledge can justify their introduction. Vague as the limits of Zones must necessarily be; they are naturally better represented in a series of clays, than in the false-bedded oolites.

In addition to Ammonites, Belemnites and Brachiopods many species of which are wide-spread, there are other forms of life that are useful locally to mark horizons. They are rather to be considered as characteristic fossils than as zonal species. Thus some species of *Avicula*, *Gryphæa*, *Trigonia*, of Echinoids and other fossils, serve locally to indicate horizons in the Oolitic rocks; but while a number of the species appear to be thus restricted, other species of the same genera have a considerable duration in time.

Prof. Phillips devoted much attention to the subject of the succession of various life-forms,* and the accompanying Table will serve to illustrate some of the species that may thus be selected as characteristic of, though not in all cases confined to, particular stages.

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* Geology of Oxford, &c., p. 399; see also H. B. W., Proc. Geol. Assoc., vol. xii. p. 305.

TABLE OF SOME LEADING ZONAL AND CHARACTERISTIC FOSSILS OF THE OOLITIC STRATA.

| | | | | |
|---|---|---|---|---|
| Purbeck Beds and Spilsby Sandstone. | | Belemnites lateralis. | Ostrea distorta. | |
| Portland Beds. | Ammonites giganteus. | | Ostrea expansa.<br>Perna mytiloides.<br>Exogyra bruntrutana. | |
| Kimeridge Clay. | Am. biplex.<br>Am. alternans. | | Ostrea deltoidea. | Discina latissima.<br>Lingula ovalis.<br>Rhynchonella inconstans. |
| Corallian Beds. | Am. plicatilis.<br>Am. perarmatus. | Bel. abbreviatus. | Ostrea solitaria.<br>O. gregaria. | |
| Oxford Clay. | Am. cordatus.<br>Am. Lamberti.<br>Am. Jason. | Bel. hastatus.<br>Bel. Oweni. | Gryphæa dilatata. | |
| Kellaways Rock. | Am. calloviensis. | | G. bilobata. | |
| Cornbrash. | Am. macrocephalus. | | Ostrea flabelloides. | Terebratula intermedia.<br>Waldheimia obovata.<br>—— lagenalis. |
| Forest Marble and Great Oolite Clays. | Am. discus. | | Ostrea Sowerbyi.<br>O. subrugulosa. | Waldheimia digona. |
| Great Oolite. | Am. arbustigerus. | Bel. bessinus. | | Terebratula maxillata. |
| Fuller's Earth. | Am. subcontractus. | Bel. parallelus. | O. acuminata. | Waldheimia ornithocephala. |
| Inferior Oolite. | Am. Parkinsoni.<br>Am. humphriesianus.<br>Am. Murchisonæ. | Bel. aalensis. | Gryphæa sublobata. | Terebratula globata.<br>Waldheimia carinata.<br>Terebratula fimbria. |
| Midford Sands (passage-beds). | Am. opalinus.<br>Am. jurensis. | | | Rhynchonella cynocephala.<br>Terebratula infra-oolitica. |

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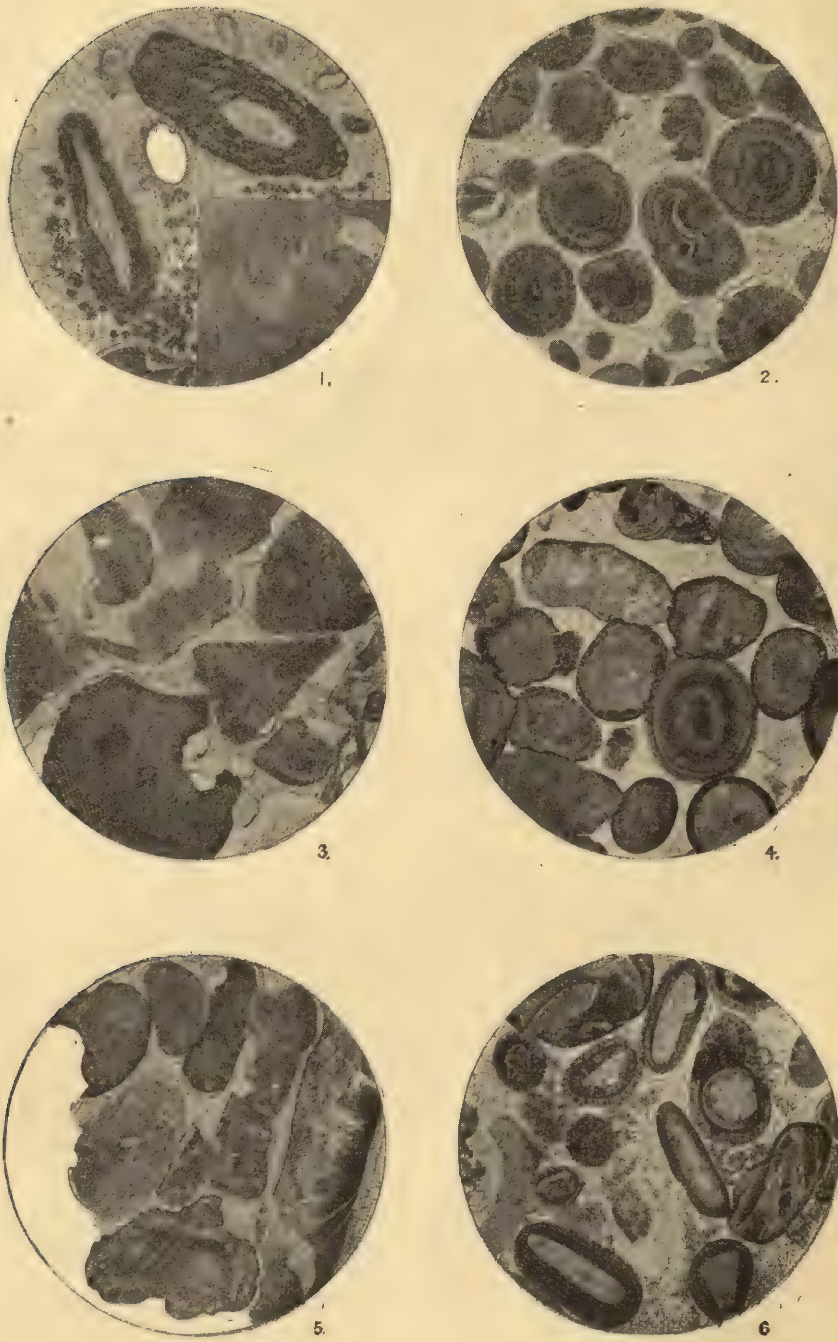
JURASSIC ROCKS OF BRITAIN, VOL. IV.

PLATE I.




MICROSCOPIC SECTIONS OF OOLITIC AND OTHER LIMESTONES.

Drawn by H. W. Gilbert Williams.

## Explanation of Plates.

### By J. J. H. Teall, F.R.S.

### Plate I.

Fig. 1.—Pea Grit, Inferior Oolite, Stroud, Gloucestershire.

Pisolitic bodies showing irregular accretions of calcareous mud and organic fragments around organic nuclei, in a matrix of crystalline calcite.

Pisolitic and Oolitic Limestone, Coralline Oolite, Stower, Dorsetshire. (*Portion shown in quadrant.*)

The margin of some of the pisolitic bodies shows a very minute form of Girvanella-structure, which is somewhat more obscure in the centre. One organic fragment is shown.

Fig. 2.—White Oolite, Upper Freestone, Inferior Oolite, Nailsworth, Gloucestershire.

Composed of grains showing very fine concentric and radial structure, in a matrix of perfectly clear crystalline calcite.

Fig. 3.—Granular Limestone, Inferior Oolite, Doulting, Somersetshire.

Clastic organic fragments, sometimes rounded, sometimes angular, in matrix of clear crystalline calcite. The secondary calcite surrounding the fragments is in optical continuity with that of the fragments themselves, so that the structure of the rock is analogous to that of quartzites in which secondary enlargement of the original grains has taken place.

Fig. 4.—Blue and brown oolitic Limestone, Lincolnshire Limestone, Castle Bytham, Lincolnshire.

Oolitic grains, showing concentric and radial structure, and pellets enclosing organic fragments.

On the unweathered oolitic grains there are crusts of pyrites, which give the blue colour to part of the rock; in the brown portions the material is limonite, as determined by Mr. A. B. Dick. The weathered and unweathered portions are separated by a sharp plane of division.

Fig. 5.—Pisolitic and shelly Limestone, Lincolnshire Limestone, Greylees Quarry, Sleaford, Lincolnshire.

Organic fragments, pellets, and compound pellets enclosing oolitic grains, &c. Some of the larger pellets contain three or four oolitic grains in a matrix of calcareous mud.

The general matrix is crystalline calcite. There is however, between the coarse-grained calcite, and the outer margin of the grains and pellets, a narrow zone of calcite in the form of minute crystals of the dog-tooth spar variety; the points projecting outwards and thus giving the external surface of the grains a very rough aspect.

Fig. 6.—Oolitic and shelly Limestone, Forest Marble, Corsham, Wiltshire.

Organic fragments without oolitic incrustations; and oolitic grains showing concentric and radial structure. The nuclei of the oolitic grains comprise amorphous calcareous matter (pellets); organic fragments; and broken oolitic grains. The matrix is clear crystalline calcite.

## Plate II.

### Fig. 7.—Iron-ore, Lower Lias, Frodingham, Lincolnshire.

Oolitic grains of ferric oxide showing concentric structure; also grains which appear to be pseudomorphs (in ferric oxide) of rolled organic fragments. Matrix of calcite.

### Fig. 8.—Iron-ore, Middle Lias, Eastwell, Leicestershire.

Organic fragments (noted by Mr. E. T. Newton as shells of Molluscs, Echinoderm plates, and calcareous Algæ) in a matrix of colourless, crystalline carbonate. There is nothing in the appearance of the section to suggest that the rock is an ironstone. [It is the green ironstone, that is rejected by the workmen.]

### Fig. 9.—Iron-ore, Middle Lias, Shelton Mine, Cleveland.

Modified oolitic grains in a matrix which consists partly of an isotropic greenish substance, probably a silicate containing iron, and partly of a crystalline carbonate.

The outer portions of the oolitic grains are formed of a ferriferous carbonate, the crystals of which show idiomorphic boundaries against the opaque nucleus. This nucleus appears white by reflected light.

### Fig. 10.—Iron-ore, Middle Lias, Raasay, near Skye.

Greenish oolitic grains showing concentric but not radial structures; and fragments of such grains and organic fragments in a matrix of colourless, crystalline carbonate. [See H. B. Woodward, Geol. Mag., 1893, p. 493.]

### Fig. 11.—Iron-shot Limestone, Cephalopoda Bed, Inferior Oolite, Wotton-under-Edge, Gloucestershire.

Dark ferruginous oolitic grains showing concentric structure; in brownish calcareous matrix showing many small quartz grains.

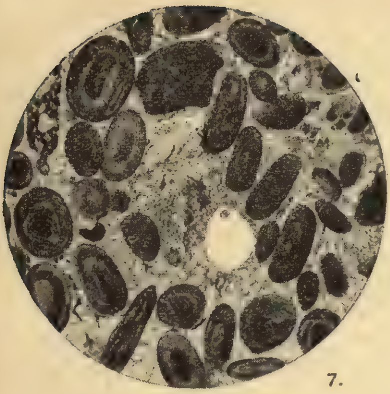
### Fig. 12.—Iron-ore, Corallian Beds, Westbury, Wiltshire.

Reddish-brown oolitic grains showing concentric structure.

The nucleus of one grain is a fragment of another grain. The matrix is yellowish-green, and contains numerous small detached grains of colourless calcite.

JURASSIC ROCKS OF BRITAIN, VOL. IV.

PLATE II.



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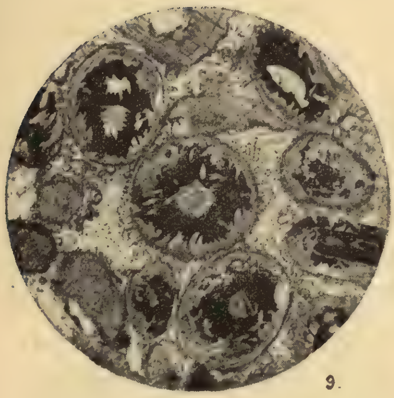

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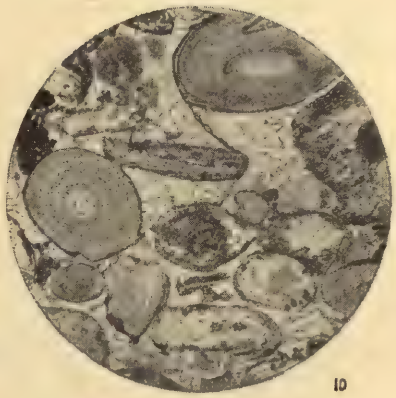

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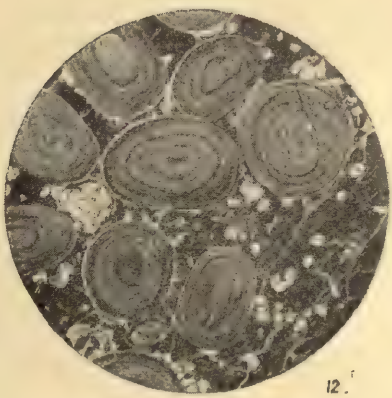

12.

MICROSCOPIC SECTIONS OF OOLITIC IRONSTONES AND LIMESTONES.

Drawn by H. W. GILBERT WILLIAMS.

# CHAPTER II

## INFERIOR OOLITE SERIES.

### (BAJOCIAN.)

### GENERAL ACCOUNT OF THE STRATA.

AMONG our Jurassic rocks no strata exhibit greater variations than do the oolitic limestones and the beds associated with them. This is the case with the Great Oolite Series, the Corallian Beds, and the Portland Beds; and perhaps even to a greater extent with that portion of the Inferior Oolite Series which is exposed to view. Essentially shallow-water deposits, we find among them not only considerable changes in sedimentary character, but evidence here and there of overlap, reconstruction, and paucity of sediment.

Broadly speaking, the Inferior Oolite Series includes the beds that lie between the Upper Lias Clay and the Great Oolite Series, but we find evidences of transition between the overlying and underlying strata, in different portions of our area. The Series, however, is practically equivalent to the Bajocian formation* of d'Orbigny, in the sense in which that term was adopted by Oppel.

As already mentioned, over great part of the area from Dorsetshire to the Cotteswold Hills, there is a gradual passage upwards from the Lias into the Inferior Oolite, so that there are "passage-beds" which, on stratigraphical grounds, may be assigned with as much propriety to one division as to the other. The Inferior Oolite is overlaid in these regions by the Fuller's Earth, between which there is, as a rule, no difficulty in fixing a boundary.

The earliest classification of the strata was taken from Somersetshire, where in 1799 William Smith recognized the occurrence of Freestone overlying Sand, between the Blue Lias and the Fuller's Earth. To this Freestone, which was known near Bath as the "Bastard Freestone," Smith at first applied the name "Under Oolite," from the fact of its underlying the locally more important Great or "Upper" Oolite. Afterwards the name Inferior Oolite was published by Townsend† in 1813, from information derived from Smith, and the name was adopted by Sowerby in 1815.

The Sand that in the same district occurs at the base of the Freestone, was eventually termed "Sand of the Inferior Oolite" by

* Named from Bayeux, in Calvados (1849).

† Character of Moses, established for veracity as an Historian. 4to. London, 1813, p. 105.

Smith, and for a long period the following divisions were adopted for the south-west of England :—

Inferior Oolite.
Inferior Oolite Sands.

In the course of time, as our knowledge of the fossils increased, it was argued by Dr. Thomas Wright, of Cheltenham, that the Sands were more intimately connected with the Lias than with the Inferior Oolite; and in 1856 he proposed that the term Upper Lias Sands be used,* and this was afterwards adopted by the Geological Survey. Wright's conclusions, which were based mainly on the range of certain Ammonites, were not however generally accepted: they were disputed by Lycett,† C. Moore,‡ J. Buckman,§ and more recently by E. Witchell.‖ The general tendency of the opposing views was to show that the Sands were intimately connected with both Upper Lias and Inferior Oolite, a fact indeed which admits of no question. In 1863 Morris and Lycett introduced the name Supra-Liassic Sands: a name not generally used, and only of late years occasionally employed by Mr. Hudleston. The adoption, however, by some geologists of the term Upper Lias Sands, and by others of Inferior Oolite Sands, has been a source of ambiguity to students, so that when in 1871 John Phillips proposed the name Midford Sands¶ it was accepted as a good stratigraphical term, whose meaning could be clearly understood, and which would satisfy the wants of field-geologists. For regarded as passage-beds, it would matter very little, with a distinctive name, whether they were bracketed, in Tables of Strata, with Inferior Oolite or Upper Lias. This name was adopted by the Geological Survey, and was for some years unchallenged.

The term Midford Sand has not, however, been suffered to remain in this tranquil position; and since more especial attention has been paid to zones, its general application to the beds of Dorset, Somerset, and Gloucester has been called in question by Mr. S. S. Buckman and Mr. Hudleston. The fact is, the sands at Midford are directly overlaid by the upper portion of the Inferior Oolite (Zone of *Ammonites Parkinsoni*); they have yielded but few fossils; and they have not furnished evidence of the presence of all the minor zones that have been identified here and there in the Cotteswold Sands and Gloucestershire Cephalopoda Bed on the one hand, and in the Yeovil and Bridport Sands on the other.

The fossils, however, which the Midford Sand has yielded, show it to belong to the same set of beds as those essentially

* Quart. Journ. Geol. Soc., vol. xii. p. 292; Lias Ammonites, pp. 148, 150

† Cotteswold Hills, pp. 16, 27.

‡ Proc. Somerset Arch. and Nat. Hist. Soc., vol. xiii. p. 195.

§ Quart. Journ. Geol. Soc., vol. xiv. p. 102, vol. xxix. p. 504, vol. xxxiii. (Proc.) p. 1; Proc. Geol. Assoc., vol. ii. p. 249; Proc. Somerset Arch. Soc., vol. xx. p. 140.

‖ Geol. Stroud, pp. 34–36.

¶ Geol. Oxford, &c., p. 118.

sandy strata in Dorsetshire and Gloucestershire, so that the opposition to the term rests very largely on negative evidence, which future work may annul. In many instances we have to deal with comparatively unfossiliferous sands which afford no evidence of any particular zone, but whose general stratigraphical position can be proved; consequently there is need for a stratigraphical term that should include the Gloucestershire Cephalopoda Bed and Cotteswold Sands, the Midford Sands, and the Yeovil and Bridport Sands. Paying due attention to the general stratigraphical and palæontological characters of the beds, and to certain lithological changes which they undergo, we find that the upper limit is on the whole fairly well-defined; for stratigraphically, in Dorsetshire as in Gloucestershire, the zone of *Ammonites opalinus* would be included in this division. In both cases the beds are covered conformably by the lower portion of the Inferior Oolite, representing the zone of *Ammonites Murchisonœ.* The lower limit is nowhere rigidly defined; and, as is natural with passage-beds, the separation of the more sandy from the more argillaceous portions would vary in horizon from place to place. From a practical point of view it is necessary to represent the essentially sandy beds separately from the Upper Lias clay on the maps, and so long as the nature of the division is understood, there need be no trouble about it.

As a stratigraphical term, therefore, the name Midford Sand may be used in this comprehensive sense, admitting that its lower boundary is one which shades down irregularly into the Upper Lias. So far as possible the palæontological characters of the beds, and the evidence of different local zones, will be indicated; but, generally speaking, the Midford Sand may be considered to include the zones of *A. opalinus* and *A. jurensis*, between which the division of Lias and Oolites is taken.

The stratigraphical divisions into which the Inferior Oolite Series was originally divided, have proved to be inapplicable to other districts in this country.

In the west of England, we find above the Upper Lias clays, a group of sands with bands and nodules of calcareous sandstone and occasional shell-limestones (Midford Sand), overlaid by a group of oolitic, earthy, and shelly limestones and marls, with occasional sandy beds (Inferior Oolite).

In the midland area, there is no continuance of the gradual passage from Upper Lias into the Inferior Oolite Series; for in Northamptonshire and Lincolnshire, though there are occasional symptoms of transition, the groups are generally separated by a well-marked plane of division, attended by some evidences of local erosion. As we pass into these central regions, distinct stratigraphical divisions become needful. The lowest beds of the Inferior Oolite Series comprise ferruginous sandstones and ironstones, white sands, and clays, grouped as the Northampton Sand and Lower Estuarine Series; and as we proceed further east these beds are overlaid by fissile sandy strata known as the Collyweston Slate, and by compact shelly and oolitic limestones, known collectively as the Lincolnshire Limestone. The upper limit of the Inferior Oolite Series is over a great part of the area well-marked, the beds being overlaid by the Upper Estuarine Series, which is the local base of the Great Oolite Series.

Thus the Inferior Oolite, in its course through England, exhibits almost every variety of stratified rock. In some places, as on the Cotteswolds, we have fine false-bedded oolites furnishing excellent freestone; also beds of soft oolite-marl; and layers of coarse oolite and pisolite. In other places, as near Bridport, the oolite becomes very ferruginous, and almost an oolitic iron-ore. Again, near Lincoln, we find beds of compact limestone, with scattered oolitic grains, and beds of shell-limestone. Conglomeratic beds are met with on the eastern borders of the Mendip Hills, and tiny quartz pebbles occur in some beds in the Cotteswold Hills. Distinct beds of sand, and even of clay, are intercalated in places on the northern Cotteswolds; and near Chipping Norton most of the strata are more or less sandy in character.

The surface-beds generally present a rubbly appearance, while some of the beds not exposed to atmospheric influences are blue in colour. False-bedding is, as a rule, conspicuously developed in the oolitic freestones.

Where best developed, as near Cheltenham, the beds attain a thickness of upwards of 250 feet, while near Bridport the full thickness is no more than 15 feet. (See Fig. 31, p. 53.) From the Cotteswold area there is evidence of attenuation as we proceed towards the neighbourhood of Oxford.* This is caused by the overlap of higher across lower members of the formation.

Beds bored by Annelides or other marine organisms occur at various horizons in the Inferior Oolite; and beds with rolled fragments of oolite are also met with at different stages. These phenomena mark a certain amount of local unconformity or contemporaneous erosion, as the case may be; but they cannot be taken in any case to indicate a great lapse of time, for they occur at different levels in the same palæontological division. There are also occasional perforations in the limestones like those characterizing the "Dagham Stone" of the Great Oolite (see p. 286).

The Inferior Oolite sometimes rests directly on the Lias, without the intervention of the Midford Sand, as near Radstock; while in other places bordering the Mendip Hills it rests on the Coal-measures and on the Carboniferous Limestone. In no other tract, however, have we any actual evidence of marginal accumulations; although some of the more sandy beds with plant-remains in Oxfordshire, the layers with rootlets in the Northampton Sand, and the estuarine beds in the midland counties, betoken the proximity of land.

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* See Hull, Geology of Cheltenham; W. C. Lucy, Proc. Cotteswold Cub, vol. v. p. 8.; Topley, Quart. Journ. Geol. Soc., vol. xxx. p. 186; and Buckman, *Ibid.*, vol. xlv. p. 468.

*Organic Remains.*

The Inferior Oolite Series has yielded a rich and varied Invertebrate fauna, but the remains of Saurians and Fishes are very rare.

The Reptilia that have been found, include *Megalosaurus* and *Steneosaurus*, and the Fishes are represented by *Hybodus*, *Strophodus*, &c.

Of Mollusca, Ammonites are exceedingly abundant in Dorsetshire and, at a more restricted horizon, in Gloucestershire. The larger cut and polished Ammonites and Nautili of dealers, are mostly obtained from the Inferior Oolite of Dorsetshire. One of the largest examples of *Nautilus* known, a gigantic specimen 2 feet in diameter, obtained from Sherborne in Dorsetshire, has been described under the name of *Nautilus ornatus*.* Belemnites are common in certain beds; *Ancyloceras* and *Toxoceras* are also recorded.

Gasteropods are plentiful in the limestones in Dorsetshire, south Somerset, and the midland counties; they include *Actæonina*, *Alaria*, *Amberleya*, *Bourguetia*, *Cerithium*, *Cylindrites*, *Malaptera* (*Pterocera*), *Monodonta*, *Natica*, *Nerinæa*, *Nerita*, *Pleurotomaria*, *Pseudomelania*, *Purpurina*, *Trochus*, *Turbo*, &c. *Nerinæa* first appears near the base of the formation; the species recorded from the Lias in this country, according to Mr. Hudleston, do not belong to this genus. *Ataphrus* (*Monodonta*) *lævigatus* and *Natica adducta* occur at various horizons.

The Lamellibranchs also are abundant, including *Arca*, *Astarte*, *Cardium*, *Ceromya*, *Cucullæa*, *Cypricardia*, *Gervillia*, *Gresslya*, *Gryphæa*, *Hinnites*, *Homomya*, *Isocardia*, *Lima*, *Lucina*, *Modiola*, *Myacites*, *Nucula*, *Opis*, *Ostrea*, *Pecten*, *Perna*, *Pholadomya*, *Pinna*, *Tancredia*, *Trichites*, *Trigonia*, &c. Of these genera, *Trigonia* is especially abundant and characteristic. Some of the species, such as *Astarte elegans*, *A. excavata*, *Avicula inæquivalvis*, *Ceromya bajociana*, *Gresslya abducta*, *Hinnites abjectus*, *H. velatus*, *Lima strigillata*, *L. duplicata*, *L. pectiniformis*, *Lucina despecta*, *L. Wrighti*, *Modiola sowerbyana* (*plicata*), *Pecten demissus*, *Pholadomya fidicula*, *P. Heraulti*, *P. media*, *Tancredia axiniformis*, *Trigonia costata*, and *T. signata* are abundant at various horizons.

Most numerous are the Brachiopods, including *Rhynchonella*, *Terebratula*, and *Waldheimia*. Some of the species are locally taken to mark horizons, as the *Spinosa*-stage characterized by *Rhynchonella spinosa*, the *Globata*-bed by *Terebratula globata*, the *Fimbria*-stage by *Terebratula fimbria*, and the *Cynocephala*-stage by *Rhynchonella cynocephala*. The species in fact occur profusely in certain layers, forming fossil-beds, but they are not as a rule confined to such beds. In Gloucestershire the specimens of *T. globata* early attracted the attention of the country people,

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* A. H. Foord and G. C. Crick, Ann. Nat. Hist., ser. vi, vol. v. p. 273.

to whom they were known as "Pundibs,"* a name still retained by quarrymen. This species is represented in Dorsetshire by *T. sphæroidalis*, which locally forms one or more Terebratula-beds. Other species, such as *Rhynchonella angulata*, *R. subtetrahedra*, *Terebratula perovalis*, *Waldheimia anglica*, and *W. carinata* occur at different horizons.

Of other fossils we find numerous Polyzoa; Crustacea are extremely rare; while Insects have only been recorded with doubt.† Many Annelides occur. Echinodermata are found in great abundance and variety; the genera including *Pentacrinus* and other Crinoids, *Cidaris*, *Clypeus*, *Hemipedina*, *Hyboclypus*, *Pygaster*, *Stomechinus*, *Astropecten*, &c. Spicules of Holothuroids have been observed. Corals are very plentiful in certain layers, the more abundant forms being *Isastræa*, *Latimæandra*, *Montlivaltia*, *Oroseris* and *Thamnastræa*. In the Cotteswold Hills there are three or four coral-beds; which, as Prof. Duncan has remarked, occur in banks rather than reefs. Again, at Dundry and also in Lincolnshire, there are well-marked coral-beds. A number of Sponges have also been obtained; and many of these, according to Prof. Sollas, are shallow-water forms.‡

The Plants include Ferns, Conifers, and Cycads; but specimens are of rare occurrence.

The distribution of the fossils, and the endeavour to picture the life-history of the strata and the physical features of the period, naturally furnish the most interesting studies connected with the Inferior Oolite Series. The richness of its fossil-beds has attracted many a collector, and whether he go to the neighbourhood of Bridport or Sherborne in Dorsetshire, to Stroud or Cheltenham in Gloucestershire, an abundant harvest of organic remains may be reaped. Other fossiliferous localities will be mentioned in the sequel, but of course there are many places where fossils are rare or but imperfectly preserved.

As is the case with the Lias and other formations, the so-called characteristic fossils are variously distributed: there are some species of Lamellibranchs, Gasteropods, and Brachiopods that occur in all divisions of the series: others are much more restricted both as to place and horizon. Moreover in beds on the same horizon, as for instance in Dorsetshire, we may notice the changes in their organic contents from place to place: Cephalopods, Lamellibranchs, or Brachiopods in turn prevailing.§

Again when the formation is represented in an attenuated form, as in Dorsetshire, we find, as with the Lias under similar conditions, that we have a rich and varied fauna preserved in a few layers: and where the beds are much more thickly developed we find occasional fossil-beds, but the fossils are more sparsely preserved.

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* J. Woodward, Nat. Hist. Fossils of England, part 2, pp. 45, 46.

† See Moore, Quart. Journ. Geol. Soc., vol. xvii. p. 513.

‡ Quart. Journ. Geol. Soc., vol. xxxix. p. 551; see also Hinde, *Ibid.*, vol. xlvii. p. 553; and British Jurassic Sponges (Pal. Soc.), Part III., 1894.

§ See also Whidborne, Quart. Journ. Geol. Soc., vol. xxxix. p. 487.

*Zones.*

The fact that the strata are so variable has naturally influenced the assemblages of fossils that characterize particular portions of the sea-bed. So that while numerous local divisions may be made in the rocks, attempts at minute correlation of particular layers are apt to provoke diversity of opinion. Ammonites, however, have come to be regarded as "time-keepers," for they appear to be less influenced than other Mollusca by the character of the sea-bottom. Their distribution at any rate was not hindered by such considerations, although the forms were subject to more rapid modifications than those of other Mollusca.

Doubtless there is a tendency at the present day to make more and more minute divisions of the strata; and so long as they are taken simply to indicate the local natural history of the beds they are useful. What is much more serious is the multiplication of the specific names of fossils and especially of the Ammonites; for now-a-days the identification of species has become well-nigh a hopeless task, unless one reverts to the definitions of the older palæontologists. Forms hitherto grouped under definite specific names, such as *Ammonites Parkinsoni*, *A. humphriesianus*, *A. Sowerbyi*, *A. Murchisonæ*, &c., are so split up that only a specialist can recognize the many so-called species or rather "mutations" into which they are divided. Their original significance, and their historical associations are obscured. Such a proceeding, too, tends considerably to modify the interpretation of zones, and to render them dependent rather on the occurrence of one of these particular forms, than on the faunas or general assemblages of fossils with which a species may be associated. In many places Ammonites are scarce, and it is known that the occasional presence or absence of a so-called zonal species cannot always be taken as definite evidence of the presence or absence of the special horizon it may characterize.

It is true, as has been stated, that the assemblages of fossils vary from place to place according, no doubt, to the particular sedimentary conditions that suited them, but there are some species sufficiently widely distributed to mark the general succession in the life-forms of the Inferior Oolite. Whether, however, we take a broad or a restricted view of species, there is great difficulty in subdividing the Inferior Oolite into definite zones, and in tracing these palæontological divisions throughout the country. Probably no other formation has given so much trouble to those who endeavour to parcel our strata into zones.*

It will be seen that the zones are not marked by any persistent lithological characters. Even in Dorsetshire, where Ammonites are most abundant, it is remarkable that the zones are nowhere all well developed at one locality where they can be studied in sequence:† the "fossil-beds" that sometimes represent distinct

* See also Hudleston, Address to Geol. Soc. 1893, Quart. Journ. Geol. Soc., vol. xlix (Proc.) pp. 129, &c.

† See Hudleston, Inf. Ool. Gasteropoda, p. 23.

horizons occurring here and there at different spots Moreover, in this and other areas, as at Dundry, there is sometimes a commingling of certain zonal species, that renders it impossible to draw rigid planes of division. Where the beds are very thin it may be that the sediment was insufficient (as remarked by Tawney in reference to the Lias of Radstock) to bury up the organic remains of successive stages.*

It is interesting to note the different minor divisions in different localities, but considering all the facts and the many varieties of opinion, it is best to adhere to broad general groupings, which may be made with a fair approximation to truth, instead of attempting to correlate the minor divisions, many of which of course are impersistent, and often unfossiliferous.

It will be desirable now to mention the species that are considered more particularly to characterize the different stages of the Inferior Oolite Series. Many of these are not confined to particular zones, and their distribution or abundance varies in different parts of the country.

It will be sufficient for our purpose to adopt the following general divisions of the strata, premising that the zones in the midland counties are not well established:—

TABLE OF THE CHIEF SUBDIVISIONS OF THE INFERIOR OOLITE SERIES.

| | | Zones. | S.W. England. | Midland Counties. |
|---|---|---|---|---|
| Inferior Oolite. | Upper Division. | Ammonites Parkinsoni | Inferior Oolite. | Lincolnshire Limestone. Collyweston Slate. Lower Estuarine Series. |
| | | A. humphriesianus (in S.W. England). | | |
| | Lower Division. | A. Murchisonæ | | |
| | | A. opalinus | Midford Sand. | Northampton Sand. |
| Upper Lias. | | A. jurensis | | |

* See Memoir on the Lias, p. 127, and Proc. Geol. Assoc., vol. xii. p. 303.

## MIDFORD SAND.—(PASSAGE BEDS.)

### Zones of *Ammonites jurensis* and *A. opalinus*.

The zones of *A. opalinus* ("Opalinusthone") and *A. jurensis* ("Jurensis-mergel") were notified by Quenstedt in 1843; and when Oppel instituted his comparisons between the Jurassic rocks of this country and the Continent, he subdivided the beds as follows*:—

| | | | |
|---|---|---|---|
| Inferior Oolite. | Zone of *Trigonia navis* | with *A. opalinus* and *Rhynchonella cynocephala*. | |
| | Zone of *Ammonites torulosus*. | | Gloucestershire Cephalopoda Bed. |
| Upper Lias. | Zone of *A. jurensis*. | | |

The names applied to the upper two zones are not applicable to this country, as *Trigonia navis* is not present, nor is it a good zonal species, and *A. torulosus* is not sufficiently abundant: but the beds are conveniently grouped under the general name, zone of *A. opalinus*.

The lowest zone of the Inferior Oolite is usually regarded as that of *A. opalinus*, while the uppermost zone of the Upper Lias is taken to be that of *A. jurensis*.

Over large areas of the Midland counties the zone of *A. jurensis* does not appear to be represented, although here and there, as at Northampton, it is partially developed. There, however, we find no difficulty in determining the respective stratigraphical limits of the Upper Lias clay and Inferior Oolite Series.

In Gloucestershire, Somersetshire, and Dorsetshire the case is different: over considerable portions of that area we have a complete passage from Lias to Oolite, and the only possible stratigraphical divisions that can be made, consist in grouping together so far as possible, the main mass of sandy strata, and the limestones locally associated with them, under the term Midford Sand, or Midford Beds, and separating them from the main mass of Upper Lias clay on the one hand, and from the Inferior Oolite on the other.

It is of course considered desirable by palæontologists that the fossils of the zone of *A. opalinus* be separated from those of the zone of *A. jurensis*, because the one zone is considered Inferior Oolite and the other Lias. Where to make the desired separation between these zones in the absence of lithological and stratigraphical guides is difficult enough: in the absence of fossils of course it is hopeless. Even at best the two zones, in the west of England, are so intimately connected by forms common to both, that a hard-and-fast line is out of the question. The field-geologist moreover has to deal with strata that in many places yield no fossils.

On local palæontological grounds the Gloucestershire Cephalopoda Bed was split in two portions (see p. 104), and the name Cephalopoda Bed is by some authorities restricted to the lower part, so as to place it in the zone of *A. jurensis*. On strati-

* Die Juraformation (1856–58), pp. 305, 321, and Table at end of volume.

graphical grounds no such separation is wanted. Indeed Dr. Wright, seeing the intimate palæontological connexion with the beds below, boldly placed the zone of *A. opalinus* in the Lias, as its highest stage, and in defiance of other authorities.* Such a plan, however locally convenient, could not be followed in the midland and north-eastern counties.

We have referred to the assemblages of Ammonites and other fossils as serving to indicate a general division between the two zones, but the subject is complicated by the differences of opinion that exist on the grouping of certain beds and fossils with one or other zone; and the still more serious differences on the identification of species—the names of Ammonites varying according to the "lumping" or "splitting" tendencies of those who assign names to them. Hence while one authority gives a wide range to a species, another may assign to it a very restricted horizon.

Thus Mr. S. S. Buckman has pointed out that *Ammonites jurensis* (as he would define the species) is by no means abundant in this country, the species having in some cases been identified from forms which occur at higher horizons, and which he would name *A confusus* and *A. Wrighti*: both as he admits approach nearly to *A. jurensis*.†

He has subdivided the zones of *A. jurensis* and *A. opalinus* into the following beds:—

| | |
|---|---|
| Zones of *A. opalinus* and *A. jurensis.* | 6. *Opalinus*-beds, with *Ammonites opalinus*. |
| | 5. *Moorei*-beds, with *A. Moorei*. |
| | 4. *Dumortieria*-beds, with *A.* (*Dumortieria*) *radians*. |
| | 3. *Dispansus*-beds, with *A. dispansus*. |
| | 2. *Striatulus*-beds, with *A. striatulus*. |
| | 1. *Variabilis*-beds, with *A. variabilis*. |

This grouping may be taken to indicate the general succession of the Ammonite-forms as defined and restricted by Mr. Buckman, but it can only be accepted in detail by those who agree with the limitations he would assign to the species, and none but a specialist could attempt to deal with the subject.

Including as we do the zone of *A. opalinus* with the Gloucestershire Cephalopoda Bed, and associating with them the Cotteswold Sands, we have a group in which Mr. Buckman recognizes his six fossil-beds: a group including the zones of *A. opalinus* and *A. jurensis*.

In the Bridport and Yeovil Sands we have a group in which Mr. Buckman recognizes the zone of *A. opalinus* and but a portion of the zone of *A. jurensis*; the other portion being, in his opinion, to some extent represented in the Upper Lias shale beneath. This view is not at all incompatible with the stratigraphical evidence, which shows, as has been pointed out, that the lower boundary of the Midford Sands is a gradual one, that may vary in horizon from place to place. A similar varying junction is met with between Kimeridge Clay and Portland

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* Lias Ammonites, pp. 1, 67, 138, 139, 148; Quart. Journ. Geol. Soc., vol. xvi. p. 8; see also S. S. Buckman, Inf. Ool. Ammonites, p. 253.

† Inf. Ool. Ammonites, pp. 50, 164, 166; Quart. Journ. Geol. Soc., vol. xxxvii. p. 601.

Beds, but it is not always practicable to accommodate our stratigraphical subdivisions strictly to palæontological horizons, even if we could find fossils more plentifully than we do, and were assured that the species were confined within definite limits. We know, however, that index-species are not always confined to the zones they indicate; they are considered only to be dominant at particular horizons, and this information rests largely on local evidence.

Whatever view we take of the species or "mutations" of Ammonites, and of the value of minute divisions of the strata, there is no means by which we can fix a boundary in this transitional series of strata in the west of England that can be traced with confidence, or that would have any practical value.

Considering the vexed subject of species, it is of course difficult to enumerate the particular fossils that may be said to belong especially to each of the two zones of *A. jurensis* and *A. opalinus.* Nor are we helped out of the difficulty by reference to the fossils recorded from continental strata, for as regards the species that have been taken as a basis for classification, we find a varying range assigned to them in different localities. For instance, such forms as *A. aalensis, A. hircinus,* and *A. subinsignis* are recorded from both zones.

In Yorkshire the name "*Striatulus*-beds" is applied generally to the zone of *A. jurensis*, and the evidence obtained in other parts of England tends to show that the species may have appeared in places much earlier, for we find it in the Basement Beds of the Upper Lias in Dorsetshire. In the Gloucestershire Cephalopoda Bed, *A. radians* and *A. striatulus* are intimately associated, and the species are very closely allied.† Mr. S. S. Buckman makes use of these two species to mark distinct sub-zones, both of which he places in the Upper Lias (zone of *A. jurensis*). Mr. Hudleston places the "*Radians*-zone" at the base of his Lower division of the Inferior Oolite. *A. aalensis* is recorded by Tate and Blake from beds low down in the Upper Lias of Yorkshire, while it occurs with *A. opalinus* in the Gloucestershire Cephalopoda Bed, and with *A. jurensis* on the Dorset coast. *A. opalinus* again is recorded from Dorsetshire in the same bed with *A. Murchisonæ.*‡

Such occurrences, which are not altogether dependent on varying views of species, are natural enough, and are parallelled by what we know of the distribution of species in the Lias. They indicate the varying local range of different species, and they show that we cannot rely on the occurrence of one or two specimens of a species to fix a positive stratigraphical horizon.

In the following list I have recorded the species that are said to characterize particular zones; but for geological purposes it is convenient to take the fauna as a whole, regarding it as that of the passage-beds between the Lias and Oolites. The species from Midford are marked "M."

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* Quart. Journ. Geol. Soc., vol. xlvi. pp. 440, 521, &c.; Journ. Northamptonshire Nat. Hist. Soc., vol. v. pp. 77, 78.

† Mr. S. S. Buckman now regards them as belonging to different sub-genera.

‡ See S. S. Buckman, Quart. Journ. Geol. Soc., vol. xxxvii. p. 608, vol. xlv. p. 455, vol. xlvi. p. 520; Tate and Blake, Yorkshire Lias, p. 180; Fox-Strangways, Jurassic Rocks of Yorkshire, vol. i. p. 131.

## List of Fossils from the Midford Sand.
## Zones of *Ammonites opalinus* and *A. jurensis*.

| Zone of Ammonites jurensis. | Zone of Am. opalinus. | —— | | Bridport and Yeovil Sands. | Cotteswold Sands. | Gloucestershire Cephalopoda Bed. |
|---|---|---|---|---|---|---|
| | o | Ammonites aalensis | M | 1 | | 3 |
| j | | —— compactilis | | | 2 | 3 |
| j | o | —— discoides | | | | 3 |
| j | | —— dispansus (var. of *A. variabilis*) | | | 2 | 3 |
| j | | —— fallaciosus | M | 1 | | 3 |
| j | o | —— hircinus | | | | 3 |
| j | o | —— insignis (Fig. 4) | | 1 | | 3 |
| j | | —— jugosus | | | 2 | |
| j | | —— jurensis (Fig. 3) | | 1 | 2 | 3 |
| j | o | —— Levesquei | M ? | | | 3 |
| | o | —— Moorei (var. of *A. aalensis*) | | 1 | | 3 |
| | o | —— opalinus (Fig. 6) | | 1 | | 3 |
| j | o | —— radians | | | | 3 |
| j | | —— striatulus (Fig. 2) | M | | 2 | 3 |
| | o | —— subinsignis | | 1 | 2 | 3 |
| j | | —— sublineatus | | | 2 | |
| j | o | —— toarcensis (thouarsensis) | M | | | 3 |
| | o | —— torulosus (Fig. 5) | | 1 | | 3 |
| j | | —— variabilis | | 1 | 2 | |
| j | o | —— Wrighti | | 1 | | 3 |
| | o | Belemnites aalensis (giganteus) | | 1 | | |
| j | o | —— breviformis | | | 2 | 3 |
| j | o | —— irregularis (Fig. 7) | | | | 3 |
| j | | —— tripartitus | | | 2 | |
| j | o | Amberleya capitanea | | | 2 | 3 |
| j | | Trochus duplicatus | | | 2 | |
| j | o | Astarte lurida | | | 2 | 3 |
| j | o | Cucullæa ferruginea | | | 2 | 3 |
| j | o | Cypricardia bathonica var. brevis | | | 2 | 3 |
| j | o | —— cordiformis (Fig. 19) | | | 2 | 3 |
| j | o | Gervillia Hartmanni | | | 2 | 3 |
| | o | —— lata | | 1 | | |
| j | o | Gresslya abducta | | | | 3 |
| j | o | Hinnites abjectus | | | | 3 |
| j | o | Lima toarcensis | M | | | 3 |
| j | o | Modiola sowerbyana (Fig. 10) | | | 2 | 3 |
| | o | Myacites tenuistriatus | | 1 | | |
| | o | Pecten demissus | | 1 | | |
| | o | —— læviradiatus | | 1 | | |
| | o | —— paradoxus | | 1 | | |
| j | o | Pholadomya fidicula | | | 2 | 3 |
| | o | Tancredia donaciformis | | 1 | | |
| | o | Trigonia Ramsayi | | | | 3 |
| | o | —— striata (Fig. 9) | | 1 | | 3 |
| j | o | Rhynchonella cynocephala (Fig. 14) | | 1 | 2 | 3 |
| j | o | —— jurensis | | 1 | | 3 |
| | o | Terebratula infra-oolitica | | 1 | | |
| j | o | —— punctata var. haresfieldensis | | | | 3 |
| j | o | Waldheimia anglica | | 1 | | |
| | o | —— carinata var. Mandelslohi | | 1 | | |
| | o | Serpula tricarinata | | 1 | | |

## Cephalopoda from the Midford Sand, or Passage-beds between the Inferior Oolite and Upper Lias.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

Fig. 6.

Fig. 7.

Fig. 2. Ammonites striatulus, *Sow.* $\frac{2}{3}$.
,, 3. ,, jurensis, *Ziet.* $\frac{1}{3}$.
,, 4. ,, insignis, *Schüb.* $\frac{1}{4}$.
,, 5. ,, torulosus, *Ziet.* $\frac{2}{3}$.
,, 6. ,, opalinus, *Rein.* $\frac{1}{2}$.
,, 7. Belemnites irregularis, *Schloth.* Nat. size.

## Inferior Oolite Fossils.

### Lower Beds and Passage Beds (Midford Sand).

Fig. 8.

Fig. 9.

Fig. 10.

Fig. 11.

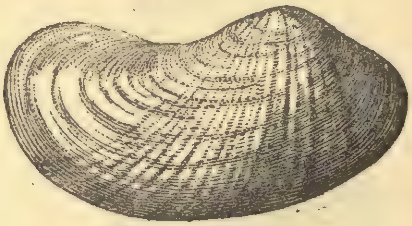

Fig. 12.

Fig. 13.

Fig. 14.

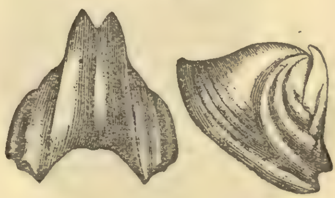

Fig. 8. Trigonia denticulata, *Ag.* $\frac{2}{3}$.
,, 9. ,, striata, *Sow.* $\frac{2}{3}$.
,, 10. Modiola sowerbyana, *d'Orb.* Nat. size.
,, 11. Pholadomya fidicula, *Sow.* $\frac{1}{2}$.
,, 12. Astarte elegans, *Sow.* Nat. size.
,, 13. Avicula braamburiensis, *Phil.* 2.
,, 14. Rhynchonella cynocephala, *Rich.* 2.

The Inferior Oolite above the stages previously described (p. 39), was divided by Oppel into the four zones, which, in ascending order, comprise those of *A. Murchisonæ*, *A. Sauzei*, *A. humphriesianus*, and *A. Parkinsoni*.

In this country we find it generally sufficient to adopt a broad grouping of the beds into the zones of *A. Murchisonæ* and *A. Parkinsoni*, because other zones are difficult to distinguish except locally; and where the distinctive species of Ammonites are absent, it is by no means easy to say to what extent the minor zones are represented, as other forms of Mollusca are somewhat variously distributed. For convenience of description I shall follow the general grouping of Mr. Hudleston, and refer to the fossils of the Inferior Oolite under the following principal zones:—

Upper Division { *A. Parkinsoni.* / *A. humphriesianus.*
Lower Division { *A. Murchisonæ.* / *A. opalinus.* (See p. 39.)

### Inferior Oolite.—(Lower Division.)

#### Zone of *Ammonites Murchisonæ*.

The zone of *Ammonites Murchisonæ* is, as a rule, well-marked, although the Ammonites, so abundant in Dorsetshire, are comparatively rare in Gloucestershire and in the midland counties. The local zones, or rather fossil-beds in Dorsetshire, yielding *A. concavus* and *A. Sauzei*, will be noticed further on.

The "*Sowerbyi*-zone," which some authorities have separated from the zone of *A. Murchisonæ*, is in trouble, for Mr. Buckman says there is considerable misconception regarding the type-form of the species.* We can, however, for stratigraphical purposes, well do without this sub-zone, with which the Lincolnshire Limestone has been generally grouped. In Dorsetshire Mr. Hudleston places the "*Concavus*—or '*Sowerbyi*'—zone" above the *Murchisonæ*-zone: and, for the sake of convenience, he groups both of them together with the *Opalinus*- and *Radians*-zones in the Lower division of the Inferior Oolite. He however remarks that "there can be no doubt that the rich and characteristic fauna of the Inferior Oolite begins with the *Murchisonæ*-zone, to which the *opalinus*-zone is little more than an appendage."†

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* Some specimens of "*A. Sowerbyi*" are referred by Mr. Buckman to *Harpoceras adicrum*. Quart. Journ. Geol. Soc., vol. xxxvii. p. 602.

† Quart. Journ. Geol. Soc., vol. xlix. (Proc.), p. 131; and Gasteropoda of the Inferior Oolite, p. 29.

## INFERIOR OOLITE AMMONITES.
## (LOWER AND MIDDLE BEDS.)

FIG 15.

FIG. 16.

FIG. 17.

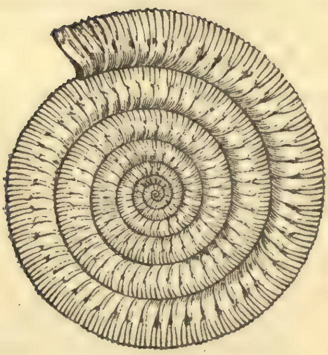


FIG. 18.

FIG. 15. Ammonites Sowerbyi, *Miller*. $\frac{2}{3}$.
,, 16. ,, Murchisonæ, *Sow*. $\frac{1}{2}$.
,, 17. ,, humphriesianus, *Sow*. $\frac{1}{6}$.
,, 18. ,, concavus, *Sow*. $\frac{1}{2}$.

## Inferior Oolite Fossils.
### (Lower and Middle Beds.)

Fig. 19.

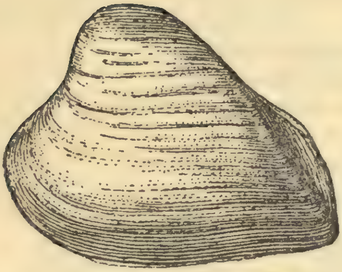


Fig. 20.

Fig. 21.

Fig. 22.

Fig. 23.

Fig. 25.

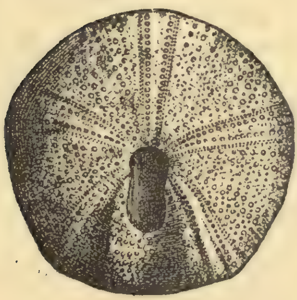


Fig. 24.

Fig. 19. Cypricardia cordiformis, *Desh.* $\frac{2}{3}$.
,, 20. Astarte excavata, *Sow.* $\frac{1}{2}$.
,, 21. Ceromya bajociana, *d'Orb.* $\frac{2}{3}$.
,, 22. Nerinæa cingenda, *Phil.* $1\frac{1}{2}$.
,, 23. Terebratula fimbria, *Sow.* Nat. size.
,, 24. Stomechinus germinans, *Phil.* $\frac{2}{3}$.
,, 25. Pygaster semisulcatus, *Phil.* $\frac{1}{2}$.

List of Fossils from the Zone of *Ammonites Murchisonæ* (including the sub-zone of *A. Sowerbyi*, and the local sub-zone of *A. concavus*).

Ammonites concavus (Fig. 18).
—— confusus.
—— corrugatus.
—— læviusculus.
—— Murchisonæ (Fig. 16).
—— Sowerbyi (Fig. 15).
Belemnites aalensis.
—— Blainvillei.
—— ellipticus.
Nautilus latidorsatus.
Actæonina glabra.
Amberleya capitanea.
—— ornata.
Cerithium Beani.
Cirrus nodosus.
Natica cincta.
Nerinæa cingenda (Fig. 22).
—— cotteswoldiæ.
—— Jonesi.
—— pisolitica.
Onustus ornatissimus.
Pleurotomaria ornata.
Purpurina elaborata.
Trochotoma calix.
Trochus duplicatus.
Astarte excavata (Fig. 20).
Avicula braamburiensis (Fig. 13).
Cardium Buckmani.
Ceromya bajociana (Fig. 21).
—— concentrica.
Cucullæa cancellata.
—— oblonga.
Cypricardia cordiformis (Fig. 19).
Gervillia acuta.
—— Hartmanni.
—— lata.
Gryphæa sublobata.
Hinnites abjectus.
—— tumidus (velatus).
Isocardia cordata.
Lima læviuscula.
—— ovalis.
—— pontonis.
Lucina bellona.
Macrodon hirsonensis.
Myacites tenuistriatus.
Myoconcha crassa.
Ostrea palmetta, var. montiformis.
Pecten personatus.
Pholadomya fidicula.
Pinna cuneata.
Tancredia axiniformis.
Trichites nodosus.
Trigonia denticulata (Fig. 8).
—— hemisphærica.
—— striata (Fig. 9).
Rhynchonella subangulata.
—— subdecorata.
—— subtetrahedra.
Terebratula fimbria (Fig. 23).
—— maxillata (submaxillata)
—— perovalis.
—— plicata.
—— simplex.
Waldheimia anglica.
Galeropygus (Hyboclypus) agariciformis.
Pseudodiadema depressum.
Pygaster semisulcatus (Fig. 25).
Stomechinus germinans (Fig. 24).
(Polyzoa.)
(Serpulæ.)
(Corals.)

## INFERIOR OOLITE.—(UPPER DIVISION.)

### Zone of *Ammonites humphriesianus* (including the local sub-zone of *A. Sauzei*).

This zone is far-less prominently developed than the zones above and below it, and indeed it hardly deserves to be recognized as a separate zone in this country. Here and there in Dorsetshire the characteristic Ammonite is fairly abundant and well-marked, but in several places in that county we find only very small specimens of a form that has been termed *A. humphriesianus*, and this is the case further on in Gloucestershire. The zone has nowhere been recognized in the midland counties, perhaps on account of the absence of the Ammonite. Where the species does occur in the Inferior Oolite, the fossils associated with it connect the so-called zone intimately with the beds above and below. It forms in fact a sort of passage-bed between the zones of *A. Murchisonæ* and *A. Parkinsoni*; but for convenience-sake we may put it, as Mr. Hudleston does, in the Upper Division of the Inferior Oolite.

Oppel records, from the *A. Sauzei*-bed, *A. Brocchii*, *A. Brongniarti*, and *A. Sowerbyi*, and in one part of his work he included this bed at the base of the *A. humphriesianus*-bed.* This is the position assigned to it by Mr. Hudleston, who regards it as an appendage to the *Humphriesianus*-zone. He says the most mixed fauna occurs in the "*Sauzei*-bed" of Oborne, and some might class it with the Lower division of the Inferior Oolite.†

Mr. S. S. Buckman remarks, "Where the *Sowerbyi* and *Sauzei*-zones are well developed, as would appear to be the case in certain localities on the Continent, it may be possible to separate them distinctly; but at Dundry we find peculiar conditions, because it would appear that *Am. Sowerbyi*, *Am. Sauzei*, and *Am. humphriesianus* occupy the same horizon."‡

Locally in Dorsetshire he recognizes another zone above that of *A. humphriesianus*,—the zone of *A. cadomensis*.§

List of Fossils from the Zone of *Ammonites humphriesianus*.

Ammonites Blagdeni.
—— Braikenridgei.
—— Brocchii.
—— Brongniarti.
—— cadomensis.
—— edouardianus.
—— garantianus.
—— Gervillei.
—— humphriesianus (Fig. 17).
—— Sauzei.
—— subfurcatus.
—— Wrighti.
Belemnites gingensis.
Nautilus polygonalis.
—— truncatus.
Bourguetia striata (Phasianella Sæmanni).
Pleurotomaria granulata.
—— punctata.
Pseudomelania coarctata.
—— (Chemnitzia) lineata.
—— (——) procera.
Purpurina bellona.
—— inflata.
Spinigera longispina.
Astarte planata.
Cypricardia cordiformis (Fig. 19).
Gryphæa sublobata.
Hinnites abjectus.
Myacites jurassi.
Rhynchonella spinosa (Fig. 29).
Terebratula sphæroidalis.
Waldheimia carinata.

* Juraformation, p. 305.
† Inf. Ool. Gasteropoda, p. 28.
‡ Inf. Ool. Ammonites, p. 63.
§ Rep. Brit. Assoc. for 1891 (1892), p. 655.

## INFERIOR OOLITE FOSSILS.
## (UPPER BEDS.)

FIG. 26.

FIG. 27.

FIG. 28.

FIG. 29.

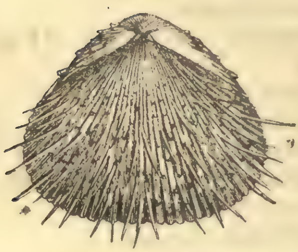


FIG. 30.

FIG. 26. Ammonites Parkinsoni, *Sow.* $\frac{1}{3}$.
,, 27. Terebratula Phillipsi, *Morris.* $\frac{2}{3}$.
,, 28. ,, globata, *Sow.* $\frac{2}{3}$
,, 29. Rhynchonella spinosa, *Schloth.* $1\frac{1}{2}$.
,, 30. Clypeus Ploti, *Klein.* $\frac{1}{2}$.

Zone of *Ammonites Parkinsoni.*

This zone is readily recognized by its fossils, which as a rule are plentiful from Dorsetshire to Gloucestershire. Away from Dorsetshire the characteristic Ammonite is not very abundant, but other fossils serve to distinguish it as far as the Cotteswold Hills and Oxfordshire.

The zone has not been recognized in the midland counties nor in Lincolnshire, although it is quite possible that here and there portions of the Lincolnshire Limestone may be of the age.

Mr. S. S. Buckman has suggested that this zone is capable of local subdivision into other zones, noting (in ascending order) the zones of *A. Truellei*, *A. zigzag*, and *A. fuscus*.* Such divisions cannot be regarded as of great stratigraphical value in this country, although the local succession of the Ammonites is interesting.

List of Fossils from the Zone of *Ammonites Parkinsoni.*

Ammonites fuscus.
—— garantianus.
—— Martinsi.
—— Parkinsoni (Fig. 26).
—— polymorphus.
—— subradiatus.
—— Truellei.
—— zigzag.
Belemnites canaliculatus.
Nautilus lineatus.
Alaria hamus.
Cerithium vetustum.
Natica bajocensis.
Nerinæa Guisei.
Pleurotomaria fasciata.
Purpurina bellona.
—— inflata.
Arca Pratti.
Astarte excavata (Fig. 20).
Gryphæa sublobata.
Lima gibbosa.
—— pectiniformis.
Myacites jurassi.
Trichites undulatus.
Trigonia duplicata.
—— hemisphærica.
—— signata.
Rhynchonella spinosa (Fig. 29).
Terebratula globata (Fig. 28).
—— Phillipsi (Fig. 27).
—— sphæroidalis.
—— Stephani.
Waldheimia carinata.
Clypeus altus.
—— Ploti (Fig. 30).
Collyrites ovalis.
—— ringens.
Holectypus depressus.
—— hemisphæricus.
(Corals and Sponges).

Dr. Hinde observes that in this subdivision British Jurassic Sponges reach their greatest development. Thus on the Dorsetshire coast, at Burton Bradstock, there are layers of limestone "mainly composed of masses of sponges growing attached to each other, apparently still in their natural position. The greater number are evidently siliceous sponges, but though they retain their original forms fairly well, their canal structures are largely obliterated, and the silica of their spicular skeletons has been entirely replaced by carbonate of lime."†

* Rep. Brit. Assoc. for 1891 (1892,) p. 655; Quart. Journ. Geol. Soc., vol. xlviii., p. 447.
† British Jurassic Sponges (Pal. Soc.), Part III., p. 190.

# CHAPTER III.

## INFERIOR OOLITE SERIES.

### Local Details.

In describing the several members of the Inferior Oolite Series, it is desirable to do so geographically, as well as geologically, and to arrange the subject-matter as follows :—

| | | |
|---|---|---|
| 1. Dorset, Somerset, and the Cotteswolds. | 2. Oxfordshire. | 3. Northamptonshire, Rutlandshire, and Lincolnshire. |

### 1. Dorset, Somerset, and the Cotteswolds.

$$\text{Inferior Oolite Series}\begin{cases}\text{Inferior Oolite.}\\ \text{Midford Sand.}\end{cases}$$

The name Midford Sands was given in 1871, by Prof. John Phillips, from Midford, a hamlet about three miles south of Bath. Here the beds were studied by William Smith, in the picturesque cliff which overhung his house at Tucking Mill, where he resided in 1798, when superintending the construction of the Somersetshire Coal-canal. He then drove curious tunnels into the sand, for dairy and other uses, giving it the name of "Sand of the Inferior Oolite."*

The beds consist of micaceous yellow sands, with bands or nodular masses of calcareous sandstone, known in some places as "sand-bats" or "sand-burrs." This is the character of the beds near Bath, in the Cotteswold Hills, and in the fine cliffs at Bridport Harbour. Near Yeovil, and at other places on the borders of Somerset and Dorset, the beds are displayed in many deep sandy lanes and road-cuttings; some of the indurated layers are made up of comminuted shells, and bands of this nature coalesce to form the famous building-stone of Ham Hill. In Gloucestershire the upper beds comprise layers of sandy, iron-shot, and fossiliferous limestone, which constitute what has been termed the "Cephalopoda Bed." Of this a more particular account will be given.

On the whole, the formation may be said to consist of the sandy sediments and occasional shell-banks, that prevailed in the south-west of England between the deposition of the Upper Lias clay and the Inferior Oolite limestones.

Where junction-sections may be observed, as in the cliffs of Thorncombe Beacon, and in the railway-cuttings near Yeovil, there is a gradual passage from the blue clays and shales of the Lias, through sandy clays into the yellow sands, with indurated bands. These concretionary masses are seen to be bluish-coloured and shaly in places, so that there is no definite plane of demarcation between the strata; as indicated long ago by Buckland, Cony-

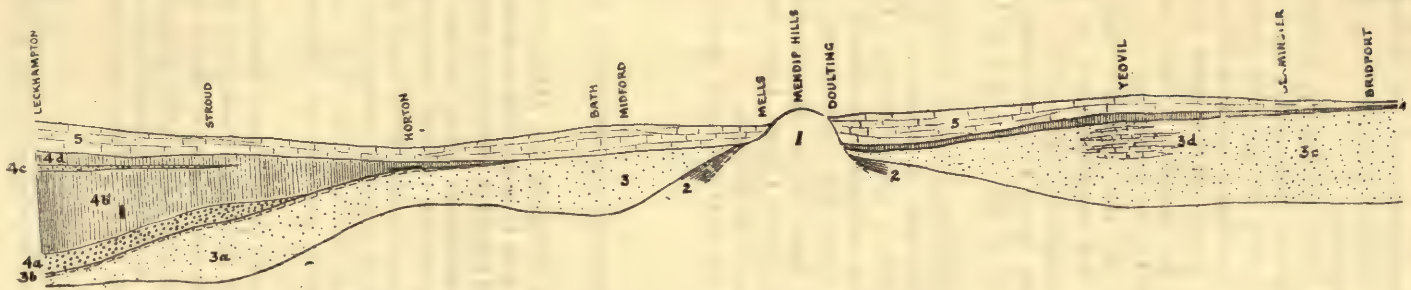
* Geology of Oxford and the Valley of the Thames, pp. 108, 109, 118.

FIG. 31.

*Diagram-section to show the main subdivisions in the Inferior Oolite Series, from Bridport in Dorsetshire, to Leckhampton near Cheltenham.*

Distance, about 80 miles. Vertical Scale, 300 feet to an inch.

North. South.




5. Upper Division: Ragstones, &c.
4. Lower Division.
   4 *d*. Upper Freestone.
   4 *c*. Oolite Marl.
   4 *b*. Lower Freestone.
   4 *a*. Pea Grit Series.

(5 and 4: Inferior Oolite.)

3. Midford Sand.
   3 *d*. Ham Hill Stone.
   3 *c*. Yeovii and Bridport Sands.
   3 *b*. Gloucestershire Cephalopoda Bed.
   3 *a*. Cotteswold Sands.
2. Lias, &c.
1. Palæozoic Rocks.

beare, and De la Beche.* Indeed, owing to the varying thickness and occasional disappearance of the Midford Sand, it is probable that the clayey conditions of the Lias endured longer in some localities than in others.†

Upwards, the beds are closely connected with the Inferior Oolite, so that we are occasionally at a loss to say whether a particular layer should be assigned to that formation or to the Midford Sand. The upper junction is however more frequently exposed than the lower, for the latter is not often to be seen in section, although its position is fairly well-marked by springs thrown out by the Upper Lias clay.

The thickness of the Midford Sand is subject to much variation, for in the neighbourhood of Bath and the Mendip Hills the beds occasionally taper away. In the Cotteswold area the beds are from 10 to 120 feet thick; in Somersetshire they attain a maximum of 200 feet; and in Dorsetshire 150 feet or more.

These beds, as previously stated, include generally the zones of *Ammonites opalinus* and *A. jurensis*. In many places however they are comparatively unfossilferous. The observations of Mr. Buckman (to which reference has already been made, p. 40) show that in different areas the mass of the sands may be assigned palæontologically more to one than to the other of these zones, and that portions of the Upper Lias shale of Dorsetshire may belong to the zone of *A. jurensis*.

In Dorsetshire the beds are often spoken of as the Yeovil and Bridport Sands.

### *Bridport (Coast Sections) to Beaminster.*

On the coast at Bridport the Midford Sand is well-exposed in the cliff-sections, and it comprises a series of yellow sands with nodular layers and bands of calcareous sandstone. (See Fig. 33.)

In proceeding eastwards from Golden Cap, the first exposure is at Thorncombe Beacon, where beneath the Upper Greensand and possible traces of Gault, there occur about 100 feet of yellow sands that exhibit a gradual passage into the Upper Lias shale beneath. The beds, however, can only be contemplated at a distance, for the higher portions of Thorncombe Beacon are not accessible.

Immediately west of Bridport Harbour there is a low cliff, about 40 feet high, showing yellow sand, with three or four bands of calcareous sandstone, having a slight inland dip. Small caves have been hollowed out in the beds, along lines of weakness, that were produced no doubt by a fault that brings the beds abruptly against the Fuller's Earth. This fault runs somewhat obliquely

* Trans. Geol. Soc., ser. 2, vol. i. p. 306, and vol. iv. p. 31.
† See H. B. W., Geol. Mag., 1872, p. 513.

FIG. 32.

*Section from Bridport Harbour to Cliff End, near Burton Bradstock, Dorsetshire.*

Distance, 2¼ miles. Vertical Scale, 800 feet to 1 inch.


4. Forest Marble (Bradfordian).
3. Fuller's Earth (Fullonian).
2. Inferior Oolite.
1. Midford (Bridport) Sand.

F. Faults.

through the cliffs, so that only a face of the Midford Sand is preserved.* The Fuller's Earth is dragged up along the fault-plane, and the Sand is also broken and disturbed, while traces of Inferior Oolite have in places been wedged in. At low-tide ledges of the harder layers in the Sand may be observed. The Sand at this end of the cliffs is gradually disappearing under the influence of denuding forces, so that in time the beds banked up against the Fuller's Earth will be entirely removed.

FIG. 33.
*Cliffs east of Bridport Harbour.*

The finest exposures of the Sand are in the cliffs east of Bridport Harbour, and these extend to Burton Bradstock. Their remarkable banded appearance is due to the influence of atmospheric denudation, the harder layers of calcareous sandstone standing out in relief. A slight inland-dip in the strata tends to keep the cliffs perpendicular; but falls of rock not infrequently take place, and their recent occurrence may be noticed here and there by the smooth unweathered faces of the cliff, where the sea has cleared away the débris. (See Fig. 33.)

Fossils are not abundant in the sands, nor are they well preserved. *Belemnites*, known to the fishermen as "Fairies fingers," and portions of *Ammonites* known as "Lobster's tails," may be found here and there. I obtained *Ammonites* (a fine variety, near to *A. concavus*), *Belemnites abbreviatus* ?, *Pecten læviradiatus*, *Cucullæa*, *Myacites tenuistriatus*, and *Rhynchonella jurensis* ?. Dr. Wright mentions *A. variabilis*; and Mr. Hudleston has recorded from the upper 7 feet of the strata, *A. torulosus*, *A. opalinus*, *A. subinsignis*, *Turbo subduplicatus*, *Waldheimia anglica*, and *Rhynchonella cynocephala*.†

* See Fig. 32; and Fig. 41, p. 52 in Memoir on the Lias of England and Wales; and H. S. Solly and J. F. Walker, Proc. Dorset Nat. Hist. Club, vol. xi. p. 118.

† Gasteropoda of the Inferior Oolite (Pal. Soc.), p. 31; see also Oppel, Juraformation, p. 316; and S. S. Buckman, Quart. Journ. Geol. Soc., vol. xlv. p. 451.

The thickness seen is nearly 150 feet, but in this case the base is not exposed.

Traces of Inferior Oolite cap the Sand in East Cliff, Bridport Harbour; but these higher beds are best shown to the east of the river Bride (or Bredy), in the cliffs of Burton Bradstock. The higher strata are not accessible, hence the majority of the fossils from this celebrated locality, have been collected from the fallen masses of rock on the beach. The Inferior Oolite is capped by the Fuller's Earth, and we have the full thickness, which does not exceed 15 feet. Huge masses of rock occasionally break away from the cliffs, and from these it is possible to measure portions of the beds, and to collect fossils, with due attention to the stratigraphical position. (See p. 51.)

A few years ago a deep cutting was made for the road leading from Burton Bradstock to the shore, and here the beds down to the sands, could be examined *in situ*, and measured in detail. It is not, however, possible to make any extensive excavations in search of fossils, although when the cutting was made a fine series of specimens was obtained by Dr. M. Poignand.* Thus the collector must still devote his attention to the fallen blocks on the beach, and to the shallow quarries that have been opened up, a little way inland, between Bridport Harbour and Burton Bradstock.

Some confusion at one time arose from the application of the name "Cephalopoda Bed" in Dorsetshire. There is indeed in this county no band corresponding in character with the Gloucestershire Cephalopoda Bed; but the mass of the Inferior Oolite itself is a series of Cephalopoda Beds, for the zones of *Ammonites Murchisonæ*, *A. humphriesianus*, and *A. Parkinsoni* are locally very fossiliferous, and constitute rich fossil-beds at different horizons. These facts were not recognized by Dr. Wright in his papers on the subject,† consequently his determination of horizons, and his lists of species, have required considerable revision. To some extent order was re-established by Prof. Buckman,‡ but we are mainly indebted to his son, Mr. S. S. Buckman,§ whose observations have been confirmed and further illustrated by Mr. Hudleston.|| Among the species recorded by Dr. Wright from the so-called Dorsetshire Cephalopoda Bed, "*Ammonites jurensis*" is the form named *A.* (*Lytoceras*) *confusus* by Mr. Buckman; while the "*A. dorsetensis*" of Dr. Wright is simply a variety of *A. Parkinsoni.*

The following is a general section of the beds at Burton Bradstock:—

* Proc. Geol. Assoc., vol. ix. p. 204.
† Quart Journ. Geol. Soc., vol. xii. p. 312; vol. xvi. p. 47.
‡ *Ibid.*, vol. xxxv. p. 737.
§ *Ibid.*, vol. xxxvii. p. 588.
|| Proc. Geol. Assoc., vol. ix. p. 187.

| | | Ft. | Ins. |
|---|---|---|---|
| Upper division—Inferior Oolite. | 9. Pale-grey, oolitic, and earthy limestones, weathering rubbly - - | 5 | 0 |
| | 8. Pale grey and brown earthy limestone, slightly oolitic and iron-shot in places. TEREBRATULA BED, with *T. sphæroidalis*, &c. - - | 1 0 to 2 | 0 |
| | 7. Grey oolitic and iron-shot limestones, compact in places and ferruginous; including ASTARTE BED with *A. obliqua*, &c. - - - - | 2 | 4 |
| Lower division—Inferior Oolite. | 6. Pale grey, shelly, oolitic limestone, much iron-stained in places - - | 1 | 6 |
| | 5. Rubbly band of sandy ochreous oolite - - - - - | 0 | 3 |
| | 4. Pale grey, brown, and yellow rubbly iron-stained oolite - - - | 1 | 6 |
| Midford Sand (Yeovil and Bridport Sands). | 3. Yellow micaceous sands - - | 2 | 0 |
| | 2. Band of calcareous sandstone. | | |
| | 1. Yellow sands with bands and nodular masses of calcareous sandstone, in Burton Cliff - - - | about 80 | 0 |

The Midford Sand belongs in its upper part to the zone of *Ammonites opalinus*. The Lower division of the Inferior Oolite constitutes the zone of *Ammonites Murchisonæ*, with which is included the zone of *A. Sowerbyi* or the "*Concavus* Beds," with *A. concavus;* while the Upper division includes the zone of *A. humphriesianus* (not always distinctly represented) and the zone of *A. Parkinsoni*. This grouping was suggested by Mr. Hudleston, who has given a section of the Cliffs; the beds are somewhat differently subdivided and grouped by Mr. S. S. Buckman.*

The most noticeable beds are the *Astarte*-bed and the *Terebratula*-bed. The former is well seen in the tumbled blocks on the coast. It contains small examples of *A. humphriesianus*, together with *A. Parkinsoni;* and these forms occur together just below the *Terebratula*-bed, in a quarry south of the road between Bridport Harbour and Burton Bradstock, and nearly due north of the mouth of the Bride. I have found *A. humphriesianus* also in the *Terebratula*-bed. This indistinct development of the zone of *A. humphriesianus* has been noticed by Oppel† and Mr. Hudleston‡; but so far as Dorsetshire is concerned, this imperfection is local, for fine specimens of this Ammonite occur at Hyde quarry south-east of Bridport, and again at Oborne.

The *Terebratula*-bed is well shown in the quarries between Bridport Harbour and Burton Bradstock, and these expose also the iron-shot oolite below. The stone in these quarries was obtained chiefly for building stone-fences, and it is now occasionally dug for road-metal. The minor details of the beds seen in the quarries,

* Hudleston, Gasteropoda of Inf. Oolite (Pal. Soc.), p. 31; see also R. Etheridge in Damon's Geology of Weymouth, ed. 2, 1884, p. 225; S. S. Buckman, Inf. Ool. Ammonites, p. 47; Quart. Journ. Geol. Soc., vol. xlv. p. 451; and Day, Quart. Journ. Geol. Soc., vol. xix. p. 287.

† Oppel, Die Juraformation, p. 339.

‡ Hudleston, *op. cit.* p. 32.

road-cutting, and cliff-section, are subject to much variation. In the *Terebratula*-bed, the common species *T. sphæroidalis* occurs in shoals, in the neighbourhood of Burton Bradstock; but this species is less abundant in some of the quarries further inland, to the east of Bridport; and sometimes two bands, with many specimens of the Brachiopod, are to be seen. At Burton Bradstock the species occurs above and below the *Terebratula*-bed, and it is associated with *T. Phillipsi* and *Waldheimia carinata*.

Further inland the main mass of the Inferior Oolite is faulted out of sight between Burton Bradstock and Bothenhampton; but reappearing at Shipton Gorge, it continues in a very irregular form, much faulted and with several outlying portions, by Powerstock (Poorstock) to Beaminster and Broadwindsor. The Sands below form a broader belt of land, not however always clearly distinguished on the Geological Survey Map, from the Upper Lias, nor indeed from the Middle Lias sands, which much resemble them. They stand out in conspicuous grassy knolls, near Bridport and Symondsbury (see Fig. 136, p. 465), distinguished thus from the gorse-covered hills of Upper Greensand, and from the flat-topped outliers of Inferior Oolite. Sections may be seen in many places in the deep lanes or hollow-ways that traverse the district; especially in the country near Beaminster, and in the neighbourhood of Yeovil.

Numerous quarries are to be met with in the Inferior Oolite, for it has been largely used for road-metal, for building-purposes, and especially stone-fences, and for lime-burning. Many of the sections have been described by Dr. Wright, Mr. Hudleston, and others; but the greatest difficulty is experienced in fixing any precise lithological or palæontological divisions, for there are no constant characters that can be depended upon.

Generally the following lithological divisions will be found in the area from Bridport to Beaminster:—

| | Ft. | Ins. |
|---|---|---|
| 4. Pale grey oolitic and earthy limestones - | 4 0 to 12 | 0 |
| 3. Iron-shot and oolitic limestones - - | 10 0 to 12 | 0 |
| 2. Brown sandy and earthy limestones, with occasional iron-shot grains - - - - | 2 0 to 3 | 0 |
| 1. Yellow micaceous sands with indurated bands of calcareous sandstone - - - - | about 150 | 0 |

The Inferior Oolite increases to some extent in thickness as we proceed inland from the coast-stations.

When studying these beds in 1884 I collected carefully from the paler oolites on top (including the *Terebratula*-beds), and from the iron-shot beds below, these being the only general distinctions that could be made; but subsequent experience shows that these characters are not to be relied upon, even locally, for fixing zónal divisions, and the evidence furnished by those who have paid especial attention to the organic remains, shows that no definite planes of demarcation separate the zones. We have practically to deal with a succession of deposits that in places at any rate were continuous, and with a succession of organic remains that represent several zones, the species belonging to which have become more or less interblended. Deposition was no doubt comparatively slow, when we compare the thin beds of Dorsetshire with those of Gloucestershire, and we find, as is the case where the Lower Lias is thinly developed, that a considerable variety as well as abundance of organic remains may be obtained from the attenuated beds. It is, moreover, quite possible that some intermixture of forms may be due to organic remains sinking through the calcareous mud into layers deposited long previously.

Fossils are readily to be obtained from the blocks of stone stacked in the quarries; but those who desire to identify zones, must seek their specimens *in situ* from the individual layers of stone—a task that means many hours of labour in each quarry.

The pale grey oolitic and earthy limestones, that form the upper portion of the Inferior Oolite of this district, belong to the zone of *Ammonites Parkinsoni*. Fine specimens of this species and of *Nautilus lineatus* and *N. polygonalis*, many of which have been cut and polished for sale, have been obtained from quarries at Vinney (Vitney or Lydney) Cross, on the Dorchester road, about 3 miles east of Bridport.* Here also two marked *Terebratula*-beds were to be seen, containing the characteristic *T. sphæroidalis*, together with *T. Phillipsi*, *Rhynchonella spinosa*, *Waldheimia carinata*, *Lima pectiniformis*, and *Belemnites*. At the base of these limestones, *Astarte obliqua* occurs, as in the coast-section.

These beds, together with the underlying iron-shot limestones, have been quarried in several places west of Shipton Beacon, and in one opening, known as Hyde quarry, south of Walditch, I obtained two fine examples of *Ammonites humphriesianus* from the lower beds. This fact is of some interest, because in the coast section only very small examples of *A. humphriesianus* have been found, and some authorities even hesitate to call them by that name.

The iron-shot beds include in places the base of the zone of *Ammonites Parkinsoni*; but in beds of this character, more especially in the lower portion, *Ammonites Murchisonæ* may usually be found. Mr. E. A. Walford obtained a number of Polyzoa and Sponges from the upper beds of the Inferior Oolite in a quarry near the New Inn, Shipton Gorge.†

The same general succession (as previously noted) may be determined in the hills between Chideock and Symondsbury, where there are several quarries and road-cuttings. The beds are much faulted, so that higher and lower divisions occur in irregular juxtaposition. Traces of Fuller's Earth were exposed in one quarry on the northern hill, faulted against the pale earthy oolitic limestones, with the *Terebratula* bed.

On the southern hill, there are pits showing, in addition to the upper beds, about 10 feet of brown iron-shot oolite in massive beds, much fissured, and with the joints filled with calc-spar. Some of these beds contain so much ferruginous matter as to

* A section here is recorded by Mr. Hudleston, Inf. Ool. Gasteropoda, pp. 37, 38.
† Quart. Journ. Geol. Soc., vol. xlv. p. 561, vol. l., p. 72.

resemble the Corallian iron-ore of Abbotsbury. South of Symondsbury these beds were also exposed to a depth of 12 feet, and there they contain concretionary ironstone. Their extent here may be too limited to render them of economic importance as an iron-ore, even if they be considered rich enough for smelting. (See analysis, p. 498.) From these beds I obtained the following fossils :—

Ammonites corrugatus.
——Murchisonæ.
Belemnites Blainvillei.
Astarte excavata.
Myacites tenuistriatus.
Ostrea.
Thracia lata.
Trigonia.
Unicardium.
Rhynchonella angulata ?.
Terebratula.

Below these iron-shot beds, there were hard brown sandy and occasionally iron-shot limestones, 2 to 3 feet thick; and, at the base, yellow sands with bands of hard and nodular bluish-grey sandy limestone. At this locality Mr. S. S. Buckman records *A. Murchisonæ* and *A. opalinus* from the same bed.* In the Museum of Practical Geology there is a specimen of *Eryma* from Chideock.

The sands were also exposed on the eastern side of the northern Chideock Hill, and from these I obtained *Ammonites* (fine var. near to *concavus*), *Belemnites, Pecten læviradiatus, Rhynchonella jurensis* ?. Dr. Wright records from the sands at Chideock, *Ammonites insignis, A. opalinus*, and *A. variabilis*.

Wide fissures or "caverns" were noticed in the Inferior Oolite of Chideock Hill by Buckland and De la Beche.†

The iron-shot beds of the Inferior Oolite have been quarried at Watton Hill, north of Bridport; the higher beds have been worked at another Watton Hill, near Lower Loders, and at Powerstock. The fossils obtained from these localities are mentioned in the accompanying list. As a rule the iron-shot beds are more fossiliferous than the pale limestones above.

The railway-cutting east of Lower Loders exhibited a fine section of the Inferior Oolite; it was as follows :—

| | | Ft. | In. |
|---|---|---|---|
| Zone of *Ammonites Parkinsoni*. | 9. Buff and grey earthy oolite, *Belemnites, Cirrus nodosus, Modiola gibbosa* - - - - - - - | 5 | 7 |
| | 8. Coarse grey and brown oolite and crystalline limestone, iron-shot in places. *Terebratula*-bed with *T. sphæroidalis* in shoals. *Rhynchonella, Belemnites* 2 0 to | 2 | 6 |
| | 7. Grey and brown earthy and iron-stained oolite, four beds, with few fossils - - - - - - | 6 | 3 |
| | 6. Iron-shot oolite (blue-hearted) - - - - - | 1 | 4 |
| | 5. Coarse blue and brown iron-shot oolite, *Ammonites Parkinsoni, Belemnites, Lima pectiniformis, T. sphæroidalis* - - - - - - - | 1 | 0 |

* Quart. Journ. Geol. Soc., vol. xlvi. p. 520; see also Wright, Quart. Journ. Geol. Soc., vol. xii. p. 312; and Lias Ammonites (Pal. Soc.), pp. 139, &c.
† Trans. Geol. Soc., ser. 2, vol. iv. p. 30.

| | | Ft. | In. |
|---|---|---|---|
| Zone of *A. Murchisonæ.* | 4. Hard compact bluish-grey limestone, *A. concavus*, *A. Murchisonæ*, *Belemnites*, *Ostrea*, *Rhynchonella*, *Terebratula* - - - - - - - | 1 | 4 |
| | 3. Grey and brown sandy limestone with ferruginous specks, *Nautilus excavatus*, *Belemnites*, *Pleurotomaria*, *Lima inoceramoides*, *Trigonia*, *Gervillia* - - | 1 | 3 |
| | 2. Pale greyish-brown sandy limestone, passing down into bed below: *Ammonites*, *Belemnites Blainvillei*, *Ataphrus* (*Monodonta*) *lævigatus*, *Natica*, *Pleurotomaria*, *Ceromya bajociana*, *Exogyra*, *Goniomya v-scripta*, *Gresslya abducta*, *Homomya crassiuscula*, *Lima pectiniformis*, *L. duplicata*, *Hinnites*, *Modiola gibbosa*, *M. sowerbyana*, *Pecten lœviradiatus*, *P. paradoxus ?*, *Thracia lata*, *Trigonia*, *Terebratula perovalis*, *Holectypus hemisphæricus* - - - - - | 3 | 6 |
| | 1. Brown calcareous sand. | | |

Other species, collected from the iron-shot beds, are included in the list, p. 64.

In the neighbourhood of Beaminster there are several quarries, but the beds are much displaced by faults, and this is the case onwards by Crewkerne and Bradford Abbas.

The total thickness of the Inferior Oolite near Beaminster is from 5 to 20 feet. The beds vary much in detail; there appears to be no special *Terbratula*-bed, as near Bridport; nor are the iron-shot beds so thick and prominent. The sequence from the upper beds of Inferior Oolite to the Sand at their base, is shown in the deep road-cutting between Broadwindsor and Coneygore. Beneath the main mass of the Inferior Oolite limestone, there is a bed 9 feet thick, formed of very sandy compact limestone. It occurs in lenticular and nodular masses in sand, and constitutes a passage into the yellow micaceous sands, with beds of calcareous sandstone, that are exposed beneath to a thickness of about 40 feet. The beds here do not exhibit themselves in a very fossiliferous form. Far more interesting sections are exposed at Stoke Knap; indeed no better place can be found for examining the fossiliferous beds, sometimes developed, in the upper part of the Midford Sand.

Stoke Knap is little more than a mile south-east of Broadwindsor, and the best sections of the lower beds are exposed on the southern slopes. Here *Terebratula infra-oolitica* occurs in profusion, accompanied by *Rhynchonella cynocephala*, *Waldheimia carinata*, var. *Mandelslohi* ;* and other fossils. There are also Brachiopods that cannot be distinguished from young forms of *Terebratula maxillata*. It is noticeable that, while these species occur in abundance, the details of the beds vary in different portions of the hill. Fossils are prevalent here and there, but all the layers appear unfossiliferous in places. The beds are slightly faulted. The occurrence of *A. torulosus* at this locality has been mentioned by Mr. Hudleston ;† and Mr. S. S. Buckman records

* Mr. Buckman, evidently referring to the same Brachiopod, notes it as *Waldheimia Blakei*. Quart. Journ. Geol. Soc., vol. xlv. p. 454.

† Gasteropoda of Inf. Oolite, p. 39.

*A. opalinus.* The bed with *T. infra-oolitica,* &c. is seen also in Crewkerne railway-cutting, and belongs to the zone of *Ammonites opalinus.*

The following is the section at Stoke Knap:—

| | | | Ft. | In. |
|---|---|---|---|---|
| | Fuller's Earth. | Grey clay. | | |
| Inferior Oolite. | Upper Division. Zone of *Ammonites Parkinsoni.* | Rubbly, pasty, and slightly oolitic limestone, ferruginous in places. *Belemnites terminalis, Ammonites Parkinsoni, Terebratula sphæroidalis, Collyrites ringens, C. ovalis, Holectypus.* | 3 0 to 4 | 0 |
| | | Hard pale-grey oolitic limestone - | 2 | 0 |
| | | Pale-grey and brown (iron-stained) sparry limestones, more or less oolitic and shelly in places: rubbly in lower part - - - - | 8 | 0 |
| | Lower Division. Zone of *A. Murchisonæ.* | Iron-stained shelly limestone, iron-shot in places: even line on top. *Belemnites* - - - - | 1 4 to 1 | 6 |
| | | Brown and blue iron-shot oolitic limestones, sandy and compact in places, and very fossiliferous. *Ammonites concavus, A. Murchisonæ, Belemnites Blainvillei* - - - - - | 5 | 4 |
| | | Rubbly, sandy, ferruginous and iron-shot limestones, imperfectly oolitic. *Pecten* - - - - | 4 0 to 5 | 0 |
| | | Rubbly and nodular sandy limestone, and yellowish sand; shelly in places. *Belemnites, Pholadomya, Trigonia.* | about 8 | 0 |
| Midford Sand. | Zone of *A. opalinus.* | Irregular rubbly and sandy limestone, and clay or marl; in places a mass of fossils. *Terebratula infra-oolitica* and *Rhynchonella cynocephala* | 0 10 to 1 | 2 |
| | | Ferruginous clayey seam - | 0 6 to 0 | 8 |
| | | Rubbly and sandy limestone, forming a prominent bed, very fossiliferous. *Ammonites, T. infra-oolitica, R. cynocephala, Myacites,* &c. With a *Serpula*-bed in and sometimes just below the bed - - - | 2 0 to 2 | 6 |
| | | Yellow sands with indurated bands and nodules of bluish-grey and yellow sandy limestone; smalled keeled *Ammonites, Myacites,* &c. - | about 3 | 0 seen. |

At the base of the zone of *A. Murchisonæ* there are some sandy limestones imperfectly oolitic in places, that have yielded *A. Murchisonæ, A. concavus* (fine var.), *A. Leckenbyi,* and other fossils. Lithologically they form a passage between that zone and the underlying beds.

Before passing on to more northerly regions it will be useful to give a list of the more abundant and important fossils of the South Dorset district.

The specimens collected by myself are marked (W), and they were identified by Messrs. Sharman and Newton, who also named a number of specimens collected by Dr. M. Poignand (P). Other species are given on the authority of Mr. Hudleston (H), and Mr. Buckman (B), as noted in the first column.

The particular zone of certain species from the iron-shot beds, is left uncertain.

## List of Fossils from the Inferior Oolite Series of South Dorset.

| Collector. | —— | Sands. | Lower Division. | Upper Division. | Iron-shot Beds. | Burton Brad-stock. | Bridport. | Loders. | Powerstock. | Stoke Knap. |
|---|---|---|---|---|---|---|---|---|---|---|
| | Ammonites aalensis | 1 | | | | Bb | | | | |
| W | — Blagdeni | | | 3 | | | B | | | |
| | — Brocchii | | | | | Bb | | | | |
| | — Brongniarti | | | | | Bb | | | | |
| W | — concavus | | 2 | | | Bb | B | L | | S |
| W | — corrugatus | | 2 | | | | B | | | |
| P | — dimorphus | | | | | Bb | | | | |
| P | — fuscus | | | 3 | | Bb | | | | |
| P | — garantianus | | | | | Bb | | | | |
| P W | — Gervillei | | | | × | Bb | B | | | |
| W | — hircinus (Leckenbyi) | 1 | | | | | | | | S |
| W | — humphriesianus | | | 3 | × | Bb | B | | | |
| B W | — jurensis | 1 | | | | Bb | B | | | |
| P | — Martinsi | | | | | Bb | | | | |
| B | — Moorei (var. of A. aalensis) | 1 | | | | Bb | | | | |
| W | — Murchisonæ | | 2 | | | Bb | B | L | | S |
| H | — opalinus | | | | | Bb | | | | |
| W | — Parkinsoni | | | 3 | | Bb | B | L | P | S |
| P | — polymorphus | | | | | Bb | | | | |
| P | — Sowerbyi, var. gingensis | | | | | Bb | | | | |
| H | — subinsignis | 1 | | | | Bb | | | | |
| W | — subradiatus | | | 3 | × | Bb | B | | P | |
| H | — torulosus | 1 | | | | Bb | | | | |
| P | — Truellei | | | | | Bb | | | | |
| | — variabilis | 1 | | | | Bb | | | | |
| | Nautilus burtonensis | | | | | Bb | | | | |
| W | — excavatus | | 2 | | × | | | L | | |
| W | — truncatus ? | | | 3 | | Bb | B | | | |
| W | Belemnites Blainvillei | ? | 2 | 3 | × | Bb | | L | | S |
| W | — ellipticus | | 2 | 3 | × | | B | L | | |
| W | — terminalis | | | 3 | | | B | L | P | |
| H | Alaria hamus | | 2 | | | Bb | | L | | |
| H | — Lorieri | | 2 | | | Bb | B | L | | |
| W | Amberleya ornata | | | 3 | | Bb | | | | |
| W | Ataphrus (Monodonta) lævigatus | | | | × | | | L | | |
| HW | Cirrus nodosus | | | 3 | × | Bb | | L | | |

## Fossils from the Inferior Oolite Series of South Dorset.

| Collector. | —— | Sands. | Lower Division. | Upper Division. | Iron-shot Beds. | Burton Bradstock. | Bridport. | Loders. | Powerstock. | Stoke Knap. |
|---|---|---|---|---|---|---|---|---|---|---|
| H | Eucycloidea (Purpurina) bianor | | 2 | | | Bb | B | L | | |
| HW | Natica bajocensis | | | 3 | | Bb | B | | | |
| H | Onustus ornatissimus | | 2 | | | Bb | | | | |
| W | Pleurotomaria fasciata | | | 3 | | | B | | | |
| W | —— granulata | | | | × | | B | | | |
| W | —— ornata | | | 3 | | Bb | | | | |
| H | Purpurina bellona | | 2 | | | Bb | | | | |
| H | —— inflata | | 2 | | | Bb | | | | |
| H | Spinigera recurva | | 2 | | | Bb | B | | | |
| W | Trochus duplicatus | | | | | Bb | | | | |
| H | —— subduplicatus | 1 | | | | Bb | | | | |
| W | Arca | | | 3 | | | B | | | |
| W | Astarte excavata | | | | | Bb | | | | |
| W | —— obliqua | | | 3 | | Bb | | | | |
| W | Avicula inæquivalvis | | | | | Bb | | | | |
| W | Cardium | | | 3 | | Bb | | | | S |
| W | Ceromya bajociana | | 2 | 3 | × | | B | L | | |
| W | Cucullæa oblonga | | 2 | | × | | | L | | S |
| W | Cypricardia bathonica, var. brevis | | | 3 | × | | | L | | |
| W | Exogyra | | 2 | | × | | | L | | S |
| W | Gervillia lata | 1 | | | | | | | | S |
| W | Goniomya v-scripta | 1 | 2 | | × | | | L | | S |
| W | Gresslya abducta | | 2 | 3 | | | | L | P | |
| W | Gryphæa mima | | 2 | | | | | | | S |
| W | Hinnites | | 2 | | × | | | L | | S |
| W | Homomya crassiuscula | | 2 | | × | | | L | | |
| W | Lima duplicata | 1 | 2 | 3 | × | Bb | | L | | S |
| W | —— gibbosa | | 2 | 3 | × | Bb | B | | | S |
| W | —— inoceramoides | | 2 | | × | | | L | | |
| W | —— pectiniformis | | 2 | 3 | | Bb | | | P | |
| W | —— strigillata | | | | × | Bb | B | | | |
| W | Modiola gibbosa | | 2 | 3 | × | Bb | | L | | |
| W | —— sowerbyana | | | | × | | | L | | |
| W | Myacites decurtatus | | | 3 | | Bb | | | | |
| W | —— jurassi | | | 3 | | Bb | B | | P | |
| W | —— tenuistriatus | 1 | 2 | 3 | × | Bb | B | | | S |
| W | Ostrea palmetta, var. montiformis | | | | | Bb | | | | |
| W | —— Münsteri | | 2 | | | | | | | S |
| W | Pecten demissus | | | 3 | × | | | L | | |

## Fossils from the Inferior Oolite Series of South Dorset.

| Collector. | —— | Sands. | Lower Division. | Upper Division. | Iron-shot Beds. | Burton Bradstock. | Bridport. | Loders. | Powerstock. | Stoke Knap. |
|---|---|---|---|---|---|---|---|---|---|---|
| W | Pecten læviradiatus | 1 | 2 | 3 | × | | | L | | |
| W | —— paradoxus | | 2 | | × | | | L | | |
| W | —— texturatus? | | | | | Bb | | | | |
| W | Pholadomya oblita | | | 3 | × | | | L | | |
| W | —— Heraulti | | 2 | | | | | | | S |
| W | —— media | | 2 | | | | | | | S |
| H | Placunopsis | | | 3 | | Bb | | | | |
| W | Thracia lata | | 2 | 3 | × | | B | L | | |
| W | Trigonia costata? | | | | | | | L | | |
| W | —— formosa | | | | | Bb | | | | |
| B W | —— striata | 1 | | 3 | | Bb | | | | |
| W | Unicardium | | | 3 | × | Bb | B | L | P | |
| W | Rhynchonella concinna | | | 3 | × | | B | L | | |
| H W | —— cynocephala | 1 | | | | Bb | | | | S |
| W | —— jurensis | 1 | | | | | | | | |
| W | —— plicatella | | | 3 | | | B | | | |
| W | —— spinosa | | | 3 | | Bb | B | L | P | |
| W | Terebratula Buckmani | | 2 | 3 | | | | | P | S |
| W | —— decipiens | | | 3 | | | | | P | |
| W | —— globata | | | 3 | | | B | | | |
| W | —— —— var. birdlipensis | | | 3 | × | Bb | | | P | |
| W | —— infra-oolitica | 1 | | | | | | | | S |
| W | —— perovalis | | 2 | 3 | × | Bb | | L | | S |
| W | —— Phillipsi | | | 3 | | Bb | B | | | |
| W | —— sphæroidalis | | | 3 | | Bb | B | L | P | S |
| W | —— Stephani | | | 3 | | Bb | | | | S |
| H | Waldheimia anglica | 1 | | | | Bb | | | | |
| W | —— carinata | | | 3 | × | Bb | B | | | |
| W | —— —— var. Mandelslohi | 1 | | | | | | | | S |
| W | Serpula tricarinata | 1 | | | | | | | | S |
| W | Clypeus altus | | | 3 | | Bb | | | P | |
| W | Collyrites ovalis | | | 3 | | | B | L | | S |
| W | —— ringens | | | 3 | | Bb | | | | |
| W | Holectypus hemisphæricus | | 2 | 3 | × | Bb | B | | P | |
| W | Hyboclypus gibberulus | | | 3 | | | | | P | |
| W | Stomechinus bigranularis | | | | | Bb | | | | |
| W | Pentacrinus | | | 3 | | Bb | | | | |

*Crewkerne to Stoford, near Yeovil.*

In the neighbourhood of Crewkerne there are many opportunities of studying the Inferior Oolite, in cuttings and quarries near the railway-station, and in quarries at Misterton and Haselbury.*

The beds are frequently displaced by faults, but we find the general stratigraphical sequence to compare well with that noted near Bridport and Beaminster (p. 59). Each section, however, presents some differences in the lithological details and in the assemblages of fossils; and it is difficult to define the limits of the zones. The upper beds, from 12 to 20 feet thick, consist of pale shelly and oolitic limestones with *Ammonites Parkinsoni*, and among the more characteristic fossils are Echinoderms.

The lower beds comprise brown shelly and more or less iron-shot limestones, resting on pale-grey sandy and hard shelly limestones, with occasional iron-shot grains. These are altogether little more than 5 feet thick; but they are very fossiliferous in places, and yield *Ammonites Murchisonæ* and many Lamellibranchs. These beds are more variable in character and in their fossil contents than the overlying beds, which belong to the zone of *A. Parkinsoni*. The iron-shot beds here, as further south, sometimes yield fossils that would assign them to the Upper Division of the Inferior Oolite; and it would appear that these beds, while belonging mainly to the zone of *A. Murchisonæ*, may locally include representatives of the zone of *A. humphriesianus* as well as of *A. Parkinsoni*. Long continued collecting of fossils from each individual bed is needful before we can state fully their palæontological contents: for there is undoubtedly some commingling of species, elsewhere assigned to different zones, in these attenuated portions of the Inferior Oolite.

The Midford Sand (Yeovil Sand) comprises, in its upper part, sands and loamy beds that are more or less indurated; and they contain *Rhynchonella cynocephala*, *Terebratula infra-oolitica*, *T. maxillata* (young forms?), and *Serpula tricarinata*, as at Stoke Knap, near Beaminster. These fossiliferous beds are well seen in the top 6 feet of the formation. The higher portions of the Sand, for a thickness of about 90 feet, consist mainly of sands, with indurated bands of calcareous sandstone, and layers of comminuted-shell-limestone. Lower down, for nearly 100 feet, we find sands, that become bluish and shaly towards the base, where they merge into the shales of the Upper Lias.

The railway-cutting west of Crewkerne railway-station, exposed a good section of these fossiliferous sandy beds (zone of *Ammonites opalinus*), overlaid by the limestones previously described (see Fig. 34). These beds are faulted obliquely across the railway, against the Fuller's Earth.

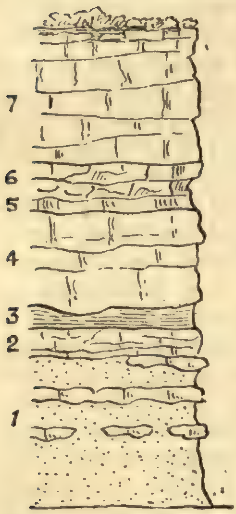
The Midford Sand, with bands of sandy limestone, was exposed in Mr. Lye's brickyard, south-east of the brewery at Crewkerne. The beds were opened up to a depth of 15 feet, and

* H. B. W., Proc. Somerset Arch. Soc., vol. xxxvii. p. 60.

were seen to be faulted against a mass of Fuller's Earth Clay, and Inferior Oolite. The clay was used for making bricks, tiles, and

FIG. 34.

*Section in Railway-cutting west of Crewkerne Station.*




| | Ft. | In. |
|---|---|---|
| 7. Pale rubbly oolitic limestones (zone of *Ammonites Parkinsoni*) - - - | 6 | 0 |
| 6. Brown shelly and iron-shot oolite - - | 2 | 0 |
| 5. Hard brown limestone passing into compact grey oolitic limestone - - - | 1 | 5 |
| 4. Pale sandy and shelly limestones - - | 3 | 0 |
| 3. Brown sandy marl with *Terebratula infra-oolitica* - - - - - | 1 | 0 |
| 2. Indurated marl and sandy limestone with *Ammonites*, *Belemnites*, *Pecten læviradiatus*, and *Rhynchonella* - - - | 1 | 3 |
| 1. Sands with irregular bands and nodules of calcareous sandstone: *Pecten*, *Rhynchonella cynocephala*, *Serpula* - - | 6 | 0 |

drain-pipes, the sand also was used in the brick-making, while the stone was burnt for lime. (See Fig. 35.)

Fossiliferous sandy beds were seen in a road-cutting west of Crewkerne, and on the main road between Crewkerne and Haselbury. At the former locality the sands, just below the Oolite, are crowded with *Serpulæ*, a small *Ostrea*, and *Rhynchonella cynocephala;* at the latter place we find, rather lower in the series, a shelly bed with *Rhynchonella*, that approaches in character to the North Perrot and Ham Hill stones.

By the cross-roads east of Little Silver, between Haselbury and East Chinnock, the following section was exposed:—

| | | Ft. | In. |
|---|---|---|---|
| Midford Sand | Sandy limestone in flaggy beds, alternating with sand. *Rhynchonella cynocephala*, *Terebratula infra-oolitica*, and *Lima strigillata* - - - | 6 | 0 |
| | Brown sandy and soft shelly limestones with small Ammonites - - | 6 | 0 |

The upper beds are like those at Crewkerne railway-cutting and Stoke Knap, while the beds below partake of the nature of the North Perrot stone, but are not so shelly.

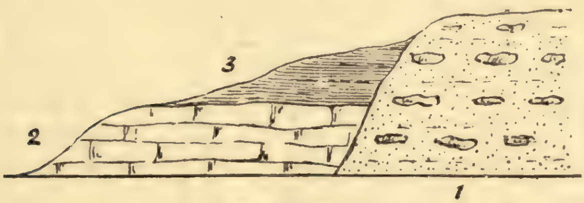
The quarry south of Misterton showed a few beds of the pale limestones, belonging to the zone of *A. Parkinsoni;* lower down there were brown oolitic and iron-shot limestones (2 ft. 2 in.); and, at the base, hard grey shelly and oolitic limestones, yielding fine specimens of *Ceromya concentrica*, and also *Gryphæa sublobata*—the latter recalling the Gryphite Grit of the Cotteswold Hills.

The same *Gryphæa*, occurs also abundantly at Haselbury: and in both of these Dorset localities it is associated with *Ammonites Murchisonæ.* It occurs in higher beds near Bruton.

The fossils mentioned in the accompanying list were mostly collected by Mr. John Rhodes and myself, from the quarries and railway-cutting at Crewkerne, and from the quarries at Misterton and Haselbury. The beds at Haselbury have been described by Mr. Hudleston, and some of the species from that locality were recorded by him.* Some Brachiopoda collected by Mr. Darell Stephens, from the neighbourhood of Crewkerne, were identified by Davidson† ; other Brachiopoda from Misterton, have been noted by Mr. J. F. Walker.‡

FIG. 35.

*Section in Brickyard, Crewkerne.*




3. Fuller's Earth Clay.
2. Inferior Oolite.
1. Midford Sand.

## LIST OF FOSSILS FROM THE INFERIOR OOLITE SERIES NEAR CREWKERNE.

| — | Sands. | Lower Beds. | Upper Beds. | Crewkerne. | Misterton. | Haselbury. |
|---|---|---|---|---|---|---|
| Ammonites concavus - - | | 3 | | C | | |
| —— corrugatus - - - | | 3 | | | | H |
| —— Murchisonæ - - - | | 3 | | | M | H |
| —— Parkinsoni - - - | | | 4 | C | M | |
| —— polymorphus - - - | | | ? | C | | |
| —— Sowerbyi - - - | | 3 | | | | H |
| Nautilus - - - - | 1 | | | C | | |
| Belemnites bessinus - - | | | 4 | C | | |
| —— sp. - - - - - | 1 | 3 | 4 | C | M | H |

* Gasteropoda of Inf. Oolite, p. 40.
† Proc. Dorset Nat. Hist. Club, vol. i., 1877, p. 73.
‡ Geol. Mag. 1878, p. 552.

FOSSILS FROM THE INFERIOR OOLITE SERIES NEAR CREWKERNE—*cont.*

| — | Sands. | Lower Beds. | Upper Beds. | Crewkerne. | Misterton. | Haselbury. |
|---|---|---|---|---|---|---|
| Amberleya | | | 4 | C | | |
| Pleurotomaria | 1 | | 4 | C | | |
| Astarte excavata | | 3 | | C | M | |
| Ceromya concentrica | | 3 | | | M | |
| —— sp. | 1 | | | C | | |
| Cucullæa cucullata | | ? | | | M | |
| —— oblonga | | 3 | | | M | |
| Cypricardia elongata | | 3 | | C | | |
| —— lebruniana | | 3 | | | M | |
| Gervillia lata | | 3 | | | M | |
| Gresslya abducta | | 3 | | | M | |
| Gryphæa cygnoides | | 3 | | | M | |
| —— sublobata | | 3 | | | M | |
| Isocardia cordata | | 3 | | | M | |
| Lima cardiiformis | | 3 | 4 | C | | |
| —— Etheridgei | | 3 | | | M | H |
| —— gibbosa | | | 4 | C | | |
| —— œpybolus | | 3 | | | M | |
| —— pectiniformis | | 3 | 4 | C | M | |
| —— strigillata | | 3 | | C | | |
| Macrodon hirsonensis | | 3 | | C | | |
| Myacites semistriatus | 1 | | | C | | |
| —— tenuistriatus | 1 | | 4 | C | | |
| Ostrea | 1 | | 4 | C | | |
| Pecten demissus | 1 | 3 | 4 | C | M | |
| —— læviradiatus | 1 | 3 | | C | M | |
| —— paradoxus ? | | 3 | | C | | |
| Pecten wollastonensis | | 3 | | | M | |
| Pholadomya fidicula | | 3 | | | M | |
| —— oblita | 1 | ? | | C | ? | |
| —— Phillipsi | | | 4 | C | | |
| Trigonia costata | | 3 | | C | | |
| —— sculpta | | 3 | | | M | |
| Rhynchonella cynocephala | 1 | | | C | | |
| —— obsoleta | | | 4 | C | | |
| Terebratula Buckmani | | | 4 | C | | |
| —— decipiens | | | 4 | | M | |
| —— globata | | | 4 | | M | |

FOSSILS FROM THE INFERIOR OOLITE SERIES NEAR CREWKERNE—*cont.*

| — | Sands. | Lower Beds. | Upper Beds. | Crewkerne. | Misterton. | Haselbury. |
|---|---|---|---|---|---|---|
| Terebratula infra-oolitica | 1 | | | C | | |
| —— perovalis | | 3 | | C | M | |
| —— Phillipsi | | | 4 | C | M | |
| —— sphæroidalis | | | 4 | C | | |
| Waldheimia anglica | | 3 | | | | H |
| —— Meriana | | | 4 | | M | |
| Serpula tricarinata | 1 | | | C | | |
| —— sp. | | | 4 | C | | |
| Clypeus Agassizi | | | 4 | C | | |
| —— altus | | | 4 | C | | |
| Collyrites ovalis | | | 4 | C | | |
| Galeropygus agariciformis | | 3 | | | | H |
| Holectypus depressus | | ? | | | M | |
| —— hemisphæricus | | | 4 | C | | |
| Pentacrinus | | 3 | | C | | |

The Midford Sand is exposed in many of the road- and lane-cuttings between Ilminster and Yeovil. From the lower beds of sandy marl at White Lackington, near Ilminster, Mr. S. S. Buckman records *Ammonites jurensis, A. insignis, A. dispansus,* and a fragment like *A. striatulus,* as occurring together.*

By New Hall, west of North Perrot Church, there was a quarry showing about 18 feet of false-bedded shell-limestones, interbedded with buff sands and sandy limestones, that (as previously mentioned) occur locally in the upper part of the Midford Sand in this district, and are well represented at Ham Hill. The shell-fragments are mostly indeterminable as to species, consisting of *Ostrea, Pecten,* and *Avicula*; but Mr. Rhodes obtained *Pecten demissus* and *Belemnites Voltzi*?

Chiselborough Hill, according to Bristow, is capped by a thin irregular shelly limestone, which has been worked out in holes, and not systematically quarried. In the road by the knoll to the south-west of Chiselborough, we find a section of micaceous and loamy sands, with spherical concretions of calcareous sandstone, and these become shaly towards the junction with the Upper Lias clays below. A similar section was exposed in the deep lane leading from Montacute Priory towards Ham Hill.

The celebrated building-stone of Ham (or Hamdon) Hill has long been recognized as a member of the Inferior Oolite, although opinions have differed on the question of its precise position in

* Inf. Ool. Ammonites, p. 165; and Quart. Journ. Geol. Soc., vol. xlv. p. 450.

the series. On the Geological Survey May it has been coloured the same as the Inferior Oolite limestone, but Bristow who surveyed the area has expressed the opinion that the Ham Hill Stone is the equivalent of the upper portion of the sands near Yeovil, which contain occasional thin and interrupted beds of limestone.* This view of the case was originally pointed out by Prof. Buckman,† and is confirmed by an examination of the areas. Thus layers of shelly limestone like Ham Hill Stone, appear in the upper part of the sands in the railway-cuttings near Yeovil junction, and in some of the deep road-cuttings or "hollow ways" of Babylon Hill. These shelly limestones may be traced in places also to the south and south-west of Yeovil, as at North Perrot, east of Crewkerne: and they evidently belong to the zone of *Ammonites opalinus*.

The fossils obtained at Ham Hill itself, are as a rule so fragmentary that precise identification is impossible, but while on a visit to the quarries in 1885, in company with Mr. F. J. Bennett, I was fortunate in finding examples of *Rhynchonella cynocephala*; a discovery subsequently confirmed by the Rev. H. H. Winwood.‡ I have since learnt that the species was recorded, though with some doubt, by Prof. Buckman.§

The following is a section of one of the principal quarries at Ham Hill (belonging to Messrs. Charles Trask and Sons):—

| | | | Ft. | In. |
|---|---|---|---|---|
| Midford Sand. | "Ochre Beds": 40 feet | Sand and thin soft stone. | | |
| | | Sand with thicker beds of stone: *Ammonites*. | | |
| | Ham Hill Stone: false-bedded shelly and sandy limestones of various shades of brown and yellow; 50 feet. | Main mass of freestone, indistinctly jointed, and false-bedded. Good stone obtained 7 or 8 feet down, and thence to bottom, in the following sequence:— | | |
| | | Yellow Beds (chief part) - Coarse Bed - | 35 | 0 |
| | | Grey Beds (most durable) about | 8 | 0 |
| | | Stone beds (not worked) 6 0 or | 7 | 0 |
| | Yellow Sands, &c.: about 80 feet. | Sands with nodular beds of calcareous sandstone; seen in road-cutting on west side of Ham Hill. ("Yellow Brim Sands," of Moore.) | | |

[For further particulars of the stone, see under "Economic Products," p. 475.]

The Grey Beds rise towards the surface at the northern end of the Camp, to the south-east of the Inn.

A quarry on the south-eastern side of Ham Hill, on the Odcombe road (north side), showed thin flaggy and sandy beds,

* Damon's Geol. Weymouth, 1884, pp. 219 and 225.

† Proc. Somerset Arch. Soc., vol. xx. p. 162; Quart. Journ. Geol. Soc., vol. xxxiii. p. 3; vol. xxxv. pp. 737, 740.

‡ H. B. W., Proc. Bath Nat. Hist. Club, vol. vi. pp. 182, 224.

§ Quart. Journ. Geol. Soc., vol. xxxv. p. 743.

resting on about 12 feet of false-bedded shell-limestones. It was here that I obtained *Rhynchonella cynocephala* somewhat abundantly.* Mr. Rhodes subsequently obtained specimens of *Ammonites, Belemnites, Avicula, Lima, Ostrea, Pecten,* and *Terebratula,* in a more or less fragmentary condition. Sands with thick bands and nodular masses of sandy limestone were seen in the lane-cutting below.

On the south side of the road another quarry showed sands with bands of shelly limestone. The building-stone evidently becomes poorer in this direction, the sand containing shelly layers only at irregular intervals.

West of Stoford the Inferior Oolite is very thin; and this perhaps accounts for the fact that the Fuller's Earth is shown on the Geological Survey Map to rest directly on the Sand, south-west of Barwick (Berwick). A quarry north-east of North Coker, near East Coker, showed about 3 feet of thin flaggy limestone, there dug for road-metal. The two outliers (marked on the Map) are not in reality separated, and they appear to be overlaid by clay (Fuller's Earth) to the south-east. Here however the low ground is in part Alluvial and no sections are to be seen. The fossils from the Inferior Oolite of East Coker, indicate the zone of *Ammonites Murchisonæ.*† Westwards, the Forest Marble and Fuller's Earth are probably faulted against the Midford Sand. No doubt a re-examination of the ground will show that the abnormal relations represented on the Survey Map, between the Fuller's Earth and Inferior Oolite in other places, near the Chinnocks and Merriot, are due to faults, although perhaps owing to the attenuation of the Inferior Oolite limestone, this rock has not in all cases been observed where present.

The thinness of the Inferior Oolite is well shown in a quarry south-west of Yeovil Junction, and north of Stoford, where the beds from the base of the Fuller's Earth down to the Sand, are reduced to about 7 feet. The beds shown were as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Fuller's Earth | Grey clay with a thin band of soft earthy limestone. *Belemnites bessinus,* and *Pholadomya Heraulti* - | 2 | 4 |
| Inferior Oolite | 3. Hard bluish-grey earthy limestones, and irregular sandy marl - - | 2 | 3 |
| | 2. Bluish-grey iron-shot limestone, with *Pleurotomaria mutabilis, Trochus duplicatus* and *Lima inoceramoides* - - - - | 3 | 3 |
| | 1. Hard blue-hearted limestone (Dew Bed) - - - - | 1 | 3 |
| Midford Sand. | Sands, &c. | | |

A number of fossils were collected by Mr. John Rhodes, and these indicate the presence of the zones of *A. Murchisonæ* and

* See also S. S. Buckman, Inf. Ool. Ammonites, p. 52; Quart. Journ. Geol. Soc. vol. xxxvii: p. 588; and vol. xlv. p. 449. Mr. Buckman speaks of the *Rhynchonella* as *R. cynocephala* or (?) *R. Beneckei.*

† See Hudleston, Gasteropoda of the Inf. Ool., p. 40.

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*A. Parkinsoni.* The fossils from the different layers of Inferior Oolite unfortunately were not separated: but nevertheless the species may be recorded, as follows:—

| | |
|---|---|
| Ammonites concavus. | Pholadomya. |
| —— Murchisonæ. | Rhynchonella obsoleta. |
| —— Parkinsoni. | —— spinosa. |
| —— polymorphus. | —— subtetrahedra. |
| Chemnitzia. | Terebratula Buckmani. |
| Pleurotomaria. | —— Phillipsi. |
| Homomya ? | —— sphæroidalis. |
| Lima pectiniformis. | Montlivaltia ? |
| Myacites jurassi. | Thamnastræa ? |
| Ostrea. | |

Attention has been directed to this quarry by Mr. Hudleston, who obtained *Cirrus gradatus* from bed No. 2, which he groups with the sub-zone of *A. Sowerbyi.*

Of much interest also is the shelly bed that occurs in the sands about 30 feet beneath the Dew Bed. From this layer, which was quarried for road-metal, Mr. Hudleston obtained *Ammonites Moorei, A. radians,* and *Trigonia angulata.** From the same bed and the associated sands Mr. J. Rhodes obtained the following additional species:—

| | |
|---|---|
| Belemnites Voltzi ? | Placunopsis. |
| Astarte depressa. | Plicatula tuberculosa. |
| Lima strigillata. | Tancredia angulata. |
| Pecten demissus. | —— donaciformis. |
| —— paradoxus. | Trigonia formosa. |
| Pinna. | |

It is noteworthy that in the list published by Mr. Hudleston, *Trigonia angulata* is recorded; in that of Mr. Buckman, *T. literata* is the one Trigonia mentioned; and in the above list, a third species only is noted! Truly the identification of species is fraught with difficulty.

### *Yeovil to Milborne Port.*

At Yeovil Junction, by the London and South-Western Railway Station, in the cutting of the Great Western Railway, and also in the loop-line to the east, the Sand contains here and there beds of hard shelly limestone, composed chiefly of comminuted shells, in addition to the ordinary bands and scattered nodules of sandy limestone or calcareous sandstone.

These shelly limestones may also be seen in the road-cutting by Key, near Red House Inn, south of Yeovil; in the lane east of Barwick House; and in that to the west of Babylon Hill, a lane which connects the Yeovil and Sherborne Road with that leading from Yeovil to Bradford Abbas. Attention was called to these shelly layers by Prof. Buckman.†

The chief interest attaching to these limestones, of which 3 or 4 bands may sometimes be found, is that they indicate the change

* Proc. Geol. Assoc., vol. ix. p. 190; Gasteropoda of Inf. Oolite, Pal. Soc., p. 42; see also S. S. Buckman, Quart. Journ. Geol. Soc., vol. xlv. p. 450; xlix. p. 484.

† Quart. Journ. Geol. Soc., vol. xxxiii. p. 6; vol. xxxv. p. 742. See also S. S. Buckman, *Ibid.*, vol. xxxvii. p. 588.

which further on at Ham Hill is marked by the celebrated building-stones of that locality. The stone there is for the most part a shelly limestone, and the palæontological as well as the stratigraphical evidence, agree in grouping it as the upper part of the Midford Sand, at the base of the Inferior Oolite.

Symptoms of false-bedding are shown here and there in the irregular disposition of the hard bands, for these occasionally meet and enclose wedge-shaped masses of sand.

In the deep road-cuttings on Babylon Hill a thickness of 40 feet or more of these beds was exposed. From one of the shelly bands Mr. J. Rhodes and myself obtained *Ammonites striatulus ? Cucullæa, Pecten læviradiatus, Ostrea, Trigonia,* and *Rhynchonella.*,

The lower portions of the Sand exhibit bluish tinges and become shaly as they merge downwards into the Upper Lias shales. These features are exhibited in the lane leading from Yeovil Junction to Yeovil-town Station, and in some of the railway-cuttings near Yeovil, as observed also by Mr. S. S. Buckman. He records *Ammonites Moorei* from the hard bands throughout the Sand ; *A. jurensis* also occurs. He would assign a thickness of about 30 feet to the zone of *A. opalinus.**

The total thickness of the Midford Sand in this region may be estimated at from 180 to 200 feet.

The Inferior Oolite of the neighbourhood of Sherborne is of especial interest on account of the rich fossil-beds that occur in it.

The confusion that for a long time existed with regard to the correlation of its divisions, has been cleared up by the labours of Mr. S. S. Buckman, followed by those of Mr. Hudleston. They have shown the desirability of collecting from each individual bed of the Inferior Oolite; for in the earlier works of Dr. Wright considerable confusion was introduced, both in this neighbourhood and in that of Bridport (as previously mentioned, p. 57), by the correlation of the Gloucestershire Cephalopoda-Bed with portions of the Dorsetshire Inferior Oolite, that belong to higher stages in the series. Even Prof. Buckman, for long a resident at Bradford Abbas, at one time spoke of the Ammonites of the zones of *A. Parkinsoni, A. humphriesianus, A. Murchisonæ,* and *A. jurensis,* as being "inextricably mixed in about three feet of rock" in his own quarry.† Such a view might be taken from the collection made at Stoford (p. 74). Attention however to the fossils of each layer reveals evidence of the general succession of the leading forms ; and Prof. Buckman himself, later on, recognized the fact that different species of Ammonites locally prevail in different quarries around Sherborne.‡ His son Mr. S. S. Buckman subsequently pointed out that the "fossil-beds" in the several quarries occur on different geological horizons,§ although unfortunately their fossiliferous development is local, and all the

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* Inf. Oolite Ammonites, p. 6 ; Quart. Journ. Geol. Soc., vol. xxxvii. p. 588.

† Proc. Somerset Arch. Soc., vol. xx. p. 140.

‡ Quart. Journ. Geol. Soc., vol. xxxiii. p. 8.

§ Quart. Journ. Geol. Soc., vol. xxxvii. pp. 588, &c. ; see also Hudleston, Inf. Ool. Gasteropoda, p. 28.

zones cannot at any one spot be studied in sequence. The distribution of the local zones may be stated as follows:—

| | Thickness. Feet. | |
|---|---|---|
| *A. Parkinsoni* - - - | 15 to 45 | Bradford Abbas, Sherborne. |
| *A. humphriesianus* - - | 1 to 6 | Oborne, Milborne Week, Oborne. |
| *A. Sauzei* - - - - | | |
| *A. concavus* or *A. Sowerbyi* - | 3 or 4 | Bradford Abbas. |
| *A. Murchisonæ* - - - | 1 to 6 | Bradford Abbas, Sherborne. |

In a recent paper describing the Inferior Oolite of the Sherborne district, Mr. Buckman introduces a term hemera as a chronological subdivision of an "age," and considers the beds dealt with to have been deposited during 12 hemeræ, which he names, in descending order, after *fuscum, zigzag, Truellei, Garantianum, niortense, Humphriesianum, Sauzei, Witchellia, discites, concavum, bradfordense,* and *Murchisonæ.** These "hemeræ" may be regarded as the horizons at which he has obtained examples of the several species (or mutations) of Ammonites, enumerated. The subject is of great biological interest, but is only intelligible to a specialist.

A quarry at East Hill, north of Bradford Abbas, formerly known as Prof. Buckman's quarry, has exposed the following beds:—

| Zone | | Bed | Ft. | In. |
|---|---|---|---|---|
| Zone of *Ammonites Parkinsoni* | | 6. Pale earthy oolitic limestones, with *A. Parkinsoni*, a few Gasteropods, and *Pholadomya* - - | 6 | 0 |
| | | 5. Marly and rubbly limestone with *Terebratula Morierei* (rare), *Waldheimia carinata*, and *Rhynchonella parvula* 0 3 to | 0 | 6 |
| Zone of *A. humphriesianus* | | 4. Ferruginous earthy limestone (Rotten bed) with *Ammonites humphriesianus* (small), *Astarte excavata*, *A. obliqua*, *Terebratula Phillipsi*, and *T. sphæroidalis* - - | 0 | 4 |
| Zone of *A. Murchisonæ* | "*Concavus*-bed," or "*Sowerbyi*-zone." | 3. Blue earthy and iron-shot oolitic limestone, much iron-stained in places. Chief Fossil Bed: with *Ammonites concavus* abundant, *A. læviusculus*, *Astarte elegans*, *A. excavata* var. *depressiusculus*, *Trigonia striata*, *Terebratula maxillata* - | 2 | 6 |
| | "*Murchisonæ*-bed." | 2. Paviour or Paving stone-bed, oolitic and iron-shot limestone, with *A. Murchisonæ*, *A. bradfordensis*, and Corals - 0 4 to | 1 | 0 |

* Quart. Journ. Geol. Soc., vol. xlix. p. 482.

| | | Ft. | In. |
|---|---|---|---|
| Zone of *A. opalinus* - | 1. Dew bed; hard sandy limestone used for road-metal. *Ammonites Moorei* 1 0 to | 2 | 0 |
| | 2. Yellow sands with indurated bands: not exposed in quarry. | | |

This famous section has been described by many geologists, and, as might be expected, with somewhat varying lithological and palæontological details. It will be sufficient to refer to the records of Dr. Wright,* Prof. Buckman,† Mr. S. S. Buckman,‡ Mr. Hudleston,§ and Mr. R. F. Tomes.|| In noting the fossils of particular beds, I include species mentioned by Mr. S. S. Buckman, Mr. Hudleston, and Mr. Tomes. The occurrence of *A. Moorei* in the Dew Bed, led Mr. Buckman to consider that his "*Opalinus*-bed" was absent: but this view can only be maintained, by inferring a fixity in the horizons of the particular species of Ammonites found in the Zone of *Ammonites opalinus* (see p. 41). It may be questioned whether the Dew Bed (so named by the quarrymen) is on the same palæontological horizon in the different quarries.

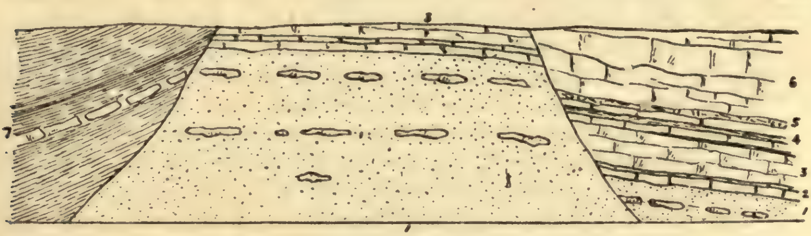
The chief fossil-bed of Bradford Abbas, spoken of as the "*Concavus*-bed" or "*Sowerbyi*-zone," is mentioned by Mr. Hudleston, as the "most important bed for Gasteropoda discovered in the English Oolites." Fine examples of *Alaria, Cerithium, Purpurina, Spinigera,* &c. have been obtained from it.

The zone of *A humphriesianus* appears to be but feebly represented; while the higher beds, belonging to the zone of *A. Parkinsoni,* are not very fossiliferous at this locality. They have however yielded one Brachiopod of considerable interest—*Terebratula Morièrei,* which was discovered in 1878, for the first time in this country, by Mr. J. F Walker.¶ The species has since been found at one or two other localities, although somewhat sparingly.

Fig. 36.

*Railway-cutting at Bradford Abbas, near Sherborne, Dorsetshire.*

West. East.



F F

The same beds have been well exposed in the railway-cutting at Bradford Abbas. There two faults displace the strata: a mass

* Quart. Journ. Geol. Soc., vol. xvi. p. 36.
† *Ibid.*, vol. xxxiii. p. 7.
‡ *Ibid.*, vol. xxxvii. p. 591, xlix. p. 485; Inf. Ool. Ammonites, pp. 5, &c.
§ Gasteropoda of Inf. Ool., pp. 43, &c.; Proc. Geol. Assoc., vol. ix. p. 187.
|| Geol. Mag., 1886, p. 389.
¶ *Ibid.*, 1878, p. 552.

of Inferior Oolite and underlying Midford Sand, being faulted on the west against the Fuller's Earth, and on the east against Inferior Oolite and Sand, with a lesser downthrow.* Many fossils are to be obtained in this cutting, and a list is given (p. 81).

| | Ft. | In. | |
|---|---|---|---|
| 7. Clays with band of shaly limestone: *Waldheimia* (crushed) | | | Fullers Earth. |
| 6. Pale-grey oolitic limestones: *Ammonites Parkinsoni, Isocardia minima, Terebratula sphæroidalis* - - - | 6 | 0 | Inferior Oolite. |
| 5. Rubbly layer: with Sponges - - - - | 0 | 3 | |
| 4. Pale grey limestones (iron-shot in places), with marly partings: *Belemnites, Ostrea,* &c. - - - | 1 | 3 | |
| 3. Brown and bluish iron-shot oolite: *Ammonites concavus, A. Sowerbyi, Belemnites, Astarte, Trigonia,* &c. - - | 3 | 0 | |
| Bluish iron-shot limestones: *Ostrea, Pecten,* Corals - | 0 | 4 | |
| 2. Hard blue-hearted sandy limestone, "Dew Bed" - - | 0 | 8 | Midford Sand. |
| 1. Sands, with concretionary masses of calcareous sandstone - | | | |

F. Faults.

The lower portion of bed (3) resembles the bluish iron-shot oolite of Loders.

At Halfway House, between Yeovil and Sherborne, the Inferior Oolite has been well exposed in several quarries. The section in 1884 was as follows:—

| | | Ft. | In. |
|---|---|---|---|
| | Rubble and red friable loamy soil - | 1 | 0 |
| Zone of *Ammonites Parkinsoni.* | Thin rubbly pale-grey and creamy oolitic limestones and marl (burnt for lime). *Ammonites Parkinsoni,* &c. - | 6 | 0 |
| | Pale grey and brown earthy oolitic limestones with marly divisions: shelly in places and false-bedded - | 9 | 0 |
| | Marl with *Astarte obliqua.* | | |
| Zone of *A. Murchisonæ.* | Pale grey, brown, and blue oolitic and iron-shot limestones; shelly in the upper part - - - - | 5 | 6 |
| | Tough bluish-grey shelly limestone (Dew-bed) - - - - | 1 | 9 |
| | Sands, &c. | | |

Here there is no marked lithological distinction in the beds which are separated only by marly partings. Large specimens of the *Ammonites "Dorsetensis"* of Dr. Wright (= *A. Parkinsoni*), together with *Nautilus lineatus,* occur in the upper beds, and like the specimens obtained near Bridport, have been cut and polished for sale. The lower beds yield *Ammonites concavus,* &c.

Sections at Halfway House have been described by Dr. Wright,† Dr. H. B. Holl,‡ Mr. Hudleston,§ and Mr. Buckman.||

To the east of the Halfway House the iron-shot limestones are shown to a thickness of 6 feet, resting on brown sandy and shelly limestones, about 2 feet thick. The lower portions of the iron-shot beds contain *Ammonites concavus, A. Murchisonæ, Nau-*

* A diagram of this cutting was given by Prof. Buckman, Bath and W. Eng. Agric. Journ., vol. xiv. p. 49. See also notes on Wyke Quarry, by S. S. Buckman, Quart. Journ. Geol. Soc., vol. xxxvii. p. 590.

† Quart. Journ. Geol. Soc., vol. xvi. p. 34.

‡ *Ibid.*, vol. xix. p. 307.

§ Inf. Ool. Gasteropoda, p. 46.

|| Quart. Journ. Geol. Soc., vol. xlix. p. 486.

*tilus, Belemnites, Pleurotomaria, Lima Etheridgei,* &c. In the central portions there occur *A. humphriesianus, Astarte excavata, A. obliqua, Gervillia, Ceromya bajociana,* &c.; and in the upper portions small examples of *A. Parkinsoni, Terebratula Phillipsi,* and *T. sphæroidalis.*

There is no lithological distinction whereby the zones can be distinctly separated; but evidently the base of the zone of *A. Parkinsoni* is incorporated in the upper part of the ironshot-beds, as we find to be the case in places near Bridport. The section above noted is probably the one called "Louse Hill" quarry by Mr. Hudleston.*

The opening known as Frogden quarry, at Oborne near Sherborne, showed the following section:—

| | | Ft. | In. |
|---|---|---|---|
| Zone of *Ammonites Parkinsoni.* | Pale-grey and brown limestones and marls with *Rhynchonella spinosa, Terebratula sphæroidalis* - - | 8 | 6 |
| Zone of *A. humphriesianus.* | Iron-shot oolites: Beds with *Ammonites Martinsi, A. garantianus, A. niortensis, A. cadomensis* ("*Cadomensis*-bed"), *Astarte, T. sphæroidalis* - | 2 | 0 |
| | Beds with *A. humphriesianus, A. Blagdeni, Lima pectiniformis,* &c. - - | 3 | 0 |
| | Bed of pale limestone with green grains; with *A. Sauzei, Pleurotomaria,* &c. - - - - | 0 | 6 |
| Zone of *A. Murchisonæ* | Hard bluish-grey shelly limestones and marls - - - - - | 2 | 0 |
| Midford Sand. | Yellow calcareous sandstone. | | |

The zonal grouping is based on that of Mr. Hudleston.† Here again we see the close connection between the zones of *A. humphriesianus* and *A. Parkinsoni,* the top iron-shot bed containing species that link them together. *Ammonites Sauzei,* as observed by Mr. Hudleston, is so rare that the term "*Sauzei*-bed" is a misnomer: the layer has mixed relations with the beds above and below. Nowhere else in this country, excepting at Dundry, has any distinctive development of this stage been recognized.

Passing on to the neighbourhood of Milborne Week (or Wyke), there is a road-side section, rather less than 2 miles N.N.E. of Frogden quarry, Oborne, to which attention has been directed by Mr. Hudleston. The lower beds comprise 3 feet of sandy limestones; and above them there occur 18 inches of soft white limestone, containing *Ammonites humphriesianus* and *A. Braikenridgei* in the lower part, and *Terebratula sphæroidalis* in the upper part.‡

* Gasteropoda of Inf. Oolite, p. 46; and Buckman, Quart. Journ. Geol. Soc., vol. xlix. p. 488.

† Inf. Ool. Gasteropoda, p. 47. See also S. S. Buckman, Inf. Ool. Ammonites, pp. 8, 10, and Quart. Journ. Geol. Soc., vol. xxxvii. p. 589, vol. xlix. p. 500.

‡ Inf. Ool. Gasteropoda, p. 50; see also S. S. Buckman, Rep. Brit. Assoc. for 1891 (1892), p. 655.

A somewhat similar series of beds, including higher strata together about 15 feet thick, were exposed in the road-cutting on the north side of Barrow Hill, between Milborne Week and the railway-station at Milborne Port. At the base there were beds of sandy limestone, and bluish-grey shelly limestone, overlaid by pale grey limestone and marl, and rubbly oolite. The pale limestone is probably the same as that above mentioned by Mr. Hudleston. Here small specimens of *A. humphriesianus* occur together with *A. Parkinsoni;* while *A. Blagdeni* and *A. Martinsi* may also be found. In the rubbly oolites, *Pholadomya Heraulti*, and *P. oblita* are abundant; and *Rhynchonella spinosa*, *Terebratula sphæroidalis*, some Corals, and other fossils were also obtained. (See list, p. 81.)

These sections are of interest in showing that the iron-shot beds of Sherborne and Oborne are represented to the north-east by strata of different lithological character.

In a quarry on Corton Down, between 3 and 4 miles north of Sherborne, the lower division of the Inferior Oolite with *A. Murchisonæ*, has been observed.§

It is difficult to state the thickness of the Inferior Oolite near Sherborne, the quarries show but portions of the formation, and the beds are so variable in character: but I doubt the validity of adding together all the "hemeræ" recognized by Mr. Buckman (see p. 76.), and thereby making a total thickness (nowhere present) of 130 feet of strata.

Passing from west to east, the beds generally increase in thickness; and at Castleton, Sherborne, a boring, recorded by J. C. Gapper in 1875, enables us to give the following approximate thicknesses of the strata:—

| | | Ft. | In. |
|---|---|---|---|
| Inferior Oolite - - - - | about | 45 | 0 |
| Midford Sand - - - - | ,, | 135 | 0 |
| Upper Lias clay and basement-beds - | ,, | 17 | 0 |
| Middle Lias ? - - - - | - | 10 | 6 |
| | | 207 | 6 |

Dr. Wright mentions that at the Halfway House the Sands were bored to a depth of 140 feet before reaching the Upper Lias clay.†

In the following list of the principal fossils from the Inferior Oolite Series of the neighbourhood of Sherborne, the species marked (R) were collected by Mr. John Rhodes, and those marked (W) by myself: the fossils were identified by Messrs. Sharman and Newton. Other species marked (H) and (B) are given on the authority of Mr. Hudleston and Mr. S. S. Buckman.

* Hudleston, Inf. Ool. Gasteropoda, p. 50; Buckman, Inf. Ool. Ammonites, p. 9.
† Quart. Journ. Geol. Soc., vol. xvi. p. 34.

## List of Fossils from the Inferior Oolite Series near Sherborne, Dorset.

| Collector. | — | Sands. | Zone of Ammonites Murchisonæ. | Zone of A. humphriesianus. | Zone of A. Parkinsoni. | Bradford Abbas. | Sherborne. | Oborne. | Milborne Port. |
|---|---|---|---|---|---|---|---|---|---|
| H | Megalosaurus Bucklandi | | | | | | S | | |
| R | Strophodus | | | | | B | | | |
| B H W | Ammonites Blagdeni | | | 3 | | | | O | M |
| H | —— Braikenridgei | | | 3 | | | | | M |
| | —— Brongniarti | | | 3 | | | S | | |
| H | —— cadomensis | | | 3 | | | | O | |
| W | —— concavus | | 2 | | | B | S | | |
| B | —— confusus | | 2 | | | | S | | |
| | —— dimorphus | | | | 4 | | | | |
| B | —— garantianus | | | 3 | 4 | | | O | |
| | —— Gervillei | | | 3 | | | S | | |
| H W | —— humphriesianus | | | 3 | | | S | O | M |
| | —— insignis | 1 | | | | | S | | |
| H | —— Martinsi | | | 3 | 4 | | | O | M |
| W R | —— Murchisonæ | | 2 | | | B | S | | |
| H | —— subfurcatus | | | 3 | | | | O | |
| W R | —— Parkinsoni | | | | | B | S | | |
| | —— polymorphus | | | | 4 | | | | |
| B | —— Sauzei | | | 3 | | | | O | |
| | —— Sowerbyi | | | 3 | | | | | |
| | —— subradiatus | | | | 4 | | | | |
| | —— Truellei | | | | 4 | | | | |
| | Nautilus lineatus | | | | | | S | | M |
| R | Belemnites bessinus | | | | 4 | B | | | M |
| H | Alaria | | | | | B | S | | |
| R | Amberleya | | | | | B | | | |
| H | Cerithium comma | | | | 4 | | S | | |
| R | Natica bajocensis | | | | 4 | B | | | |
| W | Pleurotomaria agatha | | | | | | S | | |
| W R | —— bessina | | 2 | | | B | S | | |
| R | —— elongata? | | | | | B | | | |
| R | Pseudomelania scarburgensis | | | | | B | | | |
| R | Turbo | | | | | B | | | |
| R | Arca | | | | | B | | | |
| W | Avicula | | | | | | | | M |

FOSSILS FROM THE INFERIOR OOLITE SERIES NEAR SHERBORNE—*cont.*

| — | — | Sands. | Zone of Ammonites Murchisonæ. | Zone of A. humphriesianus. | Zone of A. Parkinsoni. | Bradford Abbas. | Sherborne. | Oborne. | Milborne Port. |
|---|---|---|---|---|---|---|---|---|---|
| R | Astarte elegans - - - | | 2 | | | B | S | | |
| W R | —— excavata - - - | | 2 | | | B | S | | |
| W R | —— obliqua - - - | | | 3 | | B | S | | |
| W | Ceromya bajociana - - | | | | | | S | | |
| R | Cucullæa - - - - | | | | | B | | | |
| R | Cypricardia cordiformis? - - | | | | | B | | | |
| R | Gervillia lata - - - | | | | | B | | | |
| W R | Gresslya abducta - - - | | | 3 | | B | S | O | |
| R | Lima Etheridgei - - - | | | | | B | | | |
| W R | —— pectiniformis - - - | | 2 | | | B | S | | |
| W | Lucina - - - - | | | | | | | | M |
| W | Modiola sowerbyana - - | | | | | | S | | |
| W R | Myacites jurassi - - - | | | 3 | | B | | O | M |
| W | Nucula - - - - | | | | | | S | | |
| R | Opis cordiformis - - - | | | | | B | | | |
| R | —— elongatus - - - | | | | | B | | | |
| W R | Pecten demissus - - - | | | | | B | S | | |
| R | —— læviradiatus - - - | | | | | B | | | |
| W | Pholadomya Heraulti - - | | | | | | | | M |
| W | —— oblita - - - - | | | | | | | | M |
| R | —— Phillipsi - - - | | | | | B | | | |
| R | Thracia lata - - - | | | | | B | | | |
| | Trigonia - - - - | | | | | | | | M |
| R | Unicardium - - - | | | | | B | | | |
| R | Rhynchonella obsoleta - - | | | | | B | | | |
| R | —— panacanthina - - - | | | | | B | | | |
| W | —— plicatella - - | | | | | | S | | |
| B | —— ringens - - - | 1 | | | | | | O | |
| H W | —— spinosa - - - | | | | 4 | | | O | M |
| | —— subangulata - - - | | 2 | | | | S | | |
| R | —— subringens - - - | | | | | B | | | |
| | —— subtetrahedra - - | | 2 | | | | S | | |
| | Terebratula Buckmani - - | | | 3 | | | S | | |
| R | —— maxillata - - - | | | | | B | | | |
| | —— Morièrei - - - | | | | | B | | | |
| H W | —— perovalis - - - | | 2 | | | | S | | |
| W R | —— Phillipsi - - - | | | | 4 | B | S | | |
| R | —— simplex - - - | | | | | B | | | |

FOSSILS FROM THE INFERIOR OOLITE SERIES NEAR SHERBORNE—*cont.*

| — | — | Sands. | Zone of Ammonites Murchisonæ. | Zone of A. humphriesianus. | Zone of A. Parkinsoni. | Bradford Abbas. | Sherborne. | Oborne. | Milborne Port. |
|---|---|---|---|---|---|---|---|---|---|
| H W R | Terebratula sphæroidalis - - | | | 3 | 4 | B | S | O | M |
| W | —— Stephani - - - | | | | 4 | | S | | |
| | Waldheimia anglica - - | | 2 | | | | S | | |
| R | Serpula - - - - | | | | | B | | | |
| R | Collyrites - - - - | | | | 4 | B | | | |
| R | Holectypus hemisphæricus - | | | | 4 | B | | | |
| R | Montlivaltia ? - - - | | | | | B | | | |
| R | Thamnastræa ? - - - | | | | | B | | | |

*Milborne Port to Doulting, Glastonbury, Brent Knoll, and the Mendips.*

North of Milborne Port and Sherborne, the Inferior Oolite forms a comparatively broad tract, being repeated to some extent by a fault which raises the beds at Crackment and Pointington Hills. The comparatively flat dip-slope, near Charleton Horethorne, forms an arable tract, sheltered by the higher escarpment of the Forest Marble.

The general strike of the beds is now diverted from N.E. to N., and we find some changes in the beds. The lower fossiliferous zones are not known in the rich form exhibited near Sherborne and Bradford Abbas; while the higher zone of *Ammonites Parkinsoni* is more prominent, and contains *Rhynchonella spinosa* in great abundance, together with *Trigonia*, *Trichites*, *Clypeus altus*, and other fossils. The lithology of the beds affords no guidance to special horizons. We find iron-shot beds at all stages.

The Midford Sand is shown here and there in deep lane-cuttings, as between Woolston and Woolston Farm, and north of Blackford. The lower beds contain bluish shaly beds, as near Yeovil. East of Woolston Farm there are quarries showing the following beds:—

| | | FT. | IN. |
|---|---|---|---|
| Inferior Oolite: Upper Division. Zone of *Ammonites Parkinsoni.* | Rubbly limestones, more or less ferruginous, *Ammonites Parkinsoni*, *Rhynchonella spinosa* (abundant), *Terebratula Buckmani*, *T. globata*, *T. Phillipsi*, *T. sphæroidalis*, *Waldheimia carinata*, &c. - - - | 6 | 6 |
| | Ferruginous limestone with *Clypeus altus*. Brachiopoda very abundant - Shelly limestones. *R. spinosa* (abundant in top bed), *Belemnites*, *Trichites*, *Galeropygus agariciformis* - - | 4 | 0 |

| | | Ft. | In. |
|---|---|---|---|
| Inferior Oolite: Lower Division? | Iron-shot oolitic limestones, very shelly. *Lima gibbosa, L. pectiniformis, Trichites* - - - - - | 3 | 6 |
| Midford Sand. | Sandy limestone - - - | | |
| | Dark micaceous sand. | | |

There is no very marked lithological distinction in the beds: portions of the lower division of the Inferior Oolite are no doubt included, but the mass of the beds with *Rhynchonella spinosa* probably belongs to the zone of *A. Parkinsoni:* although *R. spinosa* and *Galeropygus agariciformis* occur in the zone of *A. humphriesianus.*

Sections at Cattle Hill, and near Shotwell Farm, north-east of Yarlington, show beds very similar to those of Woolston. We find iron-shot oolite on the top, with Corals; lower down, brown shelly oolite with *A. Parkinsoni, Lima pectiniformis, Trigonia, Rhynchonella spinosa,* and other Brachiopods, *Clypeus,* &c.; and at the base of the quarry, other beds of brown iron-shot limestone. The shelly beds here belong to the zone of *A. Parkinsoni,* and are noted as "*Trigonia*-grits" by Mr. Hudleston.*

There are two quarries to the east of Grove, near Castle Cary, and these exhibit the same set of beds. *Rhynchonella spinosa* occurs in shoals in the upper beds, and is also found in the lowest bed seen in the Grove quarry, which is opened to a depth of 18 feet. Other Brachiopods, together with *Trigonia, Clypeus,* and Corals are likewise found. In the adjoining lime-kiln quarry we find about 10 feet of oolitic and iron-shot limestones with *Ammonites Parkinsoni, Clypeus Agassizi,* &c., resting on about 10 feet of limestones with shelly layers, yielding *Trigonia;* and brown sandy and iron-shot limestones. Mr. Hudleston notes that *Cryptaulax* (*Cerithium*) *contorta* and *Cerithium sub-scalariforme* are plentiful in beds belonging to the zone of *A. Parkinsoni.*† The lowest beds are probably not far removed from the Midford (or Yeovil) Sand, but they do not exhibit themselves in a sufficiently fossiliferous form to indicate their particular zone.

The bottom bed noticed by Mr. Hudleston is a calciferous grit with "keeled Ammonites," and above it he records the presence of a pale stone with *Rhynchonella spinosa* and a small *Stephanoceras* (the sub-genus to which *Am. humphriesianus* belongs). This bed recalls that of Milborne Week (see p. 80).

In a road-cutting (Pitcomb Road) south of Cole Station, we find a section of the Midford (or Yeovil) Sand, consisting of sands indurated in places, and with *Rhynchonella;* overlaid by shelly and sandy limestones (2 ft. 8 in.); and by brown and grey iron-shot limestones (about 4 feet). These beds are not distinctly separated, for they merge in places one into the other. They afford evidence however of the zones of *A. Murchisonæ* and *A. humphriesianus:* the following fossils having been obtained‡:—

* Inf. Ool. Gasteropoda, p. 51.
† *Ibid.*, pp. 51, 52.
‡ See also Hudleston, *Ibid.*, p. 53.

| | |
|---|---|
| Ammonites Blagdeni. | Cerithium vetustum. |
| —— concavus. | Turbo Shaleri. |
| —— humphriesianus. | Astarte elegans. |
| Nautilus. | Gervillia. |
| Belemnites. | Trigonia. |
| Alaria. | Rhynchonella angulata ? |
| Amberleya ornata. | Terebratula. |

Again, along the road from Cole to Bruton there are three quarries, showing in succession the following strata:—

| | | | | Ft. | In. |
|---|---|---|---|---|---|
| Inferior Oolite. | Upper Division. | Zone of *Ammonites Parkinsoni.* | Pale false-bedded oolite - - Brown and iron-shot limestones with *Rhynchonella spinosa* - | 10 | 0 |
| | | Zone of *A. humphriesianus.* | Brown iron-shot limestone with *Ammonites humphriesianus, Nautilus, R. spinosa, Pholadomya* (large) - - - | 1 | 10 |
| | Lower Division ? - | | Hard bluish-grey limestones, iron-shot in places towards top. *Pecten* abundant, *Trigonia* allied to *signata, Chemnitzia, Nautilus* - - - | 6 | 0 |

Dr. H. B. Holl noted from the upper beds at this locality (Sunny Hill) *Ammonites Parkinsoni, Terebratula Phillipsi, T. sphæroidalis, Gryphæa sublobata, Holectypus hemisphæricus,* &c.* The Inferior Oolite has also been well exposed in the railway-cutting west of Bruton station. The species noted by Dr. Holl are given in the accompanying list; together with those collected by myself, and named by Messrs. Sharman and Newton. The species of Gasteropods have been recorded by Mr. Hudleston.

## List of Fossils from the Inferior Oolite Series near Castle Cary and Bruton.

| — | Sands. | Zone of Ammonites Murchisonæ. | Zone of A. humphriesianus. | Zone of A. Parkinsoni. | Wolston. | Grove Quarry, Castle Cary. | Cole. | Bruton. |
|---|---|---|---|---|---|---|---|---|
| Ammonites Blagdeni - - - - | | | 3 | | | | C | |
| —— concavus - - - - - | | 2 | | | | | C | |
| —— humphriesianus - - - - | | | 3 | | | | C | B |
| —— Parkinsoni - - - - - | | | | 4 | W | G | | B |
| Nautilus - - - - - - | | 2 | 3 | | W | | C | B |
| Belemnites bessinus - - - - | | | 3 | | | G | | |
| Alaria - - - - - - | | 2 | | | | | C | |
| Amberleya ornata - - - - | | 2 | | | | | C | |
| Cerithium sub-scalariforme - - - | | | ? | | | G | | |

* Quart. Journ. Geol. Soc., vol. xix. p. 308.

LIST OF FOSSILS FROM THE INFERIOR OOLITE SERIES NEAR CASTLE CARY AND BRUTON—*cont.*

| — | Sands. | Zone of A. Murchisonæ. | Zone of A. humphriesianus. | Zone of A. Parkinsoni. | Woolston. | Grove Quarry, Castle Cary. | Cole. | Bruton. |
|---|---|---|---|---|---|---|---|---|
| Cerithium vetustum - - - - | | 2 | | | | | C | |
| Cryptaulax contorta - - - - | | | ? | | | G | | |
| Pleurotomaria - - - - - | | 2 | | 4 | W | G | | |
| Turbo Shaleri - - - - - | | 2 | | | | | C | |
| Astarte elegans - - - - | | 2 | | | | | C | |
| Gresslya - - - - - | | | | | | | | B |
| Gryphæa sublobata - - - - | | | | 4 | | | | B |
| Lima gibbosa - - - - - | | ? | | 4 | W | G | | |
| —— pectiniformis - - - - | | ? | | 4 | W | G | | |
| Modiola sowerbyana - - - - | | | | | | | | B |
| Ostrea - - - - - - | | 2 | | | W | | | |
| Pecten subspinosus - - - - | | | | | | G | | |
| Trichites - - - - - | | 2 | 3 | | W | G | | |
| Trigonia - - - - - - | | | 3 | 4 | W | | | B |
| Rhynchonella obsoleta - - - | | | | | | G | | |
| —— spinosa - - - - - | | | 3 | 4 | W | G | | B |
| Terebratula Buckmani - - - | | | | 4 | W | | | |
| —— globata - - - - - | | | | 4 | W | G | | |
| —— maxillata - - - - - | | | | 4 | W | | | |
| —— Phillipsi - - - - - | | | | 4 | W | | | B |
| —— sphæroidalis - - - - | | | | 4 | W | G | | |
| —— Stephani - - - - - | | | | 4 | W | | | |
| Waldheimia carinata - - - - | | | | 4 | W | G | | |
| Clypeus Agassizi - - - - | | | | 4 | | G | | |
| —— altus - - - - - | | | | 4 | | G | | |
| Galeropygus agariciformis - - - | | | ? | | W | | | |
| Holectypus hemisphæricus - - - | | | | | | | | B |
| Montlivaltia - - - - - | | | | 4 | | G | | |

In the district north of Bruton, the quarries in the Inferior Oolite exhibit two lithological divisions as follows:—

| | Ft. In. | Ft. In. |
|---|---|---|
| Pale very oolitic limestone - - - | | 12 0 or more. |
| Sandy and shelly limestone, composed largely of comminuted shells, occasionally sparry and approaching Doulting Stone in character | 5 0 to | 8 0 |

Beds presenting these characters were exposed at Hedgestock Quarry, E.N.E. of Creech Hill; and in a quarry, further south, on the road to Bruton. Fossils are exceedingly scarce: an occasional *Terebratula, Trigonia* or Coral being the only specimens noticed.

On Creech Hill the beds are somewhat different in character and more fossiliferous. The following section was exposed in the quarries and cuttings:—

| | | | Ft. | In. |
|---|---|---|---|---|
| Inferior Oolite. | Upper Division. Zone of *Ammonites Parkinsoni.* | Reddish-brown brashy soil. | | |
| | | Pale oolite much broken up and lime-washed. *Rhynchonella spinosa, Lima, Ostrea,* and *Cerithium* - - 4 6 to | 5 | 0 |
| | | Massive beds of yellow and ochreous oolite and hard grey oolitic limestone, false-bedded in places. *Ammonites Parkinsoni?, Belemnites* - - | 5 | 6 |
| | | Very shelly limestone. *Nautilus, Lima pectiniformis* - - <br> Brown and yellow iron-shot and marly limestone. *Belemnites, Modiola, Ostrea* (abundant), *Terebratula Phillipsi, R. spinosa,* Corals - - - - | 3 | 6 |
| | Lower Division? | Cream-coloured compact, shelly and marly iron-shot oolites - | 1 | 6 |
| Midford Sand. - | | Sands with indurated bands (no fossils seen). | | |

*Rhynchonella spinosa* is here found in almost the lowest bed of the Inferior Oolite: but as it occurs in the zone of *A. humphriesianus* it is quite possible that that zone may be represented in the Upper Division, as well as the zone of *A. Parkinsoni.*

De la Beche has estimated the thickness of the Inferior Oolite to be 55 feet, and of the underlying Sands, 66 feet, at Scale Hill, Bruton.* Our information concerning the lower beds of the Inferior Oolite in this region is very scanty. From the Sands at Cranmore Mr. Hudleston obtained a specimen of *Ammonites fallaciosus.*†

The Doulting Stone, which for many centuries has been worked north of Doulting village, and eastwards towards West Cranmore, is considered a very durable stone. The beds seen are exceedingly variable, being false-bedded on a large scale and minutely current-bedded: and it is difficult to correlate the layers seen in different quarries.

The general sequence of beds was shown in the railway-cutting where the section was noted in 1868 by Messrs. W. A. E. Ussher, J. H. Blake, and myself.‡ When I again visited the

* Mem. Geol. Survey, vol. i. p. 280.

† See S. S. Buckman, Inf. Ool. Ammonites, p. 168.

‡ Geol. E. Somerset (Geol. Surv.), p. 124. The thickness of the lower beds was marked 200 instead of 20 feet.

locality in 1885 the section was by no means so clear, but the beds that could be traced were as follows:—

| | | | Ft. | In. |
|---|---|---|---|---|
| Inferior Oolite | Oolitic shelly and slightly sparry limestones, and pale oolite - - - - Very sparry limestone - - | about | 7 | 0 |
| | Brown sandy limestone, shelly and slightly oolitic - - - Oolitic freestones - - - | | 10 | 0 |
| | Massive beds of freestone (oolitic sparry rock), *Terebratula globata*, *T. Buckmani ?*, *Ostrea*, *Trigonia*, *Belemnites* - - - - - | | 20 | 0 |
| | Thick bedded sandy oolitic limestones and sparry limestones, with *Pecten* - | | 10 | 0 |
| | Sandy and sparry limestones and decomposed iron-shot limestones - | | 10 | 0 |
| | (Midford Sand.) | | | |

The most northerly pit at Doulting, worked by Mr. C. Trask, showed the following beds:—

| | Ft. | In. |
|---|---|---|
| Brown clay - - - - - - 1 0 to | 2 | 0 |
| Pale oolitic stone, rubbly on top - - - 2 0 to | 3 | 0 |
| Top or Cake Bed, 2 feet good; top, 2 or 3 feet poor, used for inside work - - - - - - | 5 | 0 |
| Rag, shelly, rarely used - - - - - | 2 | 0 |
| White Bed or Coping Bed - - - - - | 5 | 0 |
| Bottom Bed; coarse stone - - - - | 3 | 0 |

The freestone here is a sparry and somewhat earthy limestone. There are few fossils—*Trigonia* and *Pecten demissus* occur; and Charles Moore obtained, from the Rag Bed, a specimen of *Ammonites Parkinsoni*, now in the Bath Museum. More recently Mr. John Phillis, of Shepton Mallet, has obtained from the Inferior Oolite of Doulting, *Natica bajocensis*, *Rhynchonella spinosa*, *R. spinosa* var. *obornensis*, *Terebratula globata*, *T. Morierei*, and *T. sphæroidalis*.* The occurrence of *T. Morierei* is of especial interest, as it was first discovered in this country at Bradford Abbas by Mr. J. F. Walker and has since been found only rarely in one or two other localities.

At Woodcombe's pit (an old quarry by Doulting church) the following beds were shown:—

| | Ft. | In. |
|---|---|---|
| Rubbly oolitic and sparry stone - - - - | 6 | 0 |
| Shelly oolites, 3 beds - - - - - | 8 | 0 |
| Oolitic and shelly stone, good bed - - - | 2 | 6 |
| Sparry stone - - - - - - | 4 | 6 |

Here I obtained *Nautilus*, *Pseudomelania*, and *Ostrea*.

The freestone beds probably all belong to the Upper Division of the Inferior Oolite (the zone of *Ammonites Parkinsoni*), and cannot in any case be grouped with the Ham Hill Stone as suggested by Prof. Buckman.†

* The fossils were identified by Messrs. Sharman and Newton.
† Quart. Journ. Geol. Soc., vol. xxx. p. 740.

A microscopic section of the Doulting Stone has been given in the plate (p. 26); and the rock has been described by Mr. Teall. The organic fragments appear to be mostly Crinoidal. I noticed that the Carboniferous Limestone at Little Elm presented a granular appearance somewhat similar to that of the Doulting Stone. A microscopic section of that older rock showed Crinoidal fragments, and oolite grains, in a matrix of crystalline calcite; and as noted by Mr. Teall, the secondary calcite was in optical continuity with the organic fragments, as in the Doulting Stone. The same phenomena were exhibited in a microscopic section of Inferior Oolite from Oldford, near Frome. Evidently the Inferior Oolite of this region is largely of detrital origin, being formed of comminuted organic remains, and the material I think may have been mostly derived from the Carboniferous Limestone.

The Midford Sand, with occasional indurated bands, is found at the summit of Glastonbury Tor, having a thickness of about 174 feet, and resting upon a platform of Upper Lias clay.

The conspicuous hill of Brent Knoll stands out from the Alluvium of the Burnham Level between Highbridge and the Mendip Hills; its height above the sea-level is 457 feet. The area occupied by the Romano-British Camp, was regarded by Conybeare and also by William Sanders as Inferior Oolite,* while on the Geological Survey Map (sheet 20) it was originally coloured as Marlstone or Middle Lias, the lower portions of the hill being regarded as Lower Lias. During the re-survey of the district in 1872, it fell to my lot to examine Brent Knoll, and in the Memoir subsequently published, a section to illustrate the structure of the hill was inserted.† This section represented the Knoll to be capped by a thin layer of the "Cephalopoda-bed" (below the Inferior Oolite), together with other portions of the Midford or Inferior Oolite Sand; and to be based on a platform composed of Upper and Middle Lias.

No natural section was to be seen at the encampment, but there were loose blocks of sandy and ferruginous limestone which contained Ammonites; and although too imperfect for specific determination, the specimens were considered by Mr. Etheridge to belong to a type that charaterizes the so-called "Cephalopoda-bed," which occurs at the top of the Midford Sand in Gloucestershire. Since then two specimens of *Rhynchonella cynocephala* have been obtained by Mr. J. E. Clark and myself from loose blocks of calcareous sandstone on the summit of the Knoll. Specimens of *Serpula* also occurred, and these prevail at the same horizon below the Inferior Oolite in the neighbourhood of Beaminster and Crewkerne.‡

North of Doulting the Inferior Oolite overlaps the Lias and Rhætic Beds, and rests in places directly on the older rocks along the eastern borders of the Mendip Hills. Thus the Inferior Oolite rests on the Old Red Sandstone, the Carboniferous Lime-

---

* Conybeare and Phillips' "Outlines of the Geology of England and Wales," pp. 255, 275; Sanders' "Map of the Bristol Coal Fields," 1862, and Proc. Bristol Nat. Soc., ser. 2, vol. iii. p. 44.

† "Geology of East Somerset," &c., p. 116; Memoir on the Lias, p. 203.

‡ Proc. Bath Nat. Hist. Club, vol. vi. p. 125.

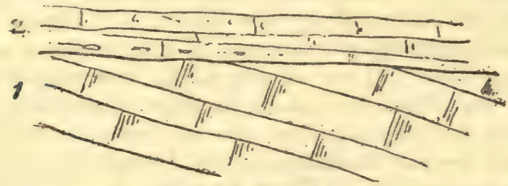
stone and Shales, and on the Millstone Grit: while near Mells it reposes on the Coal-measures and on the Dolomitic Conglomerate.

In places, as near Dean, north of West Cranmore, where fossils are absent, it is difficult to separate the marginal deposits of Inferior Oolite from those of the Lias:* the former however are usually oolitic.

Near Little Elm and on Nunney Common the top beds of Inferior Oolite are sparry and slightly oolitic limestones, like Doulting Stone; the lower beds on Nunney Common comprise hard and nodular limestones with ferruginous specks, and buff sandy limestones with a few fossils, *Nautilus*, *Terebratula*, &c.

FIG. 37.

*Section on Nunney Common, near Frome.*




2. Inferior Oolite.
1. Carboniferous Limestone.

The beds are conglomeratic in places, the matrix being oolitic, and containing small pebbles of Carboniferous Limestone. The Carboniferous Limestone, on whose upturned edges the Oolite rests, has been planed off to an apparently even surface. (See Fig. 37.)

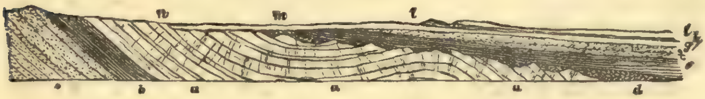
Long ago it was remarked by Sir H. T. De la Beche, that "Not only is a large portion of the area, wherein the Inferior Oolite is seen to rest on the Carboniferous Limestone, observed to have presented a marked even surface, viewed on the large scale, for the deposits of the former, but, throughout, this surface has been drilled into holes by lithodomous animals, which must have existed in the seas at the commencement of the Inferior Oolite. The holes, which were observed by Professor John Phillips in 1829, are of two kinds, one long, slender, and often sinuous, extending several inches into the Carboniferous Limestone, the other entering that rock a short distance only. In the former we find traces of shells, in the latter we often discover them, in the situations in which they lived. In both holes we find the matter of the Inferior Oolite, which entered them from above at the time of its deposit. In some places the shells of oysters may be observed attached to the surface of the Carboniferous Limestone on which the oysters lived, and these are occasionally pierced through by the borers, which found such shells remaining on the rocks after the animals which constructed them had died, as we now observe on many sea-coasts. On the top of the hill between Holwell and Leighton, oyster shells, of the date of the Inferior Oolite, adhering to the old surface of Carboniferous

* See also Conybeare and Phillips, Geol. Eng. and Wales, p. 255.

Limestone, and occasionally pierced by borers, may readily be seen."*

FIG. 38.

*Section showing overlap in the Jurassic Beds along the eastern borders of the Mendip Hills.* (After De la Beche.)

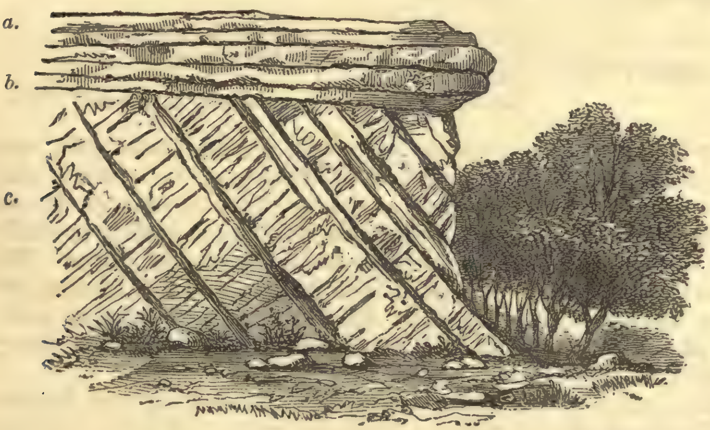


*i.* Fuller's Earth Rock.
*h. l.* Lower Fuller's Earth Clay.
*g.* Inferior Oolite overlapping the Midford Sand, and extending on to the older rocks at *m* and *n*.
*f.* Midford Sand.
*e.* Lias.
*d.* Dolomitic Conglomerate.
*a.* Carboniferous Limestone.
*b.* Lower Limestone Shales.
*c.* Old Red Sandstone.

Fossils on the whole are not abundant in the Inferior Oolite of this neighbourhood. I have obtained *Nautilus, Astarte, Lima pectiniformis, Trigonia, Placunopsis, Rhynchonella,* and *Terebratula maxillata.* Mr. Hudleston observes, "The well known section at Vallis, where something like 15 feet of Inferior Oolite rests on the Carboniferous Limestone, seems to show that only beds of the age of the *Clypeus*-grit were deposited upon the old ridge at that spot."† In places the Rhætic Beds occur beneath the Inferior Oolite as at Vallis Bottom.

FIG. 39.

*Section near the Bridge at Murdercombe, near Frome* (De la Beche.)



*a.* Inferior Oolite.
*b.* Arenaceous parting.
*c.* Carboniferous Limestone.

* Mem. Geol. Survey, vol. i. p. 289.
† Inf. Ool. Gasteropoda, p. 54.

*Oldford near Frome to Bath, and Dundry.*

At Oldford, north of Frome, there is a large quarry in the Inferior Oolite, showing nearly 25 feet of well-bedded stone, as follows:—

| | Ft. | In. |
|---|---|---|
| Rubbly oolite - - - - - - | 3 | 0 |
| Pale shelly oolite - - - - - - | 3 | 6 |
| Pale chalky oolite - - - - - - | 3 | 0 |
| Pale oolite, 4 layers - - - - - | 13 | 3 |
| Brown sandy oolitic and sparry limestone, like Doulting Stone, with *Serpula* - - - - - | 2 | 0 |

One large *Nautilus* was observed, but fossils are very scarce. The stone is employed for building-purposes, &c.

The Cromlech in Orchardleigh Park, comprises two large blocks of stone, one about 11 feet high; and these are composed of Inferior Oolite.

The peculiar characters of the Oolite where it rests on the Carboniferous Limestone have been noticed in reference to the Doulting Stone. North of Frome more remarkable changes appear in the rock, it becomes very siliceous and seemingly "cherty" in places. Here it rests on an irregular surface of the Carboniferous Limestone, which is also cherty; and bosses of the older rock protrude here and there, much in the same manner as we find near Sutton and Southerndown in Glamorganshire, where peculiar modifications of the Lower Lias rest on the same rock. The occurrence of hard blue and grey siliceous beds in the Inferior Oolite near Frome has been noticed by De la Beche* and also by Mr. J. McMurtrie.†

In the cutting of the road leading from Whatcomb Farm, north of Frome, to Bradford's Bridge near Spring Gardens, the following beds were seen:—

Gravel and sand, clay and ochreous debris

Inferior Oolite { Chert and decomposed "cherty rock."
Sandy limestone.

Carboniferous Limestone, cherty in places.

In the railway-cuttings to the north, we find hard pale very oolitic stone, shelly in places, and bluish-grey in centre; while north-east of Vallis Bottom, a quarry by the railway showed about 25 feet of oolitic limestones, resting on hard grey shelly and oolitic limestones in massive beds, siliceous in places. The "cherty rock" is decomposed, where it comes to the surface, and gives rise to an ochreous soil. This fact is interesting as ochre was at one time worked in connection with the beds of cherty Lias on Harptree Hill.

Mr. Teall who examined microscopic sections of this Inferior Oolite, found it sometimes to contain grains of oolite, organic fragments, pellets, and a few quartz grains in a matrix of calcite; at other times the oolitic grains were obscure and apparently

* Mem. Geol. Survey, vol. i. p. 287.

† Proc. Bath Nat. Field Club, vol. v. p. 98.

welded together, and irregular granular aggregates of quartz occurred and formed the matrix.

Near Mells siding the railway-cutting showed the following series of beds :—

| | | Ft. | In. |
|---|---|---|---|
| | Grey and brown clayey soil. | | |
| Inferior Oolite | Rubbly oolite - - 3 0 to | 5 | 0 or more |
| | Massive bedded pale oolite - | 3 | 0 |
| | Compact shelly oolite with quartz pebbles; *Isastræa, Trigonia* - | 1 | 3 |
| | Rather sandy and shelly limestone | 1 | 3 |
| | Oolite - - - - Brown coarsely oolitic and sandy limestone - - - | 5 | 0 |
| | Rubbly iron-shot and earthy oolitic limestone; *Pseudomelania* and *Rhynchonella spinosa* (abundant in upper part) - Hard oolitic and sandy limestone; *Serpula, Trigonia,* and casts of Gasteropods - - - | 3 | 9 |
| | Compact slightly oolitic limestone, and more or less oolitic and iron-shot limestone, having a general rubbly appearance - Friable sandy limestone - - | 6 | 3 |
| | Dark grey oolitic limestone - | 1 | 0 |
| Lias - - | Slate-coloured clay (throwing out springs). | | |

Fossils have not proved sufficiently abundant to afford evidence for zones. The Rev. G. Horner informed me that *Ammonites humphriesianus* had been obtained from this neighbourhood ; but I was unable to see the specimen.

North-west of Mells, by "Edney's Farm" (Mr. Swanton's Lower Farm), about 12 feet of pale and false-bedded oolites have been quarried, and used for inside-work in Mells church. These are evidently the upper beds of Inferior Oolite that are to be seen in the railway-cutting. I obtained only one specimen of *Trigonia.*

East and north-east of Kilmersdon there are many quarries in the Inferior Oolite, on the eastern side of the valley leading towards Radstock ; here thick beds of stone are worked, and these are equivalent to the top beds of Dundry and the limestones at Midford. The features are well marked, the Inferior Oolite forming a terrace on the brow of the valley, surmounted by the Fuller's Earth and a minor escarpment of Fuller's Earth Rock, above which is the more prominent scarp of the Forest Marble.

North-west of Bowldish, east of Paulton, there were exposed 10 feet of oolitic limestones, with a lenticular coral-bed; *Terebratula globata* is present, and *Rhynchonella spinosa* occurs in shoals at the base. The beds here are but little above the Lias : indeed the shaft at the coal-works a short distance to the west, passes through Inferior Oolite and Lias.

On Clan Down, south of Camerton Farm, there is a quarry showing about 12 feet of pale and buff, finely oolitic limestone, with shelly layers here and there, but no marked beds; *Trigonia, Lima, Pecten demissus,* and Corals occur, but no Ammonites nor Belemnites were to be seen. The stone is quarried for road-metal. Proceeding towards Camerton, brown sandy shelly and slightly oolitic limestone was exposed in the road-cutting; lower down rubbly beds with ochreous marl and clay much tumbled occur; and hereabouts comes the junction with the Lias.

Other pits on Clan Down showed pale oolite resting on compact brown sandy and oolitic limestone, with ochreous exterior, and shelly in places. Here *Ammonites Parkinsoni*? *Rhynchonella spinosa, Avicula Münsteri,* and some other fossils were obtained. Referring to the same locality Mr. Hudleston notes shell-beds with *Trigonia, Nerinæa Guisei, Natica bajocensis, Trochus,* &c. *N. Guisei* is a well-marked horizon in the Clypeus-Grit. He observes that "As far as we know at present, this is the most southern locality in England where *Nerinæa* has been found to occur in the Inferior Oolite, and abundantly too, since there are no less than three shell-beds traceable here."* *Nerinæa* occurs also at the Red Post Quarry further north.

In the railway-cutting, west of Wellow Station, the Inferior Oolite has been exposed. The top beds resemble those near Charlcombe, Bath. They contain casts of *Trigonia sculpta*? (large), and *Natica*; also *Nautilus, Terebratula,* and *Rhynchonella spinosa.* Below come thick massive beds of compact brown oolitic limestone, with *Lima pectiniformis,* and *Trichites.* This succession is similar to that seen near Woolston Farm (see p. 83). The road-cuttings south of Wellow Church, and east of the railway-station, showed beds of the Inferior Oolite containing *Rhynchonella spinosa, Avicula Münsteri,* and *Stomechinus.* Below come the Midford Sands, with concretionary masses of calcareous sandstone, but they appear to be thin and were partially obscured by slips; and at the base, there were blue micaceous sandy clays with hard cement-stones, and stiff blue more or less shaly clay, disturbed in places. I obtained no fossils in this clay, hence whether it be Upper Lias clay or not cannot be definitely affirmed.

Further south the Sands, although well developed at Midford, have entirely died out, and the Inferior Oolite rests directly upon the Lias. Sections displaying this remarkably sudden attenuation were to be seen in the railway-cuttings: it is due no doubt to unconformable overlap of the Inferior Oolite, a fact indicated also by a pebbly band that is locally found at the base of the Oolite. The fossil-evidence shows that in this neighbourhood the Upper Division of the Inferior Oolite rests in some places directly on the Midford Sand and in other cases on the Lias.

In the neighbourhood of Bath the Inferior Oolite is from 25 to 45 feet in thickness, and, so far as observation has gone, the stone-beds belong mainly if not entirely to the upper part of the formation, or the zone of *Ammonites Parkinsoni.* The occurrence

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* Inf. Ool. Gasteropoda, p. 54.

of *Rhynchonella spinosa* in the bottom beds of the Inferior Oolite between Bath and Bradford-on-Avon was pointed out by Sir W. V. Guise,* and more recent observations confirm this.

It is noteworthy that while the Great Oolite is so well developed near Bath, the Inferior Oolite is less conspicuous, but the excellence of the former stone has, no doubt, prevented the opening up of the latter rock in places where under other circumstances it might have been worked for local use. Comparatively speaking, the Inferior Oolite of this neighbourhood yields but a poor stone, and for this reason it was originally known as the Bastard Freestone,† for it abounds with vacuities like the Portland "roach," and much of it is soft and unfit for use. As remarked by the Rev. Joseph Townsend, "It everywhere reclines on calcareous sand, which is used by our cooks, at Bath, to sand their kitchens, and is procured for them on the hills behind Camden Place, and Sydney Gardens."

The sands are now rarely opened up in the hills around Bath; but their occurrence seems to be tolerably persistent, although the thickness is very irregular. At Charlcombe they are said to be about 70 feet in thickness; but they vary from 40 feet (and less) to as much as 100 feet. The following Well-section at America Buildings, Lansdown, was recorded by De la Beche‡:—

| | | FT. |
|---|---|---|
| Fuller's Earth | Light clay | 20 |
| Inferior Oolite | Oolite | 30 |
| Midford Sand | Sand | 100 |
| Lias | Blue clay | 24 |
| | | 174 |

Reference has been previously made to the Midford Sand, and to the observations of William Smith and John Phillips. (See p. 52.) Fine sections of the strata were exposed in the railway-cuttings between Midford and Bath: the long tunnel (1,900 yards) through Combe Down being almost entirely excavated in these beds, the only exception being a trace of Inferior Oolite which was faulted in near the middle of the tunnel.§

These beds rest on thin representatives of the Upper Lias clay and limestone. They contain bands and nodules of sandy limestone or calcareous sandstone ("sand-burrs"), and in these indurated layers, fossils are occasionally found. The Rev. H. H. Winwood has obtained *Ammonites aalensis* (identified by Mr. Etheridge), and several specimens of *A. striatulus* (identified by Mr. E. T. Newton) from micaceous and calcareous sandstone in the Lyncombe cutting. Mr. S. S. Buckman records from the same locality *A. fallaciosus;* and from an oolitic bed at the base of the sands, *A. striatulus* and *A. toarcensis*.|| In the William-Smith

* Proc. Cotteswold Club, vol. ii. p. 170.
† Townsend's Character of Moses, p. 105.
‡ Report on the state of Bristol, Bath, &c. (Health of Towns Commission), 1845, p. 37.
§ See also J. Lean, Proc. Bristol Nat. Soc., ser. 2, vol. iii. p. 159.
|| Inf. Ool. Ammonites, p. 165.

Collection at the British Museum, there is a specimen from the Coal-canal near Midford, identified by Mr. Etheridge and Mr. R. B. Newton as very near to *A. Levesquei*, a species found in the Cephalopoda-bed of the Cotteswold Hills. More recently Mr. Winwood has obtained from Weston, near Bath, specimens of *Ammonites radians* and *Lima toarcensis.**

Mr. Hudleston, remarking on the apparent absence of the Lower Division of the Inferior Oolite (zone of *Ammonites Murchisonæ*), has suggested that it might be represented by the upper portion of the Midford Sands.† No evidence has at present been obtained to countenance this view. In tracing the beds northwards from Dorsetshire we find the Lower Division very indistinctly represented in many places: the beds are well shown at Dundry Hill, and where they do develop further north in the Cotteswold Hills, they are largely represented by false-bedded oolitic freestones. The stratigraphical evidence is therefore in favour of the Midford Sands belonging to the same set of beds as the Yeovil and Bridport Sands in the one direction, and the Cotteswold Sands with the Gloucestershire Cephalopoda-bed in the other. If the Midford Sands have at present proved somewhat unprolific, there is no reason why they should remain so, for fossils are preserved only here and there: in some localities as near Beaminster and Crewkerne abundantly, while near at hand the beds appear quite barren.

The section south of Midford Station is as follows:—

| | | Ft. | In. |
|---|---|---|---|
| | Fuller's Earth. | | |
| Inferior Oolite | Pale fine-grained oolite with occasional casts of shells - - - about | 24 | 0 |
| | Rubbly beds of oolitic limestone with bands of Coral-rock and seams of clay: *Isastræa, Pleurotomaria, Trochotoma, Trigonia* (cast), Sponges? - | 8 | 0 |
| | Iron-shot limestones, nodular and conglomeratic at the base: *Ammonites Parkinsoni, Pleurotomaria, Cucullæa cancellata, Lima pectiniformis, Modiola, Myacites jurassi, Ostrea costata, Pholadomya, Trichites, Trigonia, Rhynchonella obsoleta, R. spinosa, Terebratula globata, T. sphæroidalis* - | 6 | 0 |
| Midford Sands | Sands with indurated bands and nodules of calcareous sandstone. | | |

The sequence is similar to that noticed by Lonsdale,‡ who assigned a thickness of 40 or 50 feet to the "soft freestone" on top. He observed the Coral-bed beneath; and hard brown limestone at the base, abounding with fossils. The lowest bed he said was provincially called the "hollow-bed" as it contains hollow moulds and casts of *Trigonia* and other fossils. A bed of this character

* H. B. W., Geol. Mag., 1888, p. 470; Proc. Bath Nat. Hist. Club, vol. iii. p. 134; Geol. E. Somerset, p. 119; and Winwood, Proc. Bath Nat. Hist. Club, vol. vii. p. 338.

† Gasteropoda of Inferior Oolite, pp. 55, 66; see also J. Buckman, Quart. Journ. Geol. Soc., vol. xxxv. p. 737; vol. xxxiii. p. 1.

‡ Trans. Geol. Soc., ser. 2, vol. iii. p. 248.

is well seen at Charlcombe, but similar layers occur throughout the mass of the Inferior Oolite.

The Inferior Oolite is exposed beneath the Fuller's Earth Clay by the canal-bridge near the waterworks at Bradford-on-Avon; and again by the canal opposite to Limpley Stoke. It consists of brown shelly limestone, imperfectly oolitic, resting on pale oolite, and lower down oolitic limestone with casts of shells. In places the beds are shown to have a thickness of nearly 40 feet; but they all apparently belong to the zone of *Ammonites Parkinsoni*. By the canal-side near Avoncliff, Mr. E. A. Walford obtained *Trigonia duplicata* and *Nerinæa;* and at Freshford Mr. Hudleston obtained *Nerinæa Guisei*.

On top of the Midford Sands in the short Lyncombe cutting, between the Combe Down tunnel and the tunnel under Devonshire Buildings, there is a bed of nodular fossiliferous limestone, containing Lithodomus-borings. The bed is fossiliferous and is suggestive of the slow accumulation of the strata, accompanied by local erosion; from it the Rev. H. H. Winwood obtained the following species, which were identified by Dr. Wright* :—

| | |
|---|---|
| Ammonites Brocchii? | Lithodomus. |
| Astarte excavata. | Pholadomya. |
| Gervillia Hartmanni. | Trichites undulatus. |
| Homomya crassiuscula. | Trigonia costata. |
| Lima gibbosa. | Rhynchonella spinosa. |

A similar bed occurs at the base of the Inferior Oolite south of Midford railway-station.

At the base of the Fuller's Earth at Midford and again at Duncorn Hill, we find clays and thin layers of earthy limestone, yielding *Terebratula globata, Ostrea*, &c.

South-east of Duncorn Hill a quarry and road-cutting showed about 15 feet of Inferior Oolite beneath the Fuller's Earth. The top layer of hard brown limestone was bored by Lithodomi and Annelides, and similar borings occurred at lower horizons in the beds; these strata consisted of hard oolitic and occasionally compact limestone, yielding *Avicula Münsteri, Cardium, Isocardia, Myacites, Ostrea, Trigonia, Rhynchonella obsoleta, Terebratula globata*, and Corals. The Geological Survey Map in this neighbourhood does not clearly explain the relations of the several groups of strata, and some revision is needed.

North-west of Highbarrow Hill (Twerton Hill), a quarry showed about 10 feet of pale oolite, thin-bedded and rubbly in the upper part, and much lime-washed; below there was 3 feet of pale and brown oolite with casts of *Trigonia*, &c. Mr. Hudleston records from this bed *Nerinæa Guisei, Alaria, Ostrea*, &c. He also observed on the opposite side of the road in a disused quarry, a shell-bed with *Nerinæa, Ceromya striata, Pholadomya Heraulti, Myacites*, and Corals.†

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* Geol. E. Somerset, p. 119.

† Inf. Ool. Gasteropoda, p. 55.

The Inferior Oolite has been exposed under Claverton Church, and also at Beechen Cliff. At the last-named locality, as well as at Limpley Stoke, it appears to be largely composed of Corals, *Trigonia*, *Ostrea*, and Brachiopoda.* This is the case also at Charlcombe.

At the northern end of Beacon Hill, near Charlcombe, a quarry exposed pale oolitic and earthy limestones with many casts of shells; like the "hollow bed" before mentioned, that resembles the "Roach" of Portland. There was also a bed of compact limestone with faint brown arborescent markings, bearing a rude resemblance to those of the Cotham Marble.† The beds were much tumbled, and they yielded the following fossils:—

| | |
|---|---|
| Ammonites. | Trigonia (costate form). |
| Phasianella. | Rhynchonella obsoleta? |
| Pleurotomaria. | —— spinosa. |
| Isocardia. | Terebratula Buckmani? |
| Lima pectiniformis. | —— globata. |
| Lithodomus. | —— sphæroidalis. |
| Myacites. | Serpula. |
| Ostrea flabelloides. | Isastræa. |
| Trichites. | Thamnastræa defranciana. |

Similar beds were exposed south-west of Gwenfield Farm, Charlcombe; and not far below were micaceous sands with masses of sandy limestone containing *Belemnites*.

The fossil-beds in the limestones, here and at Midford, Lyncombe, and Duncorn Hill, evidently belong to the Upper Division of the Inferior Oolite. Unfortunately Ammonites are very scarce, and but poorly preserved when found.

At Hill House, north-west of Box, beds of tough iron-shot and sandy limestone, with *Rhynchonalla spinosa* were exposed. Here the beds were represented as Middle Lias on the Geological Survey Map. In the Box tunnel according to Mr. Etheridge the Inferior Oolite proved to be 30 feet thick.

The Midford Sands are shown in the scarps below Grove Woods, east of Swainswick. Oolitic and sandy limestones were exposed to a depth of 10 feet in a quarry above Cross Leaze Farm, south of Woolley, but the beds have yielded no distinctive fossils.

East of Weston, near Bath, and north of Primrose Hill, there are beds of brown oolitic limestone, much lime-washed, including the limestone with casts of shells, as at Charlcombe. Again on Kelston Hill, below the Fuller's Earth, we find beds of limestone with *Terebratula globata*, &c., but no very good sections.

A little west of the above-mentioned quarry near Weston, a well-sinking has recently been made, through a few feet of Midford Sand into the Upper Lias Clay. The "sand-burrs" in the sand (which appears to be very thin in this neighbourhood), were examined by the Rev. H. H. Winwood, and from them he obtained the specimens, previously mentioned, of *Ammonites*

* C. Moore, in Wright's Historic Guide to Bath, pp. 387–392.
† H. B. W., Geol. Mag., 1892, p. 112.

*radians* and *Lima toarcensis,* which were identified by Messrs. Sharman and Newton. The sand-burrs rest on a layer of iron-shot conglomeratic limestone, the matrix of which lithologically much resembles the Gloucestershire Cephalopoda-bed. From this layer Mr. Winwood obtained specimens of *Ammonites communis, A. bifrons,* and *Rhynchonella Moorei.* The bed is to some extent *remanié,* and it evidently corresponds with a "nodular" iron-shot bed noticed by Mr. Winwood at the base of the Midford Sands, near Devonshire Buildings, Bath.*

The Inferior Oolite of Dundry Hill has attained much repute as a fossiliferous development of the beds, and this is largely due to the Bristol geologists who have for many years collected specimens from this locality. Many descriptions of the strata and their fossils have been published; but it is mainly from the Lower Division of the Inferior Oolite that the fossils have been obtained.†

There is no continuous section of the beds, and they must be studied in several disconnected quarries and cuttings; moreover, the beds are somewhat disturbed if not faulted. The following is a general account of the series:—

The *Building* or *Freestone Beds* occur on top of the series, and these are exposed in quarries and underground workings to the south-west of the church. They comprise hard flaggy and irregular brown limestones, resting on more massive layers of sandy limestone, the whole being imperfectly oolitic, and some of the beds being sparry in nature and resembling the Doulting Stone. The beds are about 15 or 16 feet thick; and the best stone is said to occur at the base. Few fossils occur, but Mr. Etheridge notes several species of Corals, and casts of *Trigonia.*

*Ragstones* (including the *Conchifera*-beds of Mr. Etheridge); east of the School, by the main road from Bristol to Chew Magna, and again further north on the brow of the hill, the following beds may be traced:—

| | Ft. | In. |
|---|---|---|
| Flaggy and earthy limestone with the lenticular masses of Coral-rock, *Isastræa, Montlivaltia, Thamnastræa, Ostrea gregaria*; resting on rubbly beds, marls and clay, with irregular beds of marly limestone, yielding *Terebratula globata,* spines of Echini, &c. - - - | 6 | 0 |
| Compact limestone with Annelide-borings - - - | 0 | 7 |

Among other fossils recorded from this upper portion of the Inferior Oolite are *Ammonites subradiatus,* with its operculum *in situ* (a specimen described by S. P. Woodward),‡ *Terebratula sphæroidalis* (original specimen figured by Sowerby), *Rhynchonella spinosa,* &c. (See p. 125.)

The above beds may be regarded as belonging to the zone of *Ammonites Parkinsoni,* and their full thickness probably exceeds 40 feet. The zonal Ammonite, as Mr. E. Wilson has stated, is of extreme rarity.

*Iron-shot limestones* (including the "Mollusca or Shelly Bed," and the "Ammonite Bed").—Beneath the compact limestone, before noted, there may be traced at the same locality, nearly 5 feet of hard brown iron-shot limestones; and similar beds, with ochreous clayey layers, were exposed

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* Geol. East Somerset (Geol. Surv.), p. 115; and Winwood, Proc. Bath Nat. Hist. Club, vol. vii., p. 337.

† De la Beche, Mem. Geol. Surv., vol. i. p. 255; Etheridge, Quart. Journ. Geol. Soc., vol. xvi. p. 22; Tawney, Proc. Bristol Nat. Soc., ser. 2, vol. i. p. 9; Hudleston, Inf. Ool. Gasteropoda, pp. 22, 56; and S. S. Buckman, Proc. Cotteswold Club, vol. ix. p. 374; Quart. Journ. Geol. Soc., vol. xlix. p. 508.

‡ Geologist, vol. iii. p. 328.

on the north side of the hill below Dundry church. The full thickness of these beds was not seen; it is probably upwards of 6 feet.

The following species have been recorded,* and they indicate that the zones of *Ammonites humphriesianus* and *A. Murchisonæ* are represented:—

Ammonites Blagdeni.
—— Braikenridgei.
—— Brocchii.
—— Brongniarti.
—— concavus.
—— corrugatus.
—— humphriesianus.
—— læviusculus.
—— Murchisonæ.
—— Sauzei.
—— Sowerbyi.
Belemnites canaliculatus.
Nautilus excavatus.
—— lineatus.
Pleurotomaria elongata.
Trochus Zetes.
Astarte elegans.
—— excavata.
Ceromya bajociana.
Lima Etheridgei.
—— pectiniformis.
Gresslya abducta.
Modiola sowerbyana.
Myacites jurassi.
Opis similis.
Ostrea flabelloides.
Pecten demissus.
Pholadomya fidicula.
—— Heraulti.
Trigonia.
Rhynchonella plicatella.
—— subtetrahedra.
Terebratula Eudesi.
—— cortonensis.
—— maxillata.

*Midford Sands.* These beds have been poorly exposed, and they appear to be very thin; but there are, according to Mr. S. S. Buckman, representatives of the zones of *Ammonites opalinus* and *A. jurensis.*†

The following fossils have been recorded:—

Ammonites aalensis.
—— radians.
—— striatulus.
—— toarcensis.
Belemnites irregularis.
Modiola sowerbyana.
Pholadomya fidicula.
Rhynchonella cynocephala.

The chief fossil-bed of Dundry is thus at the base of the Inferior Oolite limestone, and Mr. Etheridge, Mr. J. F. Walker, and Mr. Buckman have commented on the close connection between the Ammonites and Brachiopods of this locality, and the fossils of the Dorset-Somerset area. At Dundry *Ammonites concavus* occurs in the lower portion of the iron-shot division, and in the higher portion, Mr. Buckman finds *A. Sowerbyi, A. Sauzei,* and *A. humphriesianus.*‡ These three species locally occupy the same horizon, a fact of considerable interest, and there ought to be no doubt about the occurrence of *A. Sowerbyi,* for the original figured specimen came from Dundry.

Referring to the fact that the Lower Division of the Inferior Oolite has not been recognized in the Cotteswold area, between Little Sodbury and Bath, nor at Midford to the south of Bath, Mr. Buckman has suggested that the Dundry area was separated from the Cotteswold area during the time when these Lower beds were accumulated, and only united during the period of the zone of *Ammonites Parkinsoni.* This separation was, in his opinion,

* See Stoddart, Proc. Bristol Nat. Soc., ser. 2, vol. ii. p. 286. E. Wilson, Proc. Geol. Assoc., vol. xiii., p. 128.

† Quart. Journ. Geol. Soc., vol. xlv. p. 469; Inf. Ool. Ammonites, pp. 168, 292; see also Etheridge, Quart. Journ. Geol. Soc., vol. xvi. p. 22.

‡ Inf. Ool. Ammonites, p. 63.

caused by upheaval of the Lias, so as to form a barrier, along the intervening tract.* This view must be regarded as a very speculative one; but there is no doubt that the overlap of the Upper Division of the Inferior Oolite, was accompanied by some erosion of the underlying beds, and that the Oolite rests in places directly on the Lias.

* Proc. Cotteswold Club, vol. ix. p. 374; see also J. F. Walker, Geol. Mag. 1878, p. 556.

# CHAPTER IV.

## INFERIOR OOLITE SERIES.—(Local Details *continued.*)

### *Cotteswold Hills.—Bath to Stinchcombe.*

Leaving the neighbourhood of Bath and passing on to the main escarpment of the Cotteswold Hills, we find the Inferior Oolite outcropping in a regular belt from Tog Hill near Doynton to the neighbourhood of Hawkesbury. In the southern portion of this area no good sections have been recorded.

Further north the beds are exposed here and there in quarries and road-cuttings; for instance, west of Dodington Ash, near the Cross Hands above Old Sodbury, and near the Manor House, Little Sodbury. Along portions of this tract the following general subdivisions have been traced :—

| | | Ft. | In. |
|---|---|---|---|
| Inferior Oolite. | Ragstones - - - - | 20 to 30 | 0 |
| | Freestone - - - - - | 25 to 35 | 0 |
| Midford Sand. | Cephalopoda Bed - - - - | 5 to 15 | 0 |
| | Yellow sands with bands of calcareous Sandstone (Cotteswold Sands) - - | 30 to 40 | 0 |

The stone-beds above the Cephalopoda Bed increase generally in thickness northwards, and the beds become more and more divided, so that in the neighbourhood of Stroud and Cheltenham many subdivisions may be made. These subdivisions are local, and the absence of some of them, especially in the Freestone division from the southern area, shows that somewhat different sedimentary conditions prevailed.

The Ragstones (above-mentioned) are for the most part earthy and shelly limestones, and they include the zone of *Ammonites Parkinsoni* and, perhaps, part of that of *A. humphriesianus.*

The Freestones comprise false-bedded oolites assigned to the zone of *A. Murchisonæ.*

These beds will be more particularly described further on; but it may be stated generally that Ammonites are by no means so abundant in the Inferior Oolite of the Cotteswolds as they are at Dundry, and in Dorsetshire.

In the Gloucestershire Cephalopoda Bed the case is different, and over a considerable area we find a very rich fossil-bed which yields a profusion of Ammonites and Belemnites.

Since the beds have been studied in more detail, they have been subdivided into numerous minor zones, and many questions have arisen with regard to the correlation of different stages of the strata. These questions relate in particular to the beds that lie between the Upper Lias clays and the base of the Inferior

Oolite in the Cotteswold area, as compared with those of other regions.

For the sands below the Cephalopoda Bed the local names of Nailsworth, and Frocester Sands have been used; but in 1876 the name Cotteswold Sands was employed by Professor Buckman,* and it has been adopted by E. Witchell† and other geologists as a convenient local term.

The COTTESWOLD SANDS, like the Midford, Bridport, and Yeovil Sands, consist of yellow micaceous sands with bands and concretionary nodules of calcareous sandstone. Towards the base they become more or less argillaceous and merge gradually into the Upper Lias clay beneath; consequently there is no definite stratigraphical division between these formations.

Palæontologically the beds are intimately linked with the Upper Lias, and, through the Cephalopoda Bed, with the Inferior Oolite; between both formations they constitute passage-beds.

The thickness of the beds at Cam Long Down and Frocester Hill has been estimated at from 120 feet to 130, and at Stroud 100 feet. At Birdlip the beds appear to be nearly as thick,‡ but northwards they decrease to 60 feet and less; indeed at Cleeve Cloud they are hardly distinguishable, but this may arise partly from the fact that the declivities are obscured by landslips, and by a rubble of limestone.

The GLOUCESTERSHIRE CEPHALOPODA BED consists of iron-shot marly limestones and marls, from 2 to 15 feet thick, that yield, more or less abundantly, *Ammonites* and *Belemnites* as well as other organic remains. The bed was particularly described by Dr. Wright in 1856,§ but it had long been known to collectors as the "Ammonite Bed," and had been previously noticed by the Rev. P. B. Brodie as the "Ammonite and Belemnite Bed." In point of names the bed is not lacking, for Professor Hull, in describing the strata, employed the name "Ammonite Sands" to include both both Cotteswold Sands and Cephalopoda Bed.¶ Moreover the abundance of *Rhynchonella cynocephala* led Dr. Lycett, in 1857, to adopt the term "Cynocephala stage" for both Cephalopoda Band and Sands below.** This fossil is, however, chiefly found in the upper beds, and a variety of it also occurs at higher horizons in the Inferior Oolite of the Cotteswold Hills.

Palæontologically the Gloucestershire Cephalopoda Bed and the Cotteswold Sands have been divided into a number of zones, as previously indicated (p. 40.) In order to maintain a consistent

* Quart. Journ. Geol. Soc., vol. xxxiii. p. 6.
† Geology of Stroud, p. 30.
‡ Lucy, Proc. Cotteswold Club, vol. viii. p. 161.
§ Quart. Journ. Geol. Soc., vol. xii. p. 293.
|| *Ibid.*, vol. vi. p. 244, and vol. vii. p. 209.
¶ Geol. Cheltenham, p. 25.
** The Cotteswold Hills, pp. 16, 18.

palæontological division between the Lias and Oolites, it is of course necessary to take the junction between the zones of *Ammonites opalinus* and *A. jurensis*. In order to do this the "Cephalopoda Bed," as pointed out by Oppel, has to be split into two, and consequently some geologists have restricted their application of the name to the beds that lie below the zone of *A. opalinus*. From a stratigraphical point of view this is misleading, and it is far better to employ the name Cephalopoda Bed in its original sense, for all portions of it are so intimately blended that no plane of separation whatever can be marked out.

We find that the sub-zone of *A. radians* is sometimes placed in the lower division of the Inferior Oolite, and sometimes in the Upper Lias.

E. Witchell* and other geologists have recognized how impracticable it is to attempt any precise distinction between the upper and lower portions of the Cephalopoda Bed, for it is admitted that *A. opalinus* occurs in the top even of the restricted Cephalopoda Bed.

By uniting into one broad stratigraphical division the Cotteswold Sands, together with the Cephalopoda Bed (as a whole), we have a group that compares fairly well with the Yeovil and Bridport Sands; as both divisions include the zones of *A. opalinus* and *A. jurensis*, and therefore constitute the passage-beds between the Lias and the Oolites. For this intermediate formation the term Midford Sand is retained, while the name Cotteswold Sands is useful locally, as it embraces admittedly only a portion of the Midford Sands.

*Ammonites bifrons*, or a variety of it (as noted in 1856 by Dr. Wright), ranges upwards from the Upper Lias into the base of the Cotteswold Sands, and therefore from a palæontological point of view it may be extremely hard to fix any definite boundary between the Upper Lias clays and overlying sands.† It is true that Dr. Wright suggested that the specimens might be derived, but Mr. Buckman is not of this opinion.

The following grouping is therefore adopted for the beds‡ :—

| | | *Zones* and *Sub-zones.* | |
|---|---|---|---|
| Midford Sands. | Gloucestershire Cephalopoda Bed | *Ammonites opalinus.* | |
| | | *A. radians* | *A. jurensis.* |
| | Cotteswold Sands | *A. striatulus* | |
| | | *A. variabilis* | |
| Upper Lias clays. | | | |

The following fossils have been recorded from the Cotteswold Sands and Gloucestershire Cephalopoda Bed :—

* Geology of Strond, p. 34.

† See Wright, Lias Ammonites, pp. 138, 148; S. S. Buckman, Inf. Ool. Ammonites, p. 50.

‡ See also Lycett, Cotteswold Hills, p, 163; Hudleston, Gasteropoda of Inf. Oolite, pp. 60, &c.; S. S. Buckman, Inf. Ool. Ammonites, pp. 7, 42, 50, 51, 97; and Quart. Journ. Geol. Soc., vol. xlv. p. 440, vol. xlix. p. 509.

| —— | Sands. | Cephalopoda Bed. |
|---|---|---|
| Ammonites aalensis | | × |
| —— —— var. Moorei | | × |
| —— compactilis | × | × |
| —— discoides | | × |
| —— dispansus | × | × |
| —— fallaciosus | | × |
| —— hircinus | | × |
| —— insignis (Fig. 4) | | × |
| —— jugosus | × | |
| —— jurensis (Fig. 3) | × | × |
| —— Levesquei | | × |
| —— opalinus (Fig. 6) | | × |
| —— —— var. comptus | | × |
| —— radians | | × |
| —— striatulus (Fig. 2) | × | × |
| —— subinsignis | × | × |
| —— sublineatus | × | |
| —— toarcensis (thouarsensis) | | × |
| —— torulosus | | × |
| —— variabilis | × | |
| —— Wrighti (A. "Jurensis" of Wright) | | × |
| Belemnites breviformis | × | × |
| —— compressus | × | × |
| —— irregularis (Fig. 7) | | × |
| —— tripartitus | × | |
| Nautilus latidorsatus | × | × |
| Amberleya capitanea | × | × |
| Pseudomelania (Chemnitzia) procera | | × |
| Trochus duplicatus | × | |
| Astarte lurida | × | × |
| Cucullæa ferruginea | × | × |
| Cypricardia bathonica, var. brevis | × | × |
| —— cordiformis (Fig. 19) | × | × |
| Gervillia Hartmanni | × | × |
| Gresslya abducta | | × |
| Hinnites abjectus | | × |
| Lima toarcensis | | × |
| Modiola sowerbyana (plicata) (Fig. 10) | × | × |
| Opis carinatus | | × |
| —— lunulatus | | × |
| Pecten textorius | | × |
| Pholadomya fidicula (Fig. 11) | × | × |
| Trigonia Ramsayi | | × |
| —— striata | | × |
| Rhynchonella cynocephala (Fig. 14) | × | × |
| —— jurensis | | × |
| Terebratula punctata (sub-punctata), var. haresfieldensis | | × |
| Montlivaltia lens | | × |

Turning now to the stratigraphical features to be observed, we have but little evidence to fix the southern extent of the Cephalopoda Bed between Bath and Little Sodbury. At Bath we have in the Midford Sand fossils that characterize the Cephalopoda Bed; and at Wéston, the Rev. H. H. Winwood has found an iron-shot limestone that closely resembles that bed in lithological character. (*See* p. 99.) Near Bath there is not only considerable local attenuation of the Midford Sand, but evidence of local unconformity both between the Sand and Upper Lias clay, and between the Sand and Inferior Oolite.

Proceeding northwards the following section of a quarry, near the Rectory at Horton, will show the general character of the beds :—

| | | | | Ft. | In. |
|---|---|---|---|---|---|
| Inferior Oolite. | Rag-stones. | White Oolite | - - - - - about | 8 | 0 |
| | | Clypeus Grit. | Oolitic limestone with *Terebratula*-bed at base, *T. globata* and *Nerinæa Guisei* - - - - | 8 | 0 |
| | | | Rubbly and marly oolite - - | 1 | 0 |
| | | Trigonia Bed. | Hard shelly and oolitic limestones with *Trigonia costata*, *Trichites*, *Rhynchonella concinna*, *R. spinosa*, &c. - - - - - | 3 | 0 |
| | Freestones - - | | Oolitic freestone, bored at top, current-bedded in mass and in the individual layers: shelly in places - - - - | 10 | 0 |
| | | | Nodular marly layer with *Gresslya* | | |
| | | | Freestone - - - about | 2 | 0 |

The Cephalopoda Bed, consisting of sandy and iron-shot limestones and marls, was to be observed below the level of the Freestone to the north-west of the Ancient Encampment at Little Sodbury, and again in the combe east of Horton church. From this bed I obtained *Ammonites opalinus*, *A. radians*, *A. striatulus*, and *A. dispansus*.

The strata in this neighbourhood have been described by Dr. H. B. Holl who assigns a thickness of 8 feet to the Cephalopoda Bed.[*] Mr. S. S. Buckman has published a detailed section of the strata at Little Sodbury.[†] Mr. Hudleston has likewise given an account of the Horton quarry, and mentioned some of the fossils above enumerated. He obtained many Gasteropods from the bottom layer of the Ragstone.[‡] He remarks that the absence of any representative of the zone of *Ammonites humphriesianus* appears to be complete.

North of Hawkesbury the outcrop of the Inferior Oolite is less regular, for the escarpment is intersected by deep ramifying valleys, and the rock caps the straggling but bold promontories of Nibley Knoll and Stinchcombe Hill, the latter perhaps the finest of the Cotteswold Hills. The same general divisions may be noticed in the Inferior Oolite Series, northwards as far as Dursley.

In ascending the hill north of Wotton-under-Edge, by the lane north-west of the town, a fine section of the Cotteswold Sands and Cephalopoda Bed, was exposed in the deep lane-cutting. The Sands, shown to a depth of 25 feet, present their ordinary characters of yellow micaceous sand, with little or no calcareous matter, except in the bands of calcareous sandstone. They are surmounted by nearly 12 feet of marly iron-shot limestones,

* Quart. Journ. Geol. Soc., vol. xix. p. 310.

† Inf. Ool. Ammonites, p. 164.

‡ Introd. to Gasteropoda of the Inf. Oolite (Palæontogr. Soc.), p. 57.

alternating with softer clayey beds, containing in places much concretionary iron-ore. This is one of the finest sections of the Cephalopoda Bed, and here many fossils may be obtained.*

The Freestones, overlaid by the Ragstones, have been quarried for road-metal, &c., by the high road a little further north. The former beds comprise bands of false-bedded and even-bedded oolite, opened up to a depth of 33 feet. They are sparingly fossiliferous. *Belemnites*, *Nerinæa*, and *Ostrea* occur, but the beds are partially made up of shell-fragments, and they contain small rolled fragments of oolite. The top bed has been bored by Annelides. (*See* p. 34.)

The general succession of the beds is well shown again in a quarry on Nibley Knoll, near the Tyndale Monument, and in the lane leading towards the village of North Nibley. The section is as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Ragstones. | Tough irregular oolitic limestones with Trigonia-bed at base (1 ft. 2 in.); yielding *Modiola*, *Trigonia*, *Trichites*, *Terebratula globata*, *Rhynchonella spinosa*, &c. - - - - - | 6 | 6 |
| Freestones. | White oolitic freestone and coarse brown shelly oolite, bored at top, and current-bedded - - - - about | 22 | 0 |
| | Marly and pebbly oolitic layer - - - | 0 | 4 |
| | White and brown shelly and nodular oolites; *Belemnites* and *Hinnites velatus* - - - - - - | 2 | 0 |
| | Hard white shelly oolite, bored at top 5 | 0 to 7 | 0 |
| | Shelly oolitic limestones, with *Ammonites*, *Astarte*, *Gresslya*, *Pholadomya fidicula*, *Trigonia striata*, &c. - - - about | 8 | 0 |

The Cephalopoda Bed was well shown in the deep lane-cutting, and from it I obtained specimens of *Ammonites insignis*, *A. opalinus*, *A. radians*, and *A. dispansus*. Mr. Buckman, who has examined the beds in detail, has published a section of which the following is a summary of the portion of the series below the Freestones† :—

| | | Ft. | In. |
|---|---|---|---|
| Cephalopoda Bed. | Iron-shot marl and limestone, *Am. opalinus* - - - - - | 1 | 11 |
| | Rock with *Rhynchonella cynocephala* - | 0 | 8 |
| | Concretionary and oolitic marly beds - | 10 | 2 |
| | Hard yellow oolitic rock; *A. striatulus*, *A. insignis* - - - - | 1 | 0 |
| | Oolitic and iron-shot marly rock; *A. radians* - - - - - - | 0 | 7 |
| | Hard irregular rock; *A. striatulus* - | 1 | 2 |
| Cotteswold Sands. | Fine yellow sands with concretionary layers of sandy limestone, *Am. compactilis*, *A. sublineatus*, *Belemnites*, *Amberleya*, *Turbo*, *Lima* - about | 130 | 0 |
| Upper Lias. | Clay. | | |

The grouping of the beds is that adopted in this Memoir.

* See also Wright, Quart. Journ. Geol. Soc., vol. xii., p. 308.

† Inf. Ool. Ammonites, p. 46.

There are several sections of Inferior Oolite on the spur extending from Break Heart Hill to Stinchcombe Hill. At the former locality there is a quarry showing the following section:—

| | Ft. | In. |
|---|---|---|
| Rubbly oolite, used for road-stone - - - | 7 | 0 |
| Hard white and more or less oolitic limestone, false-bedded. The stone is employed for walling and other building-purposes. Near the base it is shelly, and yields *Lima pectiniformis* and *Terebratula* - - | 8 | 0 |

These beds at Break Heart Hill may represent the highest beds of the Inferior Oolite—the white oolite noticed by Witchell at Rodborough,* and seen also in the Horton quarry. (*See* p. 116.) Blocks in the wall by the roadside (said to have been taken from this quarry) contain small quartz pebbles. The beds are represented as Great Oolite on the Geological Survey Map, but they appear to pass under the Fuller's Earth. The evidence obtained was not quite satisfactory, and therefore I content myself with expressing only the opinion that the beds belong to the Inferior Oolite.

The following section south of Dursley perhaps shows the lower portion of these White Oolite beds resting on the Ragstone. It is interesting as affording evidence of the variable character of the Ragstone division:—

| | | Ft. | In. |
|---|---|---|---|
| Ragstone. | More or less oolitic limestones. | | |
| | Rubbly marly and somewhat sandy oolite, with many examples of *Terebratula globata;* also *Myacites* and other Lamellibranchs - | 10 | 0 |
| | Bed with *Rhynchonella spinosa* - - | 0 | 4 |
| | Marly limestone - - - - | 0 | 7 |
| | Marly limestone, Trigonia-bed, with costate *Trigonia, Ostrea flabelloides, Lima pectiniformis* - - - - - - | 1 | 1 |
| Freestone. | White oolitic and shelly freestone; *Trigonia*, here and there, near top - - - | 10 | 0 |
| | Oolitic freestone in regular layers, current-bedded in places - - - - | 25 | 0 |

The Ragstone was well exposed in a quarry by the road leading from Dursley to Stinchcombe Hill. The sands below the Cephalopoda Bed, were shown in the lane north-east of Break Heart Hill. They comprised micaceous yellow sands, with little or no calcareous matter, but with bands of flaggy and false-bedded calcareous sandstone.

The following section, recorded by Mr. S. S. Buckman, shows the junction of the Cotteswold Sands with the Upper Lias Clay, as exhibited in the road at Stinchcombe, about two miles north of Nibley† :—

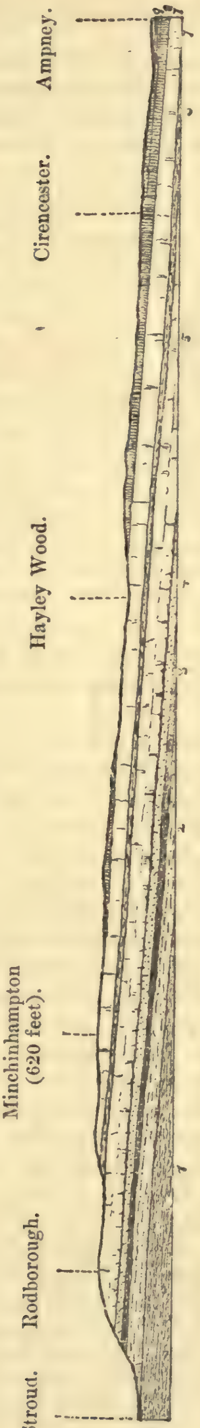
| | | Ft. | In. |
|---|---|---|---|
| Cotteswold [Midford] Sands and Upper Lias Clay. | Yellow sands. | | |
| | Dark brown argillaceous marl, with *Ammonites bifrons, A. compactilis, Belemnites* - - - - - | 0 | 1 |
| | Brown and bluish shelly and sandy stone with ferruginous specks; *A. bifrons, Rhynchonella, Terebratula,* &c. - - | 0 | 8 |
| | Dark blue clay, with large blue-hearted nodules of stone. | | |

* Geology of Stroud, p. 62.

† Inferior Ool. Ammonites, p. 47.

Fig. 40.

*Diagram-section from Stroud to Cirencester.* (Distance, about 15 miles.)




5. Inferior Oolite.
4. Midford Sands (Cephalopoda Bed and Cotteswold Sands).
3. Upper Lias Clay.
2. Middle Lias.
1. Lower Lias.

9. Cornbrash.
8. Forest Marble.
7. Great Oolite.
6. Fuller's Earth.

### *Cotteswold Hills—Dursley to Leckhampton.*

The district extending from the north-east of Dursley to Stroud, Leckhampton, and Cleeve Cloud, presents us with the finest development of the Inferior Oolite in England, and one in which the greatest number of local subdivisions have been made. These are as follows :—

| Sub-divisions of Inferior Oolite Series. | | | | Thickness in Feet. | Zones. |
|---|---|---|---|---|---|
| Upper Division. | Rag-stones. | Upper. | White Freestone - | 5 | *A. Parkinsoni.* |
| | | | Clypeus Grit - | 6 to 15 | |
| | | Lower. | Upper Trigonia Grit | 2 to 12 | |
| | | | Gryphite Grit - | 2 to 12 | *A. humphriesianus.* |
| | | | Lower Trigonia Grit | | |
| Lower Division. | Freestones | | Upper Freestone - | 6 to 20 | |
| | | | Oolite Marl - - | 5 to 10 | *A. Murchisonæ.* |
| | | | Lower Freestone - | 45 to 130 | |
| | Pea Grit Series. | | Pea Grit - - | 3 to 20 | |
| | | | Lower Limestone - | 10 to 25 | |
| | Midford Sand. | | Cephalopoda Bed - | 2 to 7 | *A. opalinus* and *A. jurensis.* |
| | | | Cotteswold Sands - | 10 to 120 | |

These divisions have been noted from time to time by Murchison, J. Buckman, Strickland, Brodie, Lycett, Hull, Wright, and Witchell.*

Descriptions have previously been given of the Cotteswold Sands and Cephalopoda Bed (p. 103). We now come to the main mass of the Inferior Oolite. In this group, which attains a thickness of 250 feet at Leckhampton, we have a considerable development of the false-bedded oolites with few fossils, probably accumulated with rapidity when compared with the more fossiliferous Pea Grit Series below and the Ragstones above.

There are at various horizons, fossil-beds rich in Echinoderms, Polyzoa, Brachiopods, and Lamellibranchs, but there are comparatively few Ammonites and Belemnites, and, as will be seen, much difference of opinion has been expressed on the subject of zones. Four coralliferous layers have been observed on different horizons, and these bands furnish evidence of coral-growth *in situ*, though occasionally, as in the uppermost bed, there are indications of derivation.† As remarked by Mr. Hudleston, *Nerinæa* is associated with the coral-growths in the Cotteswold area, and this is a genus that has not been met with in the district south of Radstock in Somersetshire.‡

* Murchison, Geol. Cheltenham, 1834; Ed. 2, by J. Buckman and H. E. Strickland; Brodie and Buckman, Quart. Journ. Geol. Soc., vol. i. p. 221; Brodie and Strickland, *Ibid.*, vol. vi. pp. 239, 249, &c.; J. Buckman, *Ibid.*, vol. xiv. p. 107; Wright, *Ibid.*, vol. xvi. p. 1; Lycett, The Cotteswold Hills, 1857; Hull, Geology of Cheltenham (Geol. Survey), 1857; Witchell, Geology of Stroud, 1882.

† See Tomes, Quart. Journ. Geol. Soc., vol. xxxviii. p. 412; Geol. Mag., 1886, p. 387; and Proc. Cotteswold Club, vol. ix. p. 301; Wright, *Ibid.*, vol. iv. p. 148.

‡ Gasteropoda of Inf. Oolite, p. 22.

The principal sections of the Inferior Oolite Series along the western Cotteswold Hills are exposed at Uley Bury, and Coaley, near Dursley; at Selsley Hill, Rodborough, and Stroud; at Haresfield and Randwick; Painswick, Birdlip, and Crickley; Leckhampton, Ravensgate and Lineover Hills, and Cleeve Cloud.

In preparing the lists of fossils from the several subdivisions of the Inferior Oolite, I have made use of the works of Lycett, Witchell, and others, and have been guided also by the species I have myself obtained.

The subdivision into zones of the Inferior Oolite of the Cotteswold Hills is attended by as much difficulty as elsewhere, and the comparative rarity of Ammonites no doubt increases the difficulty.

It must be remembered that we are seeking for divisions where none may exist in nature; hence there is little chance of adopting any grouping that can be regarded as definite. The lower beds belong to the zone of *A. Murchisonæ* (including with it, as we have done elsewhere, the sub-zone of *A. Sowerbyi*); and the upper beds belong to the zone of *A. Parkinsoni.* The source of trouble in the Cotteswolds, as in Dorsetshire and Somersetshire, is the zone of *A. humphriesianus,* for this horizon is as imperfectly developed, or as vaguely marked off, in the Cotteswolds as in more southerly parts of England. The species occurs, though sparingly, both in the Upper Freestone and in the overlying beds belonging to the Gryphite Grit; hence Dr. Wright placed the one subdivision, and E. Witchell the other, in the zone of *A. humphriesianus.* Evidently in this as in other regions the so-called zone is but a connecting link between the zones of *A. Murchisonæ* and *A. Parkinsoni;* and the beds in which *A. humphriesianus* is found are put sometimes in the Lower and sometimes in the Upper division of the Inferior Oolite. For practical purposes we might disregard it, although it is well to indicate its probable position.

Mr. S. S. Buckman is indeed disposed to place the Gryphite Grit in the sub-zone of *Ammonites concavus* (*Sowerbyi*-zone), and to regard the Upper Trigonia Grit as the base of the zone of *A. Parkinsoni;* but he admits that "we have scarcely any break of a marked character between the Upper Trigonia Grit and the Gryphæa Grit in the Stroud district."* He has stated that in no part of the Cotteswolds is the zone of *A. humphriesianus* represented, but that view depends to some extent upon the interpretation of species. I have obtained one example of the fossil from near Chipping Campden, and Prof. Tate recognized the species from Stroud.

A more particular account of the local subdivisions of the Inferior Oolite may now be given.

### Pea Grit Series.

Resting upon the Cephalopoda Bed, there are beds of coarse ferruginous oolite, brown sandy limestone, rough freestone, and

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* Proc. Cotteswold Club, vol. ix. pp. 130, 132, and 374.

pisolitic layers, 15 to 45 feet thick, that locally admit of the following divisions:—

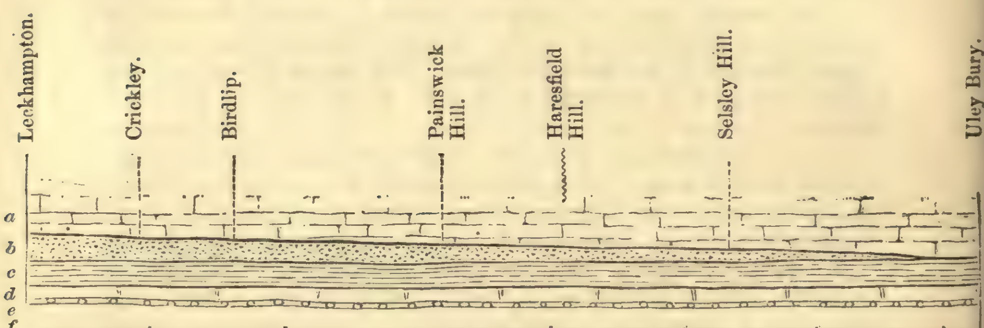
Pea Grit Series { Pea Grit.<br>Lower Limestone.<br>Brown Ferruginous Beds (Ferruginous Oolite of J. Buckman).

These beds have been variously described by different geologists, for the sections alter much in detail at every locality.

*Brown Ferruginous Beds.*—The beds of brown ferruginous oolite and sandy limestone that are sometimes met with at the base, have yielded no distinctive fossils, and may be regarded as passage-beds from the Cephalopoda Bed. They comprise two or three beds, which vary from 5 to 9 feet in thickness, and sometimes yield many Lamellibranchs in the lower portion, as observed by Witchell. Mr. Hudleston records *Nerinæa* (*Ptygmatis*) *xenos* from the beds on Crickley Hill, regarding it is the oldest species of *Nerinæa* hitherto discovered in Britain.* The beds constitute a kind of ragstone, and are occasionally used for rough masonry. The lowest beds of the Inferior Oolite, seen at the Frith quarry, Painswick, consist of brown and slightly oolitic limestone, with ramifying ferruginous tubes (*see* p. 34).

FIG. 41.

*Diagram-section from Leckhampton to Uley Bury.*
(E. Witchell.) (Distance, 16 miles.)




*a.* Lower Freestone.
*b.* Pea Grit.
*c.* Lower Limestone.
*d.* Brown Ferruginous Beds (Sandy Limestone).
} [Pea Grit Series.]

*e.* Cephalopoda Bed.
*f.* Cotteswold Sands.
} [Midford Sand.]

*Lower Limestone.*—The term "Lower Limestone" was given in 1882, by Witchell; it is only of local application. These beds, however, attain importance on Randwick Hill, where they have been opened up at the Ruscombe quarries. There, beneath the Pea Grit, the beds described by Witchell were as follows† :—

* Quart. Journ. Geol. Soc., vol. xlix. (Proc.), p. 127.
† Geol. Stroud, p. 41; and Quart. Journ. Geol. Soc., vol. xlii. p. 269.

| | | Ft. | In. |
|---|---|---|---|
| Pea Grit Series (Lower Limestone). | Freestone, with oolitic grains sparingly distributed - - - - | 10 | 0 |
| | Oolitic limestone, mainly composed of oolite with bands or seams of shelly detritus, fragments of coral, Echini, and oolitic grains, and the upper surface covered with minute valves of *Ostrea*. A good weatherstone, but worked with difficulty - - - | 16 | 0 |

Witchell noticed that these beds of limestone are in places pisolitic and highly crystalline, and that they sometimes contain rolled fragments of limestone and small quartz pebbles. He observed the beds at Cam Long Down, near Dursley, and at various points along the hills by Stroud to Leckhampton.

The beds yield a number of small Gasteropods—*Cerithium*, *Ceritella*, *Monodonta*, *Nerita*, &c., and fragments of *Nerinæa*; also *Ostrea*, *Pentacrinus*, *Cidaris*, and Polyzoa.

Mr. S. S. Buckman observes that the Lower Limestone and underlying Brown Ferruginous Beds may perhaps belong to the zone of *Ammonites opalinus*.*

*Pea Grit.*—This bed consists of hard and soft bands made up to a large extent of small bean-shaped and, less frequently, pea-shaped concretions. Where disintegrated the slopes beneath the exposed rock, as at Crickley, are strewn with the little concretions. The bed has been long known to the inhabitants of the district as the "Pea Grit," and is less commonly termed Pisolite. As early as 1729 "Pisolithi" were noticed by Dr. John Woodward, on the hill between Cirencester and Gloucester,† evidently Birdlip, where the beds are well shown, and have a thickness of about 20 feet. The name Pea Grit was adopted by Murchison in 1834.‡

Alternating with the layers of Pea Grit, there are bands of hard pisolitic limestone, and there can be no doubt that the "Lower Limestone" is so represented in places, and at Crickley we have no need to make any subdivisions in the Pea Grit Series. The harder beds have been quarried for building-stone at Crickley and Leckhampton. The thickness of the series is here about 38 feet.

The Pea Grit as a separate bed has been traced by E. Witchell§ as far south as Coaley Wood, near Uley Bury, where it is 9 inches thick, at Horsley where it is 3 feet, and at Longford Mill, near Nailsworth, where it is 5 feet. It has been observed by Prof. Hull|| as far north as Nottingham Hill, but has not been detected on Robin's Wood Hill. Eastwards he has noticed it at Colesborne, and it occurs also near Andoversford. (See Fig. 41.)

Witchell has remarked that "The coral bed above the pea-grit consists of masses of coralline limestone, embedded in a

* Inf. Ool. Ammonites, pp. 7, 42; see also Hudleston, Address to Geol. Soc., 1893, Quart. Journ. Geol. Soc., vol. xlix. (Proc.), p. 126.

† Nat. Hist. Foss., Eng., Part 1, p. 30.

‡ Geol. Cheltenham, p. 33.

§ Quart. Journ. Geol. Soc., vol. xlii. p. 266.

|| Geol. Cheltenham, p. 33.

whitish mudstone; the corals are crystalline, and are extracted with difficulty. Their structure is best seen in polished hand specimens; these can always be obtained from the broken heaps of stone on the sides of the road repaired with it, and can be easily ground to a smooth surface and polished." The Coral Bed can be traced from Haresfield Hill to Painswick Edge and Stroud, and again to Witcombe, Crickley, and Cubberley.* The particular places at which it has been observed are Juniper Hill, near Painswick, Huddingknoll, Horsepools, Sheepscombe, Birdlip, and Crickley. This Coral Bed is sometimes termed the Fourth or Lower Coral Bed (in descending order) in the Inferior Oolite of the Cotteswold Hills.

The following are among the more conspicuous fossils of the Pea Grit Series:—

Ammonites Murchisonæ (Fig. 16).
Belemnites aalensis.
Nerinæa oppelensis.
—— pisolitica.
—— producta.
Patella rugosa.
Trochotoma carinata.
Arca Pratti.
Avicula complicata.
Hinnites abjectus.
—— tumidus.
Lima alticosta.
—— Lycetti? ("punctata").
Modiola furcata.
—— imbricata.
—— sowerbyana.
Ostrea rugosa.
Pecten articulatus.
—— comatus.
—— lens.
Trichites nodosus.
Trigonia costatula.
—— pullus.
Rhynchonella angulata.
—— oolitica.
—— sub-decorata.
Terebratula pisolitica.
—— plicata.
—— simplex.
Diastopora (*several species*).
Entalophora (Spiropora) straminea.
Heteropora pustulosa.
Acrosalenia Lycetti.
Galeopygus (Hyboclypus) agariciformis.
Hemipedina Bakeri.
Pseudodiadema depressum.
Pygaster semisulcatus (Fig. 25).
Stomechinus germinans (Fig. 24).
Pentacrinus Austeni.
—— Desori.
Galeolaria (Serpula) socialis.
Adelastræa consobrina.
Chorisastræa rugosa.
Donacosmilia (Axosmilia) Wrighti.
Isastræa depressa.
Latimæandra Flemingi.
Montlivaltia lens.
—— painswicki.
Thamnastræa flabelliformis.
Lymnorella.
Peronidella.

## Freestones and Oolite Marl.

The Lower Freestone Beds consist of pale oolite often hard and compact at the top, more or less shelly in places, but on the whole sufficiently free from organic remains to be readily dressed into blocks for building-purposes and for carving.

The beds are locally overlaid by a band of oolitic marl, 5 to 10 (and rarely 30) feet thick, with indurated layers of oolite in places. Known as the Oolite Marl, this division is not always distinctly separated from the Lower Freestone below, while it more frequently merges into the Upper Freestone above.

* Witchell, Geol. Stroud, p. 45.

The Lower Freestone, being more thickly developed, and altogether the more important division, is known as the "Building Freestone," although in some localities the upper freestone yields good beds of building-stone. It varies in thickness from about 45 feet at Uley Bury to 130 feet at Leckhampton. It contains *Pecten personatus*, &c., but no distinctive species.

The Oolite Marl (Oolite Marlstone of J. Buckman) being characterized by *Terebratula fimbria*, was termed the "*Fimbria*-stage" by Dr. Lycett. It contains also *Terebratula maxillata* (var. *submaxillata*), *Waldheimia Leckenbyi*, *Rhynchonella subobsoleta*, and *R. Lycetti*: an assemblage not met with in Dorsetshire.*

At the base of the Freestone there is at Leckhampton a bed of "Flaggy Oolite" according to Prof. Buckman (="Shelly Freestone" of Brodie) that is extensively quarried for rough kinds of stone-work, and in which there are many forms of life similar to those of the Great Oolite.† The strata likewise present great similarities in lithological characters with some beds in the Great Oolite of Minchinhampton. These lower beds are not separated by any marked plane of division from the underlying Pea Grit Series.

The Upper Freestone (which includes the "Rubbly Oolite" of Brodie) is often a pale closely-packed oolite, and is of variable thickness, being from 6 to 20 feet at Stroud and Nailsworth, 20 feet at Leckhampton, and about 30 feet at Cleeve Cloud.

In the neighbourhood of Cleeve Cloud and north-eastwards, sandy and clayey subdivisions become associated with the higher portions of the Freestone Series, replacing to a certain extent the Upper Freestone.

The Coral Bed that occurs in the Oolite Marl has been termed the Middle Coral Bed, but other Coral Beds having been subsequently observed, it is noted as the Third Coral Bed (in descending order) in the beds of this district. It has been found at Juniper and Birdlip Hills, at Leckhampton, and Notgrove.

The following fossils are among those recorded from the Oolite Marl:—

Ammonites Murchisonæ (Fig. 16).
Nautilus clausus.
Discohelix (Solarium) cotteswoldiæ.
Natica cincta (leckhamptonensis).
Nerinæa cotteswoldiæ.
—— gracilis.
Astarte depressa.
—— elegans (Fig. 12).
—— excavata.
Ceromya concentrica.
Cucullæa cucullata.
Cyprina curvirostris.
—— nuciformis.
Gervillia aurita.
Hinnites abjectus.
Lima pectiniformis.
—— pontonis.
Lucina Wrighti.
Modiola imbricata.
Mytilus pectinatus.
Ostrea flabelloides.
—— palmetta, var. montiformis.
Pecten subcomatus.
Perna rugosa, var. quadrata.
Pholadomya Heraulti.
Trichites nodosus.
Trigonia angulata.
—— costatula.
—— pullus.

* J. F. Walker, Geol. Mag., 1878, p. 556.

† Buckman, Quart. Journ. Geol. Soc., vol. xiv. p. 109; Brodie, *Ibid.*, vol. vi. pp. 244, &c.

Trigonia striata (Fig. 9).
Rhynchonella concinna (Fig. 77).
—— Lycetti.
—— subobsoleta.
—— subtetrahedra.
—— Tatei.
Terebratula curvifrons.
—— fimbria (Fig 23).
—— maxillata (submaxillata) (Fig. 78).
Terebratula plicata.
Waldheimia carinata.
—— Leckenbyi.
Eryma elegans (Guisei).
Comoseris vermicularis.
Convexastræa Waltoni.
Isastræa limitata.
Latimæandra Flemingi.
Stylina solida.
Thamnastræa defranciana.
Thecosmilia gregaria.

This division has by some authorities been placed in the sub-zone of *A. Sowerbyi.*

### RAGSTONES.

This general name is applied to the upper beds of the Inferior Oolite in the Cotteswold area: beds that furnish little or no free-stone. They comprise layers of more or less earthy ferruginous and oolitic limestone, and are far more fossiliferous than the Free-stones below. Occasionally they yield blocks serviceable for building-purposes, for rough walling, &c., but they are chiefly employed for road-metal. They are from 20 to 40 feet thick.

Very many local divisions have been made, to which the name "Grit" has unfortunately been applied, for, strickly speaking, this term should be confined to coarse-grained sandstones. The "Grits" of the Oolitic series are for the most part earthy lime-stones, and occasionally calciferous sandstones, as is the case with certain beds in the Corallian Series.

In this Upper Division of the Inferior Oolite Series we have locally the "Gryphite Grit," a term used by Murchison in 1834, because the beds are characterized by *Gryphæa sublobata,* a form which occurs very abundantly.

The "Trigonia Grits" (recognized by Murchison and Buck-man in 1845) of which two horizons were pointed out by Lycett in 1857, are characterized by an abundance of Trigonias, but the upper bed is more extensively developed than the lower. A "Chemnitzia Grit" has also been noticed locally by Dr. Wright in association with the Lower Trigonia Grit; but the forms at one time identified as *Phasianella* and *Chemnitzia,* are now named *Bourguetia* and *Pseudomelania.*

On top of these Grits there are beds characterized by an abun-dance of *Clypeus Ploti;* to them the name "Clypeus Grit" has been applied (= Clypeus Brash of J. Buckman); and in this subdivision a "Pholadomya Grit" was noticed by Lycett. Again, from the prevalance of *Rhynchonella spinosa* in all these Grits or Ragstones, the term "Spinosa-stage" was applied to them collectively by Lycett.

In some localities above the Clypeus Grit there have been noticed certain beds of pale oolite termed the White Oolite (or Freestone) by Witchell.* This bed is not very fossiliferous, but it contains *Terebratula globata, Trigonia,* and *Pecten.*

* Proc. Cottesw. Club, vol. vii. p. 117.

The Upper Trigonia Grit, and more especially the Clypeus Grit, yield in abundance *Terebratula globata:* hence these divisions are sometimes known as the "Globata Beds."

Thus the following minor palæontological divisions have been recognized in the Upper Division of the Inferior Oolite near Cheltenham:—

| | | Ft. | In. |
|---|---|---|---|
| Upper Ragstones (Hull). | White Oolite - - - - - | 5 | 0 |
| | Clypeus Grit (with Pholadomya Grit) - | 6 to 15 | 0 |
| Lower Ragstones (Hull). | Trigonia Grit (Upper Trigonia Grit) - | 2 to 12 | 0 |
| | Gryphite Grit (including Lower Trigonia Grit and "Chemnitzia" Grit) - | 2 to 12 | 0 |

These subdivisions may be looked upon as fossil-beds of a more or less local character, for as Lycett remarked in reference to them, probably in no single locality are they all exhibited; and in some places (as will be noticed) lithological divisions occur that cannot be precisely correlated with any of these fossil-beds.

In the Ragstones there are few Cephalopoda, Gasteropoda, and few Echinoderms (excepting *Clypeus*); but Lamellibranchs and Brachiopoda are abundant.

Two Coral Beds have been observed; the Second Coral Bed, which occurs at the bottom of the Lower Trigonia Grit, having been observed at Ravensgate Hill, Birdlip, Leckhampton, Cleeve Hill, Juniper Hill, near Painswick, and Brown's Hill, nearer to Stroud. The First or Upper Coral Bed occurs at the base of the Clypeus Grit or on top of the Upper Trigonia Grit, at Stroud Hill, Rodborough, and in the Slad Valley, Stroud.

Specimens of *Clypeus Ploti* (*sinuatus*) are very abundant in some places. Prof. Buckman stated that "The platform upon which the houses at Birdlip stand, rests on this bed, which is well exposed by the denudation of the Fuller's earth. Here the plough on the Stone-brash turns up this Urchin in large quantities; the same is the case in the Stow district, where we have frequently seen it gathered up in heaps for removal from the barley-field, and have not always succeeded in convincing our bucolic friends that it was not an *annual production*."* Some of the railway-cuttings near Notgrove, and the ploughed fields near Naunton have also yielded these fossils in abundance. John Phillips mentions that they were known as "poundstones" or "quoitstones," and were in the early days of William Smith not unfrequently employed as a "pound-weight" by the dairy-women.† Strict regulations with regard to weights and measures were not in force.

The following fossils have been recorded from the Gryphite Grit (including the Lower Trigonia Grit):—

Ammonites humphriesianus (Fig. 17).
Nautilus lineatus.
Belemnites canaliculatus.
Bourguetia striata (Chemnitzia Sæmanni or Phasianella).

* Quart. Journ. Geol. Soc., vol. xiv. p. 108.
† Memoirs of Wm. Smith, p. 3.

Pseudomelania procera.
Astarte elegans (Fig. 12).
—— excavata (Fig. 20).
Ceromya bajociana (Fig. 21).
Cucullæa oblonga.
Cypricardia cordiformis (Fig. 19).
Gervillia Hartmanni.
—— tortuosa.
Gresslya abducta.
Gryphæa sublobata (Buckmani).
Homomya Vezelayi.
Isocardia cordata.
Lima pectiniformis.
—— strigillata (bellula).
Macrodon hirsonensis.
Myacites tenuistriatus.
Myoconcha crassa.
Ostrea flabelloides.
—— palmetta, var. montiformis.
Pecten articulatus.
Pecten demissus.
—— lens.
Perna rugosa.
Pholadomya fidicula (Fig. 11).
—— Heraulti.
—— media.
—— ovulum.
Pinna cuneata.
Trichites undulatus.
Trigonia angulata.
—— costata.
—— hemisphærica.
—— sculpta.
—— striata (Fig. 9).
Unicardium depressum.
Terebratula Buckmani.
—— Phillipsi (Fig. 27).
Isastræa tenuistriata.
Thamnâstræa defranciana.
Thecosmilia gregaria.

The following fossils have been recorded from the Upper Trigonia Grit:—

Ammonites Martinsi.
—— Parkinsoni (Fig. 26).
Belemnites abbreviatus.
Avicula digitata.
Cardium Buckmani.
Ceromya striata.
Gresslya abducta.
Lima gibbosa.
—— strigillata.
Macrodon hirsonensis.
Ostrea concentrica, var. munda.
Pecten articulatus.
—— demissus.
Perna rugosa.
Pholadomya Heraulti.
Trichites undulatus.
Trigonia angulata.
—— costata.
—— duplicata.
—— producta.
—— signata.
Rhynchonella angulata.
—— concinna (Fig. 77).
—— spinosa (Fig. 29).
Terebratula globata (Fig. 28).
Waldheimia carinata.
Vermilia sulcata.
Holectypus depressus.

The following fossils have been recorded from the Clypeus Grit:—

Ammonites Brocchii.
—— Parkinsoni (Fig. 26).
Nerinæa Guisei.
Astarte depressa.
Cardium cognatum.
Ceromya plicata.
—— striata.
Cucullæa oblonga.
Cypricardia cordiformis (Fig. 19).
Cyprina Lucyi.
Homomya gibbosa.
Isoarca clypeata.
Lima gibbosa.
—— pectiniformis.
Lucina clypeata.
Modiola sowerbyana (Fig. 10).
Myacites æquatus.
Myacites compressiusculus.
Ostrea flabelloides.
Pecten demissus.
Pholadomya Dewalquei.
—— Heraulti.
Sowerbya elongata.
Trichites undulatus.
Unicardium incertum.
Rhynchonella angulata.
—— spinosa (Fig. 29).
—— subtetrahedra.
Terebratula globata (Fig. 28).
—— perovalis.
—— Whitakeri.
Vermilia sulcata.
Clypeus Ploti (sinuatus) (Fig. 30).
Holectypus depressus.

The White Oolite (or Freestone), described by Witchell, constitutes over a limited area the uppermost division of the Inferior Oolite, underlying the Fuller's Earth on Rodborough Common, and at Stroud Hill. It is a white fine-grained oolite; but has not, so far as I know, been employed as a freestone. The few fossils recorded from it include *Pecten demissus, Trigonia costata,* and *Terebratula globata.*

It is now desirable to note some of the principal sections that have been exposed from Dursley to Leckhampton.

The following section at Coaley Wood, Uley Bury, has been described in detail by Mr. S. S. Buckman,* in whose company I had the advantage of examining the strata:—

| | | | Ft. | In. |
|---|---|---|---|---|
| Base of Pea Grit Series | | Brown ferruginous sandy oolite - - - | 5 | 6 |
| Cephalopoda Bed. | Zone of *Ammonites opalinus.* | Hard brown iron-shot oolite, *Am. opalinus* - | 1 | 5 |
| | | Marly iron-shot limestone, *Am. opalinus, Belemnites, Chemnitzia* - | 0 | 6 |
| | | Marl with *Am. Wrighti, Belemnites, Astarte lurida, Cypricardia, Gresslya* - - | 0 | 10 |
| | Sub-zone of *A. striatulus.* | Iron-shot marly limestone, *A. discoides* - - | 0 | 7 |
| | | Iron-shot marl, *A. striatulus, A. radians* - 0 3 to | 0 | 7 |
| Cotteswold Sands. | Sub-zone of *A. variabilis.* | Fine yellow micaceous sands with bands and nodules of calcareous sandstone, *A. sublineatus, A. variabilis, Pecten* about | 65 | 0 |
| | | Fine yellow sands - about | 25 | 0 |
| | | Sandstone with *A. bifrons* var., and *A. compactilis* - | 1 | 0 |
| | | Yellow sands - about | 40 | 0 |
| Upper Lias - - - | | Clay. | | |

The Cephalopoda Bed may be examined in other places along the wooded escarpment which extends to Frocester Hill.† The Pea Grit Series, Freestones, and Ragstones are here and there exposed. The beds may also be studied at Selsley Hill.

Excellent sections of the Inferior Oolite are again to be seen on Rodborough Common, and on the hill (Stroud Hill) east of Stroud. Here lived and laboured for many years Edwin Witchell, who (following Lycett) worked out the palæontology of the beds in great detail. Under his guidance I had the advantage of seeing in this neighbourhood the principal sections, of which the following may be taken as a summary.

General section of the Inferior Oolite Series near Stroud‡:—

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* Inf. Ool. Ammonites (Pal. Soc.), pp. 45, 166.

† For accounts of the beds at Frocester, *see* Brodie, Quart. Journ. Geol. Soc., vol. vii. p. 210; J. Buckman, *Ibid.*, vol. xiv. p. 103; Witchell, Geol. Stroud, p. 32.

‡ Witchell, Geol. Stroud, p. 5 (plate), and pp. 55, &c. *See also* Hudleston, Gasteropoda of Inf. Oolite (Pal. Soc.), p. 62.

| | | | Ft. | In. |
|---|---|---|---|---|
| Ragstones | White Oolite. Pale oolite with few fossils - - - - - | | 5 | 0 |
| | Clypeus Grit. Coarse marly oolite; *Terebratula globata* very abundant, especially in upper part. *Clypeus Ploti*, *Nerinœa Guisei* (*Guisei*-bed of Hudleston), &c. - - - - | | 5 | 6 |
| | Hard earthy and sandy limestones with few fossils - - - - | | 4 | 0 |
| | Upper Coral Bed - - - - | | 3 | 0 |
| | Upper Trigonia Grit. Hard grey shelly and marly limestones, with *Trigonia angulata*, *T. costata*, *Rhynchonella spinosa*, &c. - | 2 6 to | 4 | 0 |
| | Gryphite Grit. Brown ferruginous marly and sandy limestone, with loamy layers, *Gryphœa sublobata*, *Astarte elegans*, &c. - | 1 6 to | 12 | 0 |
| Freestones | Upper Freestone. False-bedded oolite, bored on top; with few fossils | 10 0 to | 20 | 0 |
| | Oolite Marl. Soft oolitic marly limestone and marl; *Nerinœa*, *Terebratula fimbria*, *Rhynchonella subobsoleta*, &c. | 4 0 to | 6 | 0 |
| | Lower Freestone. Fine and coarse-grained oolite, more or less false-bedded, and with shelly detritus in places - - - - | 50 0 to | 90 | 0 |
| Pea Grit Series. | Pea Grit - - - - | 3 0 to | 4 | 0 |
| | Lower Limestone - - - | 15 0 to | 25 | 0 |
| | Brown Ferruginous Beds - - | | 9 | 0 |
| Midford Sand. | Cephalopoda Bed - - - | | 5 | 0 |
| | Cotteswold Sands - - - | about | 110 | 0 |

In addition to the sections on Stroud Hill, which are known as the Workhouse quarry, Conygre quarry, and another quarry in Horns Valley on the southern slope of the hill, there are many sections along the borders of the Stroudwater Hills. The same subdivisions may be studied in different places; thus the opening known as Walls quarry, south of Brimscombe, affords a good section of the Ragstones, Upper Freestone, Oolite Marl, and Lower Freestone, and the building-stones have been worked by means of extensive galleries in this quarry.* Other sections are exposed in the Golden Valley east of Chalford.

Sapperton Canal-tunnel, which was completed in 1789, showed, at the Stroud end, Fuller's Earth overlying Inferior Oolite. From the latter rock *Rhynchonella spinosa* and also *Terebratula fimbria* were obtained; thus indicating that the Oolite Marl as well as the Ragstones were penetrated. Further on, a mass of Fuller's Earth was encountered, faulted against the Inferior Oolite on the Stroud side, and against the Great Oolite on the other side, and this latter rock continued until the end of the tunnel. Its length was 3,817 yards and the water-level was 363 feet above sea-level.

* *See* Geol. parts of Wilts and Gloucester, p. 10.

In the tunnel of the Great Western Railway, the beds exposed, near the Stroud valley, were Fuller's Earth resting on Inferior Oolite; and these dipped towards the hill, being followed by the Great Oolite, and being only slightly faulted in one place.* In the Frampton Cutting the Ragstones, yielding *Terebratula globata* and *Rhynchonella spinosa*, were exposed.

At a quarry, by the first milestone, on the Bath road, beyond Nailsworth, the following section was noted :—

| | | FT. | IN. |
|---|---|---|---|
| Ragstones | Pale rubbly and fissured oolite - - about | 8 | 0 |
| | Hard white oolite, with *Terebratula globata*, *Pholadomya*, *Clypeus Ploti*, *Nerinæa Guisei* - | 1 | 10 |
| | Hard brown oolite, with *Trigonia*, *Lima pectiniformis*, *Rhynchonella spinosa*, &c. - - | 2 | 6 |
| | Shelly oolite, with *T. globata*, *Rhynchonella concinna*, and *Trigonia* - - - - | 6 | 0 |
| Upper Freestone. | White oolitic freestone, very hard, and bored at top - - - seen to depth of | 7 | 0 |

The freestones burn to a good lime; while the ragstones here yield the best weatherstone.

It is noteworthy that at this locality we have no trace of the Gryphite Grit; and the Oolite Marl is hardly discernible, so that the Upper and Lower Freestones practically form one division, that is estimated to be about 35 feet thick.

The Lower Freestone, as remarked by Witchell, has been largely quarried at Ball's Green, near Nailsworth, where galleries, a quarter of a mile long, have been driven into the hill. The Pea Grit (3 feet thick), as remarked by Mr. Hudleston, has been well exposed at Longford Mill, east of Nailsworth, and has yielded several species of *Nerinæa*. The Lower Limestones attain a thickness of about 25 feet; and the Gloucestershire Cephalopoda Bed about 14 feet.†

North-east of Stroud, the beds may be studied at Swift's Hill, near Knap Farm, and on the spur that separates Painswick Slade from Painswick, at the Frith quarry, and at Longridge, S.E. of Painswick.‡

At the Frith quarry, the Upper Freestone and Oolite Marl are not separable, for the latter consists of oolitic marl, with bands of hard pale earthy and fine oolitic limestone, merging upwards into the Upper Freestone. Together these beds attain a thickness of upwards of 30 feet. They yield in some abundance a variety of *Rhynchonella cynocephala* and *R. Tatei*, the former occurring in quite the highest part of the beds, where it was found by Mr. P. N. Datta, who accompanied Mr. Witchell and myself.

On the spur of Inferior Oolite, that extends to Standish Hill or Haresfield Beacon, Randwick Hill, and Ruscombe, there are numerous exposures of the beds, including the quarries at White Hill (Whiteshill), the Horsepools, Painswick Hill, and Kimsbury Castle.§

* J. H. Taunton, Proc. Cottesw. Club, vol. v. p. 255; Ibbetson, Rep. Brit. Assoc. for 1846, Sections, p. 61.

† Witchell, Geol. Stroud, pp. 46, &c.; Hudleston, Gasteropoda of Inf. Ool., p. 60.

‡ *See also* Hudleston, Inf. Ool. Gasteropoda, p. 63.

§ *See* Witchell, Proc. Cotteswold Club, vol. vii. p. 117, and vol. viii. p. 44.

The following section at Haresfield Beacon was examined under the guidance of Mr. S. S. Buckman, who has published a detailed account of it* :—

| | | Ft. | In. |
|---|---|---|---|
| Pea Grit Series. | Pea Grit - - - - - | 5 | 0 |
| | Lower Limestones - - - about | 35 | 0 |
| | Brown ferruginous sandy limestones and oolite with quartz grains - - - | 8 | 4 |
| Cephalopoda Bed. | 5. Iron-shot marly limestones and marl; *Ammonites opalinus*, *A. comptus*, *A. aalensis*, *Trigonia Ramsayi* - - | 2 | 1 |
| | 4. Brown marl, with *Rhynchonella cynocephala*, *A. Moorei*, *A. Wrighti* - 0 2 to | 0 | 6 |
| | 3. Iron-shot marl, with *Terebratula punctata*, var. *haresfieldensis* - - - | 0 | 5 |
| | 2. Hard nodular bluish-grey sandy limestone, *Am. striatulus*, *Ostrea* - - | 0 | 7 |
| Cotteswold Sands. | 1. Yellow sands; with *Am. bifrons*, var. about 70 feet down in sandy stone - about | 100 | 0 |

The division between the zone of *Ammonites opalinus* (Cephalopoda Bed) and overlying beds is from a palæontological point of view indefinite. Mr. Buckman includes beds 2 and 3 in the sub-zone of *Ammonites striatulus*. Belemnites are abundant in the Cephalopoda Bed.

The Cotteswold Sands, and traces of the Cephalopoda Bed, were exposed in a lane-cutting west of Edge, and south of the Horsepools. The sands here contain very fine mealy beds, that, according to Mr. W. C. Lucy, were formerly used for cleaning silver.

The Lower Limestones were exposed in a quarry near by, and again further north of the Horsepools. At the latter place the beds were much tilted, with appearances of "terminal curvature" on top. Here we find sandy, shelly, ferruginous, and oolitic limestones, with rolled pebbles of oolite, and occasionally small quartz pebbles, as pointed out many years ago by Strickland. Annelide borings occur in different layers, and there is a marked band with ramifying ferruginous markings, like the bed seen at the base of the Frith section, and resembling the Great Oolite "Dagham Stone." (*See* p 286.) Mr. Lucy, who has described these beds, considers that the quartz grains may have been derived from the older rocks of the Forest of Dean. In the Huddingknoll quarry, at Horsepools, the conglomeratic Oolite is known as the "Dapple Bed"; it contains tiny quartz pebbles, and pebbles of oolite, and is from 9 inches to 1 foot thick.†

The Lower Freestone, Oolite Marl (6 feet), and Upper Freestone are shown on Quar hill to the south of the Horsepools, where the beds are quarried for building-stone, and burnt for lime. Freestone is largely worked on Painswick Hill. The stone-beds are somewhat shattered, and consist of pale oolite with alternate layers of darker oolite. The stone, although reckoned a good weatherstone, does not last well if placed directly on the ground.

* Inf. Ool. Ammonites, p. 43; and Quart. Journ. Geol. Soc., vol. xxxv. p. 737.

† Proc. Cotteswold Club, vol. ix. p. 388. A specimen of this Dapple Bed, was presented to the Museum of Practical Geology by Mr. S. S. Buckman.

Traces of Gryphite Grit occur by Kimsbury Castle, and below this camp, on the western side, tough ferruginous oolite, a good weatherstone has been worked at the Jackdaw quarry. This stone (or set of rag-beds) has been used for road-metal, and also for the new reservoir near Gloucester. Ammonites have been found here. The beds overlie the Freestone; but there are many faults in the neighbourhood, and without detailed mapping on on the 6-inch scale, it is difficult to make out the relations of the beds seen in different quarries.

Passing to the north-east, we have fine sections at Birdlip, Crickley, and Leckhampton, near Cheltenham.* Birdlip is of especial historic interest, for at its "Black Horse" the Cotteswold Club was founded in 1846. The Pea Grit is well exposed in the lower part of the scarp by the Knap, and higher up come the Freestones and Ragstones: the latter are also exposed in the banks of the lane south of the Black Horse. The Clypeus Grit yields many specimens of *Clypeus Ploti* and *Terebratula globata,* including the variety known as *T. globata*, var. *birdlipensis,* which is found also in Dorsetshire. The Gryphite Grit has however not been noticed at this locality, and the relations of the several subdivisions are not so clearly exhibited as at Leckhampton.

A well-boring made south-east of Birdlip, showed that the Inferior Oolite, from the Clypeus Grit to the top of the Cephalopoda Bed, attains a thickness of 187 feet. The boring further penetrated sands and clay 116 feet.†

The Pea Grit Series is well exposed along the southern scarp of Crickley Hill. It comprises thick beds of pisolite, alternating with marly pisolitic layers, the talus here and there being largely made up of loose pisolitic concretions. Beds of more or less pisolitic oolite occur here and there, especially in the upper part of the series, which is overlaid by a hard and ragged bed (the Polyzoa Bed), sometimes two layers of which are present. The beds are bored in places by Annelides; and they contain *Terebratula plicata, Ostrea, Ammonites Murchisonæ,* &c.

The nature of the particular layers varies considerably as the beds are traced along the scarp. The following section gives their general characters:—

| | | Ft. | In. |
|---|---|---|---|
| Lower Freestone. | Pale oolitic freestones, with hard limestone at base. | | |
| Pea Grit Series. | Rubbly pisolitic beds, merging into - - | 2 | 6 |
| | Hard shelly layer with Gasteropods (*Nerinæa*), *Rhynchonella,* Polyzoa. [Coral Bed] 2 0 to | 4 | 0 |
| | More or less rubbly and shelly marl, oolitic and slightly pisolitic; *Terebratula plicata* - - | 1 | 6 |
| | Hard shelly oolites and pisolitic limestones, current-bedded in places; *Rhynchonella* - | 7 | 9 |
| | Alternations of pisolitic limestone and marly pisolitic beds - - - - - | 12 | 6 |

* The term Cheltenham Beds has been used by Sir A. Geikie for the Inferior Oolite. Text Book of Geology, Ed. 2, 1885, p. 788.

† W. C. Lucy, Proc. Cotteswold Club, vol. viii. p. 161.

| | | Ft. | In. |
|---|---|---|---|
| | Hard shelly and pisolitic limestones, current-bedded in places and bored at different horizons - - - - - | 11 | 8 |
| | White oolites, bored here and there - - | 8 | 10 |
| | White and brown ochreous and sparry oolitic and slightly pisolitic limestones; *Ostrea*, *Pecten articulatus*, Corals - - - - - | 6 | 0 |
| Cephalopoda Bed. | Pale brown marly iron-shot and ochreous beds; *Belemnites* - - - 1 6 to | 2 | 6 |
| | Sandy marl with *Rhynchonella cynocephala*, &c. - | 2 | 0 |
| | Sands. (Not exposed.) | | |

The beds are somewhat differently grouped by different observers, but practically there are no marked divisions to be made in the Pea Grit Series at this locality.* E. Witchell has grouped the beds as follows† :—

| | | Ft. | In. |
|---|---|---|---|
| Pea Grit Series. | Pisolite - - - - | 35 | 0 |
| | Lower Limestone - - - | 22 | 6 |
| | Sandy Limestone - - - | 6 | 3 |

On a higher horizon, a lenticular Coral Bed, 11 feet thick in places, was shown S.E. of Crickley Hill, resting on rubbly oolitic marls 3 or 4 feet thick, beneath which came the Pea Grit Series.

The best known sections of the Inferior Oolite on the Cotteswold Hills, are those at Leckhampton Hill. They have been described by numerous geologists, whose measurements and descriptive details differ to some extent, on account of the varying nature of the beds.‡ The following is an account of the strata exposed in the quarries, though it does not include the highest beds present in the hill :—

| | | Ft. | In. |
|---|---|---|---|
| Upper Trigonia Grit, &c. | Hard irregular earthy shelly and oolitic limestones; *Ammonites Parkinsoni*, *Lima pectiniformis*, *Trigonia*, *Terebratula globata*, *Rhynchonella*, &c. - - | 5 | 0 |
| | Hard oolite, bored at surface; passing down into hard shelly oolite (? = the Notgrove Freestone, p. 132) - - | 3 | 6 |
| Gryphite Grit. | Hard brown rubbly and gritty oolitic and iron-shot limestone, in several beds; with *Gryphæa sublobata* in abundance 5 0 to | 7 | 0 |
| Lower Trigonia Grit, &c. (not clearly exposed). | Rubbly limestones - - 5 0 to | 6 | 0 |
| | Marly and shelly oolite - - - | 1 | 6 |
| | Brown marly layer - - - - | 0 | 6 |

* An excessive thickness of about 70 feet was assigned to the Pisolitic Beds by Mr. T. B. Ll. Baker, Proc. Cotteswold Club, vol. ii. p. iv.; *see also* J. Buckman, Quart. Journ. Geol. Soc., vol. xiv. p. 106; Hudleston, Gasteropoda of Inf. Oolite, p. 67; E. Witchell, Proc. Cotteswold Club, vol. viii. p. 43; and W. C. Lucy, *Ibid.*, vol. ix. p. 288.

† Quart. Journ. Geol. Soc., vol. xlii. p. 268.

‡ H. E. Strickland, Quart. Journ. Geol. Soc., vol. vi. pp. 242, &c.; and Memoirs, p. 189; J. Buckman, Quart. Journ. Geol. Soc., vol. xiv. p. 101, and Proc. Cotteswold Club, vol. ii. p. ix.; Hull, Geol. Cheltenham, pp. 28, 32, 44, 45, and plate 2; Wright, Lias Ammonites (Pal. Soc.), p. 150; Witchell, Geol. Stroud, pp. 37, &c.; S. S. Buckman, Quart. Journ. Geol. Soc., vol. xlix., p. 511.

| | | Ft. | In. |
|---|---|---|---|
| Upper Freestone | False-bedded oolite with marly layers; shading down into beds below - 20 0 to | 25 | 0 |
| Oolite Marl | Soft marly oolite or rubbly marl, with *Lima, Lucina bellona, Terebratula fimbria*, &c. - - - - 7 0 to | 10 | 0 |
| Lower Freestone | Pale oolite, with occasional marly layers, the upper part much false-bedded and shattered, the lower part more or less shelly - - - - about | 130 | 0 |
| Pea Grit Series | Rubbly ochreous shelly and pisolitic beds, with Lamellibranchs, Brachiopods, Echini, and Polyzoa - - - | 12 | 0 |
| | Coarse oolitic and pisolitic limestone, iron-stained - - - 15 0 to | 20 | 0 |
| | Brown and grey limestones - - about | 6 | 0 |
| Cephalopoda Bed. | —Ferruginous iron-shot limestone and sandy beds with *Rhynchonella cynocephala* 1 0 to | 4 | 0 |
| Cotteswold Sands. | —Sands. | | |

Witchell estimated the total thickness of the Inferior Oolite at 236 feet: including the uppermost beds, not above noted; the full thickness may be about 250 feet.

The thickness of the Sands was estimated at 20 feet by Prof. Hull, but the beds have not been clearly exposed; for the lower strata along the scarp are much obscured by oolitic rubble, which is used as "gravel" for mending paths. The harder pisolitic limestones are employed for building walls and for road-metal.

Many of the pisolitic granules are covered with Polyzoa, indicating paucity of sediment and slow accumulation of the beds. At or near the top of the Pea Grit Series there is usually a marked Polyzoa Bed, but here and there at lower horizons similar beds occur. A weathered slab obtained by Mr. J. J. H. Teall from the top of the series, contained the following fossils, which were identified by Mr. G. Sharman:—*Lima*, *Ostrea*, *Acrosalenia*, *Pseudodiadema*, *Pentacrinus cingulatus*?, *Diastopora*, *Heteropora*, and *Entalophora* (*Spiropora*) *straminea*.

The Crustacean, *Eryma elegans* (*Guisei*), was found in the Oolite Marl of Leckhampton;* such remains are rare, but an example of the same genus was lately found at Dundry, by Mr. H. W. Monckton, and it has been obtained at Cleeve Hill, and also at Chideock in Dorset.

### *Northern and Eastern Cotteswolds—Cleeve Cloud, Bredon Hill, Chipping Campden, and Burford.*

The cuttings on the railway between Andoversford and Chedworth exhibited some fine sections of the Inferior Oolite, the records of which may be summarized as follows† :—

* Wright, Proc. Cotteswold Club, vol. viii., p. 58. The species is regarded by Mr. J. Carter as *E. elegans*.

† The sections have also been described in detail by Mr. S. S. Buckman, Proc. Cotteswold Club, vol. x. p. 94.

| Series | Division | Beds | Ft. | In. |
|---|---|---|---|---|
| | Fuller's Earth | Clay, with bands of reddish ferruginous limestone at base: *Avicula echinata, Homomya, Pholadomya,* &c. | 6 | 0 |
| Inferior Oolite Series. | Clypeus Grit (7). | 22. Soft marly and rubbly beds, with coarse oolitic grains—the top layer a hard brown iron-shot bed: *Clypeus Ploti, Homomya, Pholadomya, Terebratula globata,* &c. | 15 | 0 |
| | Trigonia Grit (6). | 21. Hard earthy and shelly oolitic limestones, unfossiliferous in places. *Ammonites Martinsi, Cardium Buckmani, Modiola, Myacites, Trichites, Ostrea, Pecten, Rhynchonella spinosa, Terebratula globata,* &c. | 25 | 0 |
| | Gryphite Grit (5). | 20. Marly ferruginous oolite, *Ammonites, Gryphæa sublobata, Modiola, Myacites, Pholadomya fidicula,* &c. 16 0 to | 18 | 0 |
| | | 19. Black shelly clay and laminated loamy bed - 0 8 to | 1 | 6 |
| | Upper Freestone (4). | 18. Hard freestone, bored on top, shelly in places, *Trigonia* | 18 | 0 |
| | | * * * | | |
| | Lower Freestone (4). | 17. Rather sandy oolite, iron-stained in places and obliquely bedded, with calcareous sandy beds - 15 0 to | 25 | 0 |
| | | 16. Ferruginous marly bed, nodular in places (impersistent) 1 0 to | 1 | 2 |
| | | 15. False-bedded white oolite, bored at various horizons 8 0 to | 9 | 0 |
| | | 14. Marl | 2 | 0 |
| | | 13. Oolite | 1 | 0 |
| | Pea Grit Series (3). | 12. Oolitic and pisolitic marl | 3 | 0 |
| | | 11. Shelly oolite and pea-grit in massive beds, used for building: Echini, *Trichites, Terebratula plicata* | 9 | 0 |
| | | 10. Ferruginous oolite or ironstone, and brownish shelly limestone, with earthy layers, *Gresslya* - 10 0 to | 12 | 0 |
| | Midford Sand (2). | 9. Ferruginous earthy limestone, with veins like Dagham Stone, and softer earthy and sandy layers: *Belemnites, Isocardia*<br>8. Hard ferruginous, shelly and crinoidal limestone | 12 | 0 |
| | | 7. Brown sand | 2 | 0 |
| | | 6. Clay | 0 | 4 |
| | | 5. Yellow ferruginous sand | 0 | 6 |
| | | 4. Bluish-grey clay with ferruginous streaks | 5 | 0 |
| | | 3. Yellow micaceous and ferruginous sands | 4 | 0 |
| | | 2. Rubbly ironstone layer | 2 | 0 |
| | | 1. Grey laminated clay and sand | 2 | 0 |

Interesting modifications of the beds are met with, but the series is not complete, as we have no exposure of the Oolite Marl in these railway-cuttings, although that division may be found in the neighbourhood of Chedworth. These marls with *Terebratula fimbria* were exposed by the road-side to the east of the Roman Villa, and they occur above freestone that is worked in a quarry on Yanworth Common.

Commencing with the lowest strata, the Midford Sand, or passage-beds from the Upper Lias Clay; we find them well exposed in cuttings west of Cleevely Wood (c) and again at Withington (E). Beds 1 to 11 were exposed at Cleveley Wood (c), and they are intimately connected with the Pea Grit Series. The Cephalopoda Bed may be represented, in point of time, by beds 8 and 9, but no particular fossil evidence was forthcoming to distinguish it. Bed 10 may represent the Brown Ferruginous Beds (or Lower Limestone) that elsewhere belong to the lower part of the Pea Grit Series. (See Fig. 42.)

A cutting at Withington (E), disclosed about 30 feet of more or less micaceous clays, alternating with greenish-grey sands. Fine sections of Pea Grit, in massive beds, that were employed for building-purposes, were shown in the cutting south of Frogmill Inn (B), and in the cutting north of Withington (D). The beds were overlaid by the Lower Freestone (including beds 11 to 15); and south of Frogmill (B) the oolitic and sandy beds (No. 17) were likewise shown. These beds were more or less shattered and disturbed, features due partly to faulting, but in great measure to the local dissolution of calcareous matter from the sandy limestones. The lower beds of white oolite, above the Pea Grit, are shelly in places, and also bored by Annelides. They were shown again in a cutting east of the river Coln, and west of Ravenswell (D), where the beds are much disturbed and faulted. There can be little doubt that the strata exposed in the cutting to the south of Withington (F) belong to the same series. The section showed, at the base, some 8 or 9 feet of false-bedded oolitic freestone, bored at various horizons by Annelides. The beds reminded me of the Upper Freestone of Nailsworth, but the evidence is in favour of their belonging to the Lower Freestone. Resting on them was an impersistent ferruginous nodular and marly layer, about 1 foot thick, and on the top there was from 15 to 25 feet of obliquely bedded, rather sandy oolite (resembling the Chipping Norton Limestone) iron-stained in places and much lime-washed. The mass of the beds here shown, evidently belongs to the group immediately above the Pea Grit, as seen in sections further north.

Evidence of Upper Freestone* overlaid by Gryphite Grit, was obtained in a cutting north of Chedworth tunnel and south-west of the Roman Villa (L); and again further north in the great cutting west of the Barrow (K). At the latter spot a bed of black shelly clay, 8 inches to 1 foot thick, separated these divisions. This clay-bed becomes a trifle thicker in a northerly direction, for east of Woodbridge a cutting showed the following section (H):—

| | FT. | IN. |
|---|---|---|
| Gryphite Grit - - - - - - | 6 | 0 |
| Laminated loamy bed - - - - - | 1 to 1 | 6 |
| Upper Freestone (at base of cutting). | | |

The clay-bed forms part of a more marked layer further north. (*See* pp. 137–143.)

The Gryphite Grit, having a thickness of from 15 to 18 feet, was well shown in the cutting (K) west of the Barrow (near Chedworth Villa). This, and the overlying beds, were faulted on the north against the Clypeus Grit, and on the south against the Fuller's Earth.

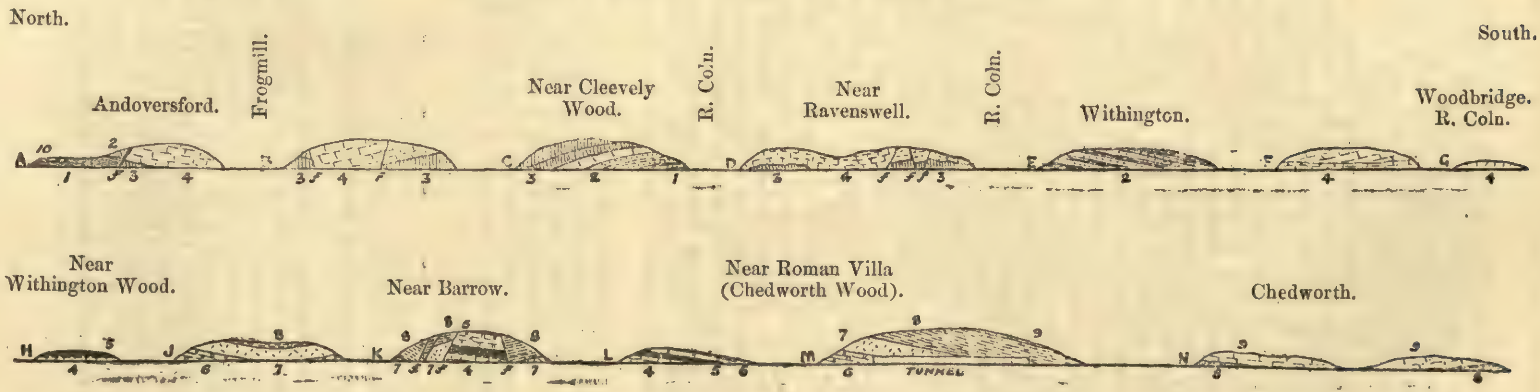
The Trigonia Grits comprise a variable set of hard earthy and shelly oolites. On the north side of Chedworth tunnel (L) they were shown to a depth of from 10 to 18 feet, and here are fairly fossiliferous. In the cutting (K) west of Barrow the beds attain a thickness of 25 feet, yielding

* This bed is regarded by Mr. Buckman as representing the "Lower Trigonia Grit."

FIG. 42.

*Sections along the Midland and South-Western Junction Railway between Andoversford and Chedworth, Gloucestershire.*

(Distance, 6½ miles. Vertical scale, 80 feet to half an inch.)




10. Valley Gravel.
9. Great Oolite.
8. Stonesfield Series, and Fuller's Earth.
7. *Clypeus* Grit.
6. *Trigonia* Grit.
5. Gryphite Grit.
4. Freestones.
3. Pea Grit Series.
(7–3: Inferior Oolite.)
2. Midford Sand.
1. Upper Lias Clay.
*f.* Faults.

The distances between the cuttings are in most cases greatly reduced.

a *Trigonia*-bed at the base, but are otherwise somewhat barren. Mr. Buckman identifies the "Notgrove freestone" as forming the lower and greater portion of this division. To the S.S.E. of Woodbridge (J) the Trigonia Beds are shown beneath the Clypeus Grit, and, in their upper portion, they yield *Rhynchonella spinosa* and *Terebratula globata*, but are otherwise not very fossiliferous.

The Clypeus Grit was well shown in the cutting at the north end of Chedworth tunnel (M), where it consists of about 15 feet of coarse-grained rubbly oolite with many specimens of *Pholadomya* and *Clypeus Ploti.* On top a thin layer of reddish clay, probably belonging to the Fuller's Earth, was exposed. The Clypeus Grit was again exposed, in faulted positions, at the northern and southern ends of the deep cutting west of the Barrow (K), where it was overlaid by the Fuller's Earth. The top portion was somewhat ferruginous, and presented the aspect of iron-shot oolite. The best section of the beds was shown in the cutting S.S.E. of Woodbridge (J), where the beds occupy a gentle synclinal; we see the junction with the Trigonia Grit at the northern and southern ends, and the beds are overlaid, in the centre of the basin, by the Fuller's Earth.

The top of the Clypeus Grit, is a hard brown iron-shot oolite, with *Pholadomya*, *Homomya*, *Terebratula globata*, and *Clypeus Ploti*; and above, there is about 6 feet of stiff red and blue clay with bands of ferruginous limestone at the base, yielding also *Pholadomya* and *Homomya*. These bands, which here seem hardly separable from the Fuller's Earth, are doubtless equivalent to the oolitic and sandy ragstones that overlie the Clypeus Grit between Notgrove and Bourton-on-the-Water. (*See* p. 133.)

The cuttings on the railway between Andoversford and Bourton-on-the-Water, have furnished a number of interesting sections of the Inferior Oolite, as well as of the Great Oolite Series. Attention was first drawn to some of these sections in 1883 by Mr. E. A. Walford.* The beds, however, are faulted in so many places that it is only by piecing together the evidence in different cuttings that the sequence can be made out. This has been done by Mr. Buckman,† who has given a minute account of the beds and their fossils, and I have independently measured the sections and constructed diagrams of the strata exhibited in each cutting. In some minor respects my reading differs from that of Mr. Buckman.

The General Section of the Inferior Oolite Series, between Andoversford and Bourton-on-the-Water, is as follows :—

| | | Ft. | In. | | Ft. | In. |
|---|---|---|---|---|---|---|
| Ragstones | 10. Ferruginous beds (local) | 3 | 0 | to | 8 | 0 |
| | 9. Clypeus Grit | 35 | 0 | to | 40 | 0 |
| | 8. Trigonia Grit | 1 | 8 | to | 4 | 8 |
| | 7. Notgrove Freestone | | - | | 10 | 0 |
| | 6. Gryphite Grit | | - | | 15 | 0 |
| Freestones | 5. Upper Freestone and Harford Sands - about | 8 | 0 | to | 14 | 0 |
| | 4. Oolite Marl | | - | | 30 | 0 |
| | 3. Lower Freestone (not fully seen) | | | | 25 | 0 |
| Midford Sand | 2. Sands | 12 | 0 | to | 15 | 0 |
| Upper Lias | 1. Clay. | | | | | |

The Cotteswold (Midford) Sands were shown in the first cutting (T) west of Bourton station. There 12 to 15 feet of yellow slightly calcareous

* Quart. Journ. Geol. Soc., vol. xxxix. p. 225.

† Proc. Cotteswold Club, vol. ix. p. 108; *see also* Hudleston, Inf. Ool. Gasteropoda, pp. 69, 70.

micaceous sands, with concretions of calcareous sandstone, were to be seen. *Belemnites*, *Myacites*, and Serpulæ occur in them. The beds rest on blue micaceous loamy clay, and are overlaid by tumbled masses of the Lower Freestones, including flaggy and shelly oolite, and beds like the "yellow freestone" of the northern Cotteswolds. *Pecten personatus*, and *Pholadomya fidicula* were found.

The junction with the Sands was not clearly exposed, but there was no evidence of the occurrence of the Pea Grit nor of the Gloucestershire Cephalopoda Bed, although both may be represented in point of time.

The full thickness of the Lower Freestone cannot here be estimated, for we find little more than 20 feet of the beds along the line of railway. Evidently there is a considerable fault near by, for the next cutting westwards (s) shows the Clypeus Grit, faulted against the Oolite Marl and top of the Lower Freestone, and we have no more evidence of Lower Freestone along the line of railway until we reach Syreford, except perhaps at the base of the cutting east of Notgrove. (Fig. 43.)

Proceeding further west to near Syreford, the following beds were exposed in the cutting east of Andoversford:—

| | | Ft. | In. |
|---|---|---|---|
| Lower Freestone. | Micaceous and ferruginous sands more or less indurated at different levels, yielding few fossils: *Lima* and *Terebratula* - - - - about | 25 | 0 |
| | False-bedded white oolite. | | |

This sandy series was originally grouped with the Midford Sands on the Geological Survey Map; but the occurrence of the Oolite below clearly disproved this view; and Mr. Buckman at first regarded these sands as equivalent to the Harford Sands, which further west come beneath the Gryphite Grit. Later on sections on the railway between Andoversford and Chedworth disclosed, south of Frogmill Hill, sections of hardened calcareous sand and rubble resting on Oolite, belonging to the Lower Freestone series, and there can be little doubt, as Mr. Buckman points out, that the sandy beds and underlying oolite of Syreford belong to this division.

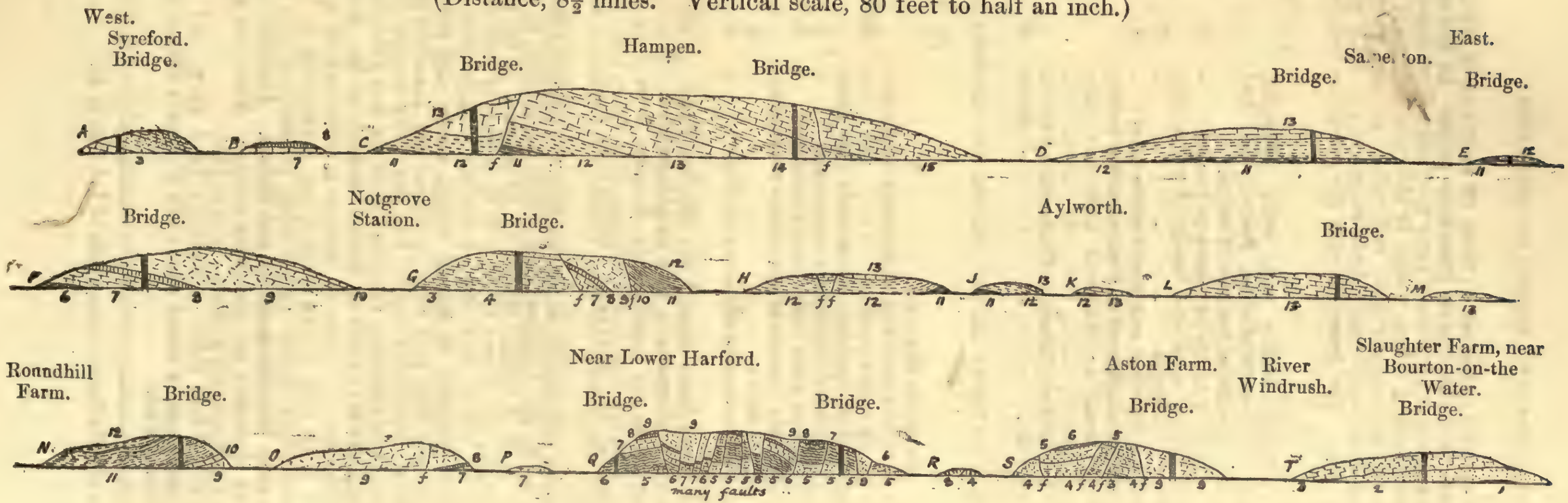
The Oolite Marl is well shown in the cutting east of Notgrove railway station, where the following beds were shown:—

| | | Ft. | In. |
|---|---|---|---|
| Harford Sands and Upper Freestone. | Rubble - - - - 3 0 to | 4 | 0 |
| | Yellow sand - - - about | 1 | 0 |
| | Sandy fissile stone - - - | 3 | 0 |
| | Fissile marly and stony beds - - | 7 | 0 |
| Oolite Marl | Brown shelly clay and marl - - | 3 | 0 |
| | Harder oolitic beds, with irregular bluish patches - - - 4 0 to | 5 | 0 |
| | Soft bluish oolitic marls, with indurated shelly and ochreous bands: *Natica cincta*, *Ceromya concentrica*, *Lucina*, *Lima*, *Terebratula fimbria*, *Rhynchonella subobsoleta*, Corals 18 0 to | 20 | 0 |
| | Hard marly and oolitic limestone, and soft shaly marl, with *Lima* and many Brachiopoda; *Rhynchonella Lycetti*, *Terebratula curvifrons*, *T. maxillata*, *T. plicata*, *T. Whitakeri*, *Waldheimia Leckenbyi*, &c. - - - | 4 | 3 |
| Lower Freestone | Hard brown oolite (at base of cutting). | | |

Many of the fossils mentioned, and others, have been recorded by Mr. Buckman.

Fig. 43.

*Sections along the Banbury and Cheltenham Railway between Andoversford and Bourton-on the-Water, Gloucestershire.*
(Distance, 8½ miles. Vertical scale, 80 feet to half an inch.)




15. White Limestones.
14. Marls.
13. Freestones.
12. Stonesfield Series.
11. Fuller's Earth.

} Great Oolite.

10. Ferruginous limestones.
9. *Clypeus* Grit.
8. *Trigonia* Grit.
7. Notgrove Oolite.
6. Gryphite Grit.
5. Upper Freestone and Harford Sands.
4. Oolite Marl.
3. Lower Freestone.

} Inferior Oolite.

2. Midford Sand.
1. Upper Lias Clay.
*f.* Faults.

The distances between the cuttings are in most cases greatly reduced. The thick black vertical lines denote bridges.

The Oolite Marl may be estimated at from 28 to 38 feet in thickness, for it shades upwards into the Upper Freestone series. In the second cutting west of Bourton (that by Aston Farm) the Oolite Marl passes into a pale fissile and false-bedded oolite, which is shown to a depth of about 20 feet, beneath a series of sandy beds and oolite, as near Notgrove. Some of the lower fissile and shelly beds resemble the slaty beds of Hyatt's Pits (*see* p. 140). The junction with the overlying beds was as follows*:—

| | | Ft. | In. |
|---|---|---|---|
| Gryphite Grit | Shelly oolitic rag, with *Myacites*, *Ostrea flabelloides*, *Pecten*, &c., and occasional pebbles of oolite. | | |
| Harford Sands and Upper Freestone passing down into Oolite Marl. | Oolite, shelly in places and bored - | 2 | 3 |
| | Yellow sand and bands of calcareous sandstone - - - - - | 7 | 0 |
| | Loamy sand and fissile oolite marl - | 1 | 2 |
| | Coarse-grained and false-bedded oolite, bored at different horizons; pale, fissile, oolite, and oolite marl, with *Natica*, *Ceromya*, *Terebratula fimbria*, &c. - - - - about | 20 | 0 |

Cuttings to the S.E. of Lower Harford showed the following succession:—

| | | Ft. | In. |
|---|---|---|---|
| | Gryphite Grit, &c. | | |
| Harford Sands and Upper Freestone. | Oolite bored, and with marly fragments in upper portion - - - | 2 | 4 |
| | Oolite, merging downwards into blue-hearted calcareous sandstone - | 2 | 6 |
| | Yellow sand with fissile sandstone - | 4 | 0 |
| | Hard, blue-hearted, calcareous sandstone - - - - - - | 2 | 0 |
| | Calcareous sandy loam or clay - - | 2 | 6 |

These sandy beds have been termed the Harford Sands by Mr. S. S. Buckman from their development in this neighbourhood. They form a variable sandy, calcareous, and argillaceous division, from 8 to 11 feet thick, that in great measure replaces the Upper Freestone, and connects the Oolite Marl with the Gryphite Grit. These beds have been exposed at Bourton Clump.

Overlying this sandy and oolitic series, we find the Gryphite Grit and succeeding strata up to the Clypeus Grit. This succession is clearly shown in a cutting west of Lower Harford. At the base of the section, 4 feet of oolite was seen, and above it from 1 to 2 feet of yellow micaceous and calcareous sands, and thin ironstone. Then comes the Gryphite Grit, which includes 15 feet of tough sandy and calcareous ragstones with sandy partings, and with, in places, flat bean-like pebbles or rolled concretions. *Belemnites* occur, but the chief fossils are the Lamellibranchs, *Gryphœa sublobata*, *Gresslya*, *Myacites*, and *Pholadomya*.

Above the Gryphite Grit is a bed of Oolite, termed by Mr. Buckman the "Notgrove Freestone." Here it attains a thickness of 10 feet. It comprises hard grey and brown limestones presenting a banded appearance and with white oolitic grains (thus resembling beds in the Great Oolite, seen near Minchinhampton and Bisley). Annelide borings occur, and *Ostrea* is abundant on the upper surface. This bed may be represented in the Leckhampton section. (*See* p. 124.)

The Trigonia Grit, 3 feet thick, comprising hard grey, and brown shelly, and oolitic limestone, is found above this Notgrove Oolite, and on top there is the Clypeus Grit.

* See also Hudleston, Gasteropoda of Inf. Ool., p. 68.

The cutting west of Notgrove station showed the following beds:—

| | | Ft. | In. |
|---|---|---|---|
| Clypeus Grit | Brown rubbly and pasty oolites; *Clypeus Ploti* abundant, *Pholadomya* | 5 | 0 |
| | Paler marly oolites, with indurated bands, blue-hearted in places; *C. Ploti* and *Terebratula globata* abundant; also *Homomya, Ostrea, Pholadomya, Rhynchonella*, &c. | 9 | 0 |
| | Brown marly layer, with *T. globata*, &c. | | |
| | Harder pale and marly oolites, with bluish bands here and there; *C. Ploti* occasionally, *T. globata* abundant here and there, *Pholadomya Heraulti* not uncommon, large specimens of *Homomya*, also *Modiola sowerbyana, Myacites, Quenstedtia?*, &c. - about | 25 | 0 |
| Upper Trigonia Grit. | Hard brown shelly, marly, and iron-shot oolite, with bored top; *Ammonites Parkinsoni, Belemnites, Lima gibbosa, Ostrea, Pecten demissus, Trigonia, Rhynchonella spinosa, Serpula*, &c. | 4 | 8 |
| Notgrove Oolite | Pale oolite, with white grains in darker matrix, and with bored top; large *Rhynchonella obsoleta?* | 10 | 0 |
| | Harder fine-grained oolites, shelly in places; *Trigonia*, small *Pecten* | 4 | 6 |
| Gryphite Grit | Brown oolitic and iron-shot limestones, &c., with *Gryphæa sublobata, Lima pectiniformis, Myoconcha?* (not clearly exposed). | | |

South-east of Roundhill Farm the following beds were shown:—

| | | Ft. | In. |
|---|---|---|---|
| | Stonesfield Slate. | | |
| | Fuller's Earth. | | |
| Inferior Oolite (Upper Ragstones). | Brown obscurely oolitic and sandy ragstone, weathering in an irregular fissile way; with *Homomya, Ostrea acuminata, Trigonia* | 8 | 0 |
| | Coarse rubbly oolitic and marly limestones, with *Clypeus Ploti* (Clypeus Grit). | | |

The Clypeus Grit with its characteristic Urchin, was well exposed. The overlying beds, which are first seen in the cutting east of Notgrove Station, thicken eastwards, and probably represent the Chipping Norton Limestone. Attention was first drawn to them by Mr. E. A. Walford,* who remarks on the Bathonian aspect of that limestone, and compares it with the "White Oolite" of Witchell, that occupies a similar position above the Clypeus Grit in the Stroud district. (*See* p. 149.)

Returning to the western side of the Cotteswold Hills we come to the well-known sections at Cleeve Hill or Cleeve Cloud. Beds belonging to the Pea Grit Series crop out on the slope of the hill and stand out in thick massive layers irregularly modified by the action of the weather. (See Fig. 44.)

The lowest beds of the Lower Freestone consist of false-bedded oolite with Annelide borings, *Rhynchonella*, Polyzoa, &c.; and at their base are thick and ragged beds of shelly oolite, termed the Polyzoa Bed by Messrs. Buckman and Wethered.

* Quart. Journ. Geol. Soc., vol. xxxix. pp. 225, 237.

The strata beneath are about 30 feet thick and very variable in character; they are as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Pea Grit Series | Sandy beds. | | |
| | Pale oolite with tubiform makings. | | |
| | Sandy beds with *Pholadomya.* | | |
| | Oolite. | | |
| | Pisolite. | | |
| | Massive beds of brown oolite. | | |
| | Pisolite. | | |
| | Shelly and oolitic, more or less pisolitic, limestones in harder and softer beds, *Terebratula, Trigonia* - - - | 9 | 6 |
| Midford Sand - | Marly and ferruginous limestone, *Myacites.* | | |
| | Sands - - - - about | 25 | 0 |

The pisolitic beds are worked for building-stone. The upper beds, below the Polyzoa Bed, become sandy further north, resembling in some measure the sandy series in the cutting east of Andoversford. The Pea Grit Series has yielded also *Lima, Lucina bellona, Ostrea gregaria, Myacites dilatus, Waldheimia Leckenbyi,* &c.

Fig. 44.

*Outcrop of Pea Grit at Cleeve Hill, near Cheltenham.*
(From a Photograph by Mr. E. Wethered.)

The general section of the Inferior Oolite Series at Cleeve Hill, described by Wright and others,* appears to be as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Ragstones | 13. Hard irregular beds of ferruginous and oolitic limestone, with *Trigonia*, and a Coral Bed (Upper Trigonia Grit) - 12. Sandy limestone, with *Gryphæa sublobata*, *Astarte elegans*, &c. (Gryphite Grit) - | about 17 | 0 |
| | 11. Sandy and marly bed (Chemnitzia" Grit of Wright) with *Pseudomelania* (*Chemnitzia*) *procera* - - - 10. Hard limestones with many specimens of *Terebratula Buckmani*, *T. Phillipsi*, &c. (Brachiopoda Bed of Wright) | 6 | 8 |
| | 9. Brown ferruginous oolitic limestones (Road-stone of Wright), with *Pseudomelania lineata*, *Bourguetia striata*, *Lima pectiniformis*, *Pecten articulatus*, *Trigonia*, *Pholadomya Heraulti*, *P. media*, *Trichites*, &c. - - | 10 | 0 |
| Harford Sands and Upper Freestone. | 8. Coarse brown ferruginous sandy marl (Oyster Bed of Wright) with *Ostrea flabelloides* - - - - 7. Yellow and brown calciferous sands - - - - 6. Hard wavy sandstone, with *Galeolaria socialis* - - | 12 | 0 |
| | 5. Sandy and oolitic limestone bored by Annelides - | ? 35 | 0 |
| Oolite Marl - | 4. Marl passing down into bed below - - - | 10 | 0 |
| Lower Freestone | 3. Freestone - - - | about 60 | 0 |
| Pea Grit Series - | 2. Pisolitic beds, &c. - - | 35 | 0 |
| Midford Sand - | 1. Sands. | | |

As the beds are not shown in one connected section, it is somewhat difficult to place them in direct sequence. The district is more or less faulted, and detailed mapping on the 6-inch scale is needed for the interpretation of the structure. The sequence here noted corresponds with that of which we have evidence further east.

Near the "Rising Sun" there are several quarries, one known as the Pavingstone quarry, another as the Rolling Bank quarry from an undulation in the strata, and a third as the Freestone quarry. In the Rolling Bank quarry beds Nos. 9 to 13 have been exposed, and the measurements of these strata are given on the authority of Mr. S. S. Buckman.

* Wright, Proc. Cotteswold Club, vol. iv. p. 62; and Lias Ammonites (Pal. Soc.), pp. 155, 157; Hull, Geol. Cheltenham, p. 45; H. B. Holl, Quart. Journ. Geol. Soc., vol. xix. p. 313; S. S. Buckman, Proc. Cotteswold Club, vol. ix. p. 132; vol. x. p. 95.

From bed 9 (the Road-stones of Cleeve Hill) Dr. Wright records *Ammonites Brocchii*, *A. Braikenridgei*, *A. humphriesianus*, and *A. Sowerbyi*, &c., an assemblage that recalls that noted at Dundry (*see* p. 100). As remarked by Dr. Holl, "at Cleeve a series of beds of very unstable character occupies the interval between the top of the Oolite Marl and the base of the Lower Ragstone." From his description it would appear that the Rolling Bank quarry was originally excavated through much débris, and that many of the fossils (which belong to the Lower Ragstone) were obtained from this tumbled material. The Rev. T. W. Norwood informed me that he obtained *A. Sowerbyi* and *Terebratula Wrighti* in an old quarry north-east of Hewlets, near Cheltenham. The large specimens of "*Chemnitzia Sæmanni*," noted by Dr. Wright, are identical with the Corallian species *Bourguetia* (*Phasianella*) *striata*.* Examples of *Pholadomya* found at Cleeve Hill, attain large dimensions.

The Freestone quarry showed the Upper Freestone overlaid by about 12 feet of sandy beds.

The beds on Huntly Hill to the south-east of Cleeve Hill, are noted in a general way by Prof. Hull.†

The general section of the Inferior Oolite Series at the northern end of the Cotteswolds is as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Clypeus Grit | Coarse Oolite, with *C. Ploti*, *Terebratula globata*, &c. - - - | 5 | 0 |
| Trigonia Grit | Hard irregular limestone, with nodular and pebbly beds - - - | 1 | 8 |
| Notgrove Oolite | Oolitic freestone, hard brown and shelly stone; *Pecten personatus*, *Ostrea* - - - 15 0 to | 18 | 0 |
| Gryphite Grit | Hard rubbly sandy limestones and marls; *Belemnites*, *Gryphæa*, *Myacites*, *Serpula* - - - - | 8 | 0 |
| Harford Sands and Upper Freestone. | Brown and white sandstones and sands, and dark clays and shales - 7 0 to | 17 | 0 |
| | Hard limestone and shelly oolite, with fissile beds - - - - - | 3 | 0 |
| Oolite Marl | Pale marly and oolitic limestone and marl - - - - - - | 16 | 0 |
| Lower Freestone | False-bedded and shelly oolite - - / Ferruginous sandy layer (local) - - | 30 | 0 |
| | White and yellow freestones - - | 19 | 0 |
| | * * (beds not seen) * * about | 30 | 0 |
| | Rag bed, yellow ochreous oolite (bored), and fissile shelly oolite - - | 12 | 0 |
| Midford Sand | Sandy beds with concretions of calcareous sandstone and shelly limestone - - - - about | 25 | 0 |

Sections of the Midford Sand are but rarely exposed. The beds were to be seen at Hewlets Hill, near Cheltenham, at Farmcott Hill, south-east of Winchcomb, and in the valley at Kyneton, south of Temple Guiting, where their thickness was estimated at

* *See* Hudleston, Geol. Mag., 1880, p. 396, 1884, p. 49; and Inf. Ool. Gasteropoda, p. 249.

† Explan. Hor. Sec., Sheet 59, pp. 4, 5.

from 25 to 30 feet by Prof. Hull. Sections also are exposed in the lane- and road-cuttings at Coscomb Grove, south-east of Stanway, where we find yellow sands with concretions of calcareous sandstone and very shelly limestone. These beds are overlaid by ferruginous sandy beds (probably belonging to the Pea Grit Series), and these again are surmounted by the Lower Freestones. The bottom beds of the Freestone were shown in a quarry north of Coscomb Farm, where there were exposed about 12 feet of yellowish oolite with ochreous infillings, and fissile shelly oolite yielding a few fossils—*Myacites*, *Rhynchonella*, and *Terebratula maxillata.*

The mass of the Freestone, near Stanway, was exposed at the Jackdaw quarry (worked for Lord Elcho), where the section showed the following beds:—

| | Ft. | In. |
|---|---|---|
| Well-bedded oolite, much jointed and false-bedded in places | 25 | 0 |
| White oolite | 3 | 0 |
| Brown oolite (best freestone) | 6 | 0 |
| Yellow oolite | 10 | 0 |

We have no evidence of the Oolite Marl, although its presence is noted by Prof. Hull in the hills east of Winchcomb. He gives the following section of the quarry east of Stanway Hill Barn*:—

| | | Ft. | In. |
|---|---|---|---|
| [Gryphite Grit and Harford Sands.] | Thin-bedded, brown calcareous sandstone, alternating with marly beds, with *Modiola sowerbyana*, *Ostrea flabelloides*, and *Trigonia* (casts) | 7 | 6 |
| | Yellow calcareous sandstone | 2 | 0 |
| | Variegated sandy shales | 4 | 6 |
| | Light brown sandstone | 1 | 0 |
| | Variegated sandy shales and clay | 8 | 0 |
| | Yellow, brown, and black shale, with a bed of small oysters | 2 | 0 |
| Upper Freestone | Hard limestone with blue centre | 3 | 0 |

The mass of these beds evidently belongs to the horizon of the Lower Trigonia Grit and Gryphite Grit of Cleeve, but they appear to a certain extent to replace portions of the Upper Freestone. The beds in this quarry were not well exposed at the time of my visit, but I obtained from the upper beds of impure limestone, *Belemnites*, *Myacites*, *Gryphæa sublobata*, *Pinna cuneata*, and *Serpulæ*; while beds of iron-shot oolite were intercalated with the clays and sandy rocks beneath. The beds were much disturbed and bent into a synclinal, and those exposed were somewhat different in detail from the strata recorded by Prof. Hull.

About 12 feet of the Lower Freestone has been opened up on Stanley Hill to the west of Winchcomb; the underlying beds of Inferior Oolite appear to be much reduced in thickness, the Pea

* Geol. Cheltenham, p. 45.

Grit being represented by a 2-foot bed of coarse-grained oolite, full of broken shells, Echini, &c. Underlying this bed there is a layer of calcareous sandstone with *Belemnites*, also 2 feet thick, and about 4 feet of yellow sand.*

The Inferior Oolite has been quarried in several places on Bredon Hill, and there are good exposures west of Overbury. As remarked by Prof. Hull, "Everywhere on the Bredon outlier the oolite is in a most disjointed state, showing apparent dips in all directions, and this not only along the skirts but in the very centre of the area."† These appearances are partly due to the dissolution of calcareous matter from the calcareous sandstones, whereby the strata (like the "broken beds" of Purbeck) present a disturbed and shattered aspect to a depth of from 20 to nearly 40 feet (*see* Fig. 134, p. 460). I am disposed, however, to think that the excessive weathering of the Inferior Oolite may belong to Glacial times, when some of the thick accumulations of rubble were formed along the slopes of the Cotteswold Hills.

The beds are of the age of the Lower Freestone and underlying strata. The basement-beds consist according to Prof. Hull, of thick-bedded calcareous sandstone, highly ferruginous in character. Overlying these are the brown and more or less shelly oolites that are worked in the quarries. Some of the beds are largely made up of Crinoidal fragments. Fossils, however, are scarce, and those that do occur are poorly preserved. Among these *Ammonites, Belemnites ellipticus, Hinnites abjectus, Pecten personatus, Trigonia, Terebratula plicata, T. perovalis, T. maxillata*, and Polyzoa have been recorded.‡ Prof. Judd notes the occurrence of *Rhynchonella cynocephala* in the sandy and ferruginous rocks at the base of the series, and most of the species above mentioned, are recorded by him from these strata. He remarks that in an old pit opposite to Kemerton Castle House, we find the upper beds to be composed of white freestone, that pass down into a ferruginous rock of the most variable character; sometimes consisting of loose brown sand, at other times of brown sand indurated by carbonate of lime into a hard rock, and again becoming oolitic and shelly. Certain beds consist of brown sandstone, including hard calcareous ramifying masses, which cause the whole to weather into blocks with very rough surfaces. Some of the layers have a curious vesicular structure, being made up of rounded fragments of white or pink oolitic limestone cemented together by crystallized carbonate of lime, the interstices being filled with brown sand. Occasionally the rock is traversed by bands of hydrated peroxide of iron, and in places these assume that cellular and concentric arrangement, due to weathering along the joint planes, which is so commonly presented by both the calcareous and arenaceous varieties of the

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* Hull, Geol. Cheltenham, p. 29.

† *Ibid.*, p. 40.

‡ *See* Memoirs of H. E. Strickland, p. 82; H. B. Holl, Quart. Journ. Geol. Soc., vol. xix. p. 315; and Judd, Geol. Rutland, p. 15.

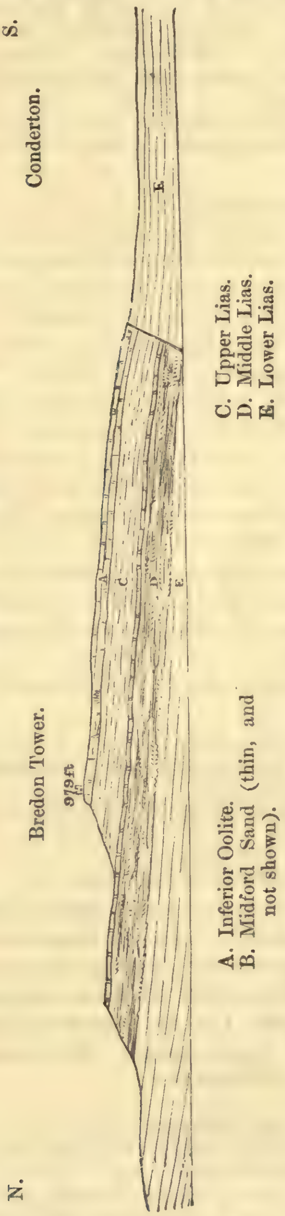
Northampton Sand. He adds that in the same great outlier of Bredon Hill, we find, above the villages of Conderton and Overbury, a similar series of sections.* The Bambury (Banbury or Benbury) Stone is a block of the Inferior Oolite, of a more or less rubbly character, cemented into a hard rock, as in the cases above mentioned.†

FIG. 45.

*Section across Bredon Hill, Gloucestershire.*

(Prof. E. Hull.)

(Scale, 2 inches to 1 mile.)




The railway-cuttings between Andoversford and Bourton-on-the-Water prepare us for some modifications in the Inferior Oolite Series that may occur further north. We have, however, to piece together isolated sections, and this can only be done approximately until the area is mapped in detail.

The Ragstones are well shown at Snowshill where we find the Clypeus Grit and Upper Trigonia Grit, resting on freestone that is exposed to a depth of 18 feet. The Trigonia Grit is a hard irregular ferruginous and earthy limestone, about 1 foot 8 inches thick and of a somewhat nodular character. The freestone below exhibits a bored surface. It contains *Pecten personatus* and *Ostrea*, and appears rather to belong to the main Freestone division than to the horizon noted previously as the Notgrove Freestone. In this case there is evidence of some overlap of the Ragstones in this neighbourhood.

By the farm, to the east of Snowshill, we find

* Geology of Rutland, p. 14.
† G. F. Playne, Proc. Cottesw. Club, vol. vi. p. 225.

an opening in sandy beds like those described by Prof. Hull at Stanway Hill Barn (*see* p. 137). The section, which I visited in company with Mr. T. J. Slatter, was as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Harford Sands, &c. | Brown sandy and loamy bed - 2 0 to | 2 | 6 |
| | Flaggy oolitic and sandy limestone; with *Nerinæa*, *Lucina bellona*, *Modiola*, *Pholadomya*, *Holectypus hemisphæricus*, and *Serpula* (as near Glendon) - - - 1 6 to | 2 | 0 |
| | Pale buff or whitish sand, with calcareous concretions near top, below joint - - - - - | 4 | 0 |

The sand is dug for mortar-making.

These beds reminded me of the Lincolnshire Limestone of Glendon which there overlies the Lower Estuarine Sands. They occur above the mass of the Lower Freestone, and are probably intimately connected with the Upper Freestone.*

North of the sand-pit, freestone-beds, like those at the base of Snowshill quarry, were exposed. (*See* p. 139.)

Slaty beds were formerly worked for roofing-purposes on the summit of the Cotteswold Hills, south-east of Snowshill, at a spot known as Hyatt's pits; and there also were "slate quarries" further to the south-east. The stone-tiles have been used in the village of Snowshill together with Kyneton (Keynton) Slates from the Great Oolite. The former are very thick and heavy. Somewhat similar beds are exposed in the freestone quarries near Longborough, and there can be little doubt that these slaty beds belong to the upper part of the Lower Freestone, or to the horizon of the Oolite Marl.

Near the Fish Inn, Broadway, the following section was shown:—

| | | Ft. | In. |
|---|---|---|---|
| Freestones | Rubbly limestone, oolitic - 2 0 to | 3 | 0 |
| | Softer earthy and oolitic limestones (? Oolite Marl) - - - | 7 | 6 |
| | Hard shelly limestone, with *Pecten personatus* - - - - <br> Impure limestone - - - <br> Shelly and oolitic limestone - - | 3 | 6 |

West of the Fish Inn, there is a large quarry, now abandoned, as there is no call for the stone. The freestones there are faulted on the west against the upper beds of the Inferior Oolite. We see rubbly Clypeus Grit, &c., with *Nerinæa*, underlaid by a thin band of greenish-grey clay (as at Bourton Clump), brought abruptly, and at a high angle, against the lower beds. The section of freestone was as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Lower Freestone | Rubble and shattered beds - - - | 10 | 0 |
| | False-bedded oolite in thin beds; "White Stone" - - 8 0 to | 9 | 0 |
| | Massive bed of oolite, including on top "Red bed," about 4 feet, and below "Yellow bed" - - 5 0 to 5 6 | 9 | 6 |

* Hull, Geol. Cheltenham, p. 45.

An important section has been exposed at Westington Hill quarry, about two miles south of Chipping Campden; it is as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Upper Freestone Beds. | Yellowish sand, in pockets. | | |
| | Thin-bedded oolite and fissile calcareous sandstone - - - | 2 | 6 |
| Oolite Marl | Pale marly stone, with occasional grains of oolite - - - - | 2 | 2 |
| | Rubbly marl and clay - - - | 3 | 0 |
| | Hard oolite - - - - | 2 | 0 |
| | Indurated pale marl and marly stone, with scattered grains of oolite; with seam of clay near the middle - | 9 | 0 |
| Lower Freestone | Hard brown false-bedded shelly oolite, with closely-packed grains. Stone used for planking, covering drains, culverts, and road-mending - 5 6 to | 6 | 0 |
| | Irregular ferruginous sandy and calcareous bed with fossils: called "Ironstone" - - 1 6 to | 2 | 0 |
| | Oolitic freestones:— | | |
| | White Post, used for building 6 0 to | 7 | 0 |
| | Yellow freestone, with bored-bed in the middle of the stone; used for carving - - - 5 0 to | 7 | 0 |
| | Freestone - - - - | 3 | 0 |
| | Ragstone and sandy and ferruginous beds proved by boring to depth of 44 feet. | | |

From the Oolite Marl, I obtained a number of fossils, including *Natica cincta*, *Pleurotomaria*, *Lima pectiniformis*, *Lucina bellona*, *Ostrea flabelloides*, *Pholadomya*, *Rhynchonella subobsoleta ? Terebratula fimbria*, *T. maxillata*, &c.* I was informed also that Ammonites were found in these beds (a fact subsequently confirmed by Mr. T. J. Slatter), and a good specimen of *Ammonites humphriesianus* was forwarded to me. This came, as I was told by the workman who obtained it, from the top layer of pale marly and oolitic limestone. These uppermost beds clearly belong to the Upper Freestone and Harford Sands. The fossils were named by Messrs. Sharman and Newton.

At Stanley's quarry, north-east of Northwick Hill Farm, near Blockley, about 30 feet of oolite has been exposed. The top layers are much lime-washed, and these beds are too hard, as a rule, to be worked as freestone; they are burnt for lime, and used for building walls, and for road-metal. The lower layers, which are more false-bedded, are quarried for freestone. West of Blockley, the Oolite Marl, with *Terebratula fimbria*, and *T. maxillata*, has been observed.

The beds on Ebrington Hill, much resemble those of Bredon. No sections of the Midford Sand have been observed on the borders of the hill, although Mr. Howell has stated that these beds "may be concealed in the broken ground, round the edge of the tumbled Inferior Oolite that caps the hill."†

* *See also* Judd, Geol. Rutland, p. 15.
† Hull, Geol. Cheltenham, p. 30.

In reference to the strata on Ebrington Hill, Prof. Judd remarks that the beds of the Inferior Oolite, which constitute an outlying mass, consist mainly of yellow and brown, somewhat siliceous and coarsely oolitic limestone-rock, and exhibit in places ferruginous banding like that of the Northampton Sand. Some of the beds are composed of a ferruginous shelly rock, in places almost wholly made up of plates of *Pentacrinus*, with abundant specimens of *Pecten personatus*, *Trigonia signata*, *Terebratula perovalis*, &c. In one of the pits he noticed a very instructive section. At its southern end are yellow and ferruginous sands, a little to the northward irregular hard beds occur in these sands, and still farther north the whole passes into a calciferous sandstone rock with ironstone-banding; in fact there is presented, in one section, "examples of the different aspects which the Northampton Sand assumes at various points. Still further north, however, the rock becomes more and more oolitic in structure, and thus passes into the ordinary oolitic limestone which caps the hill. All these changes take place within a distance of about 40 yards. Everywhere on this outlier of Ebrington Hill, the limestones of the Lower Freestones may be seen to assume arenaceous characters, thus graduating in places into calcareous sand-rock, cr or into sandy calcareous stone with some imperfect cellular ironstone." Prof. Judd adds, that above Ilmington Downs, on the north side of the Hill, we find the ordinary yellow freestones passing down into beds of sand, sometimes containing "pot-lids," and graduating into a mass of fissile calcareo-siliceous rock with ferruginous banding Beds similar to these are found above Stoke Wood. In the extensive pits above Little Hilcote, courses of the fine oolitic rock with ferruginous banding, occur, sometimes interstratified with beds of sand. At the rabbit-warren above Great Hilcote, though no good faces of rock are exposed, the strata, which constitute the lower part of the Inferior Oolite, are seen to consist of yellowish-red, calcareo-ferruginous sand, with layers of fissile, iron-banded, calcareo-siliceous stone. These beds, he says, are undistinguishable in character from many portions of the Northampton Sand, as seen in Oxfordshire and Northamptonshire.*

Although the sands and soft sandstones of the Midford Beds have been traced along the northern borders of the Cotteswold Hills, no traces of the Cephalopoda Bed have been observed. The junction with the Upper Lias clay was exposed on Cadley Hill, above Batsford, as follows :—

| | | Ft. | In. |
|---|---|---|---|
| | Reddish-brown loamy soil. | | |
| Midford Sand. | —Brown and yellow sands | 5 | 0 |
| Upper Lias Clay. | Stiff grey and blue clay, with small hard septarian nodules | 6 | 0 |

Further south near Seizincote, the sands and calcareous sand stones were observed by Prof. Hull.† (*See* p. 12.)

* Geol. Rutland, p. 15.
† Geol. Cheltenham, p. 29.

Large freestones quarries have been opened to the west of the village of Bourton-on-the-Hill, where the following beds were exposed:—

| | | Ft. | In. |
|---|---|---|---|
| Lower Freestone | False-bedded oolite; White Rock: burnt for lime, and used for rough inside walling - - 11 0 to | 12 | 0 |
| | Earthy sand - - - - | 2 | 6 |
| | Hard and rough oolitic limestone, with irregular ferruginous bands; Red Bed, used for foundations - - | 5 | 0 |
| | Buff oolite; Yellow Bed; good freestone - - - - - | 6 | 0 |
| | Ferruginous oolitic limestone with irregular cavities - - - | 10 | 0 |
| | Brown sandy and oolitic limestones; Bottom Beds - - 5 0 to | 6 | 0 |

I obtained a specimen of *Hinnites abjectus* from this quarry.

North of Bourton Clump, the following section was exposed:—

| | | Ft. | In. |
|---|---|---|---|
| Ragstones - | Rubble of oolite with *Homomya*, *Pholadomya*, *Pecten*, *Rhynchonella*, *Terebratula globata*, &c. - - - | 5 | 0 |
| Harford Sands and Upper Freestone. | Blue, brown, and grey racy clay - | 6 | 0 |
| | Calcareous, sandy, and ferruginous rock - - - - - | 0 | 3 |
| | Grey and brown clay - - - | 1 | 0 |
| | White and yellow sand with concretionary band of calcareous sandy rock | 3 | 0 |
| | Brown sandy oolitic rock - - - | 3 | 0 |
| | Shelly oolite - - - - | 5 | 6 |

These argillaceous and sandy beds are no doubt on the horizon of the strata seen east of Snowshill, at Stanway Hill Barn, and again near Harford, north-west of Bourton-on-the-Water; they represent the Harford Sands and Upper Freestone.

The thickness of the Inferior Oolite, proved in a well at the Worcester Lodge, Batsford Park, north-west of Bourton-on-the-Hill, was 160 feet. The Oolite Marl was not observed in this immediate neighbourhood, but its presence at Condicote was noted by Prof. Hull.

On the hill above Longborough, we again find good sections of the Lower Freestones as follows:—

| | Ft. | In. |
|---|---|---|
| Fissile and false-bedded shelly oolite, like the slaty beds of Hyatt's Pits; with pisolitic band near the middle - - - - - | 8 | 0 |
| White freestone - - - - 6 0 to | 7 | 0 |
| Freestone, shelly in places, with concretionary ferruginous patches and veins (Red and Yellow freestones) - - - - - 9 0 to | 10 | 0 |

The stone is here mostly quarried for road-metal.

Further south there is a quarry to the east of Banks Fee Farm, that showed from 18 to 20 feet of pale shelly limestones, with *Ostrea*, the beds were more or less oolitic, and minutely current-bedded. The higher layers were fissile like the slaty beds of

Hyatt's Pits, and these are overlaid by a bed of hard brown oolitic limestone, and by about 3 feet of rubbly oolitic limestones with *Ostrea*. Still further south the lower beds of the Inferior Oolite become much attenuated. The Midford Sands have been exposed near Stow-on-the-Wold to a depth of from 6 to 10 feet, and above them are beds with Polyzoa and Crinoidal remains,* suggestive of the Pea Grit Series; but there the Lower Freestones appear to be much reduced in thickness, while the higher strata become more important. Thus in the road-cutting, and in a quarry to the west of Stow, the following beds were shown:—

| | | Ft. | In. |
|---|---|---|---|
| Inferior Oolite (Ragstones). | Flaggy oolitic limestone, and hard brown obscurely oolitic limestone (resembling the Chipping Norton Limestone) - - - - | 8 | 0 |
| | Rubbly oolite with *Clypeus Ploti*. | | |

Again at Little Rissington, as remarked by Prof. Hull, the Clypeus Grit comes very near to the Upper Lias, the intervening subdivisions being for the most part unrepresented.†

The easterly attenuation of the Inferior Oolite may be judged from the following sections. Prof. Hull states that at Turkdean, north of Northleach, the thickness of the Inferior Oolite is as follows:—

| | Ft. | In. |
|---|---|---|
| Ragstone - - - - - - <br> Oolitic Marl - - - - - | 24 | 0 |
| Lower Freestone - - - - - | 46 | 0 |
| Yellow Sandstone - - - - | 14 | 0 |

South-west of Bourton-on-the-Water, freestone with bored-beds has been quarried along the Foss Way, and near Clapton, while further south at Sherborne, east of Northleach, Prof. Hull gives the following section‡:—

| | | Ft. | In. |
|---|---|---|---|
| Inferior Oolite and Sands. | Rubbly oolite, with *Clypeus Ploti*, *Gresslya*, *Lima gibbosa*, *Trigonia costata*, *Terebratula globata*, &c. | | |
| | Freestone - - - about | 5 | 0 |
| | Yellow sandstone and sands - - | 8 | 0 |
| Upper Lias - | Blue clay with *Ammonites bifrons*. | | |

The thickness of the Inferior Oolite between Northleach and Bourton-on-the-Water probably varies from 40 to 80 feet, attenuation taking place generally in an easterly or south-easterly direction.

North-east of Dodds Mill, Barrington Spinneys, a section showed apparently the upper beds of the Inferior Oolite, consisting of about 6 feet of rubbly and marly oolite, with grey clay in pockets on the top. *Terebratula globata* is abundant, and *Rhynchonella* also occurs.

* Hull, Geol. Cheltenham, p. 30; and E. A. Walford, Quart. Journ. Geol. Soc., vol. xxxix. p. 225.

† Hull, *op. cit.*, p. 47.

‡ *Ibid.*, p. 40.

East of the county-boundary, at Little Barrington, where the stone is quarried for road-metal, the following section was exposed:—

| | | Ft. | In. |
|---|---|---|---|
| Fuller's Earth | Tough unctuous and marly grey and yellowish clay, small *Ostrea acuminata*: racy at base - - - | 2 | 0 + |
| Inferior Oolite (Clypeus Grit). | Pale coarse-grained oolite, lime-washed. *Terebratula globata, Clypeus Ploti.* | | |

The Clypeus Grit was also exposed at Weston, to the north-west of Burford, in close proximity to the Upper Lias Clay as represented on the Geological Survey Map. There is evidence therefore of overlap of the lower beds of the Inferior Oolite, as we proceed southwards from Stow-on-the-Wold to the neighbourhood of Sherborne and Burford. (*See* Fig. 46.)

# CHAPTER V.

## INFERIOR OOLITE SERIES—(Local Details *continued*).

### 2. Oxfordshire.

*Chipping Norton to Fawler and Banbury.*

In the area commencing in Oxfordshire and extending north-eastwards through the counties of Northampton, Rutland, and Lincoln, the Inferior Oolite Series undergoes considerable modifications; for in its Lower Division we find evidences of estuarine and terrestrial conditions, characters that are more prominently exhibited in the greater portion of the series in Yorkshire.*

The geographical extent of the several beds, now grouped as belonging to the Great and Inferior Oolite Series, was, as early as 1822, indicated with much accuracy by Conybeare; but the two divisions were not clearly distinguished over the Midland area.† This is by no means surprising, for during the succeeding fifty years the relations of the beds above the Upper Lias in the country around Chipping Norton, Deddington, and Banbury, proved a source of much perplexity to geologists. It is true that the main portion of the Great Oolite—the white marly limestones and marls—have in general been clearly recognized; and the Geological Survey Map by Messrs. H. Bauerman and T. R. Polwhele, showed these beds resting on a complex series denominated the "Northampton Sand." The difficulties arose in connection with the age and relations of this so-called "Northampton Sand," for the Survey at that time, on the evidence of some fossils obtained near Deddington, regarded certain beds (now grouped with the Inferior Oolite) as of the age of the lower part of the Great Oolite, equivalent to the Stonesfield Slate.‡

Later on, the researches of Samuel Sharp, near Northampton, and those of Prof. Judd (who re-surveyed portions of the Northampton area), showed that the true Northampton Sand of Northampton belonged entirely to the Inferior Oolite. Prof. Judd, who re-examined the country around Banbury and Chipping Norton, while recognizing that portions of the so-called Northampton Sand of that area belonged to the Inferior Oolite, was unable to devote sufficient time to the matter to draw any satisfactory line between these beds and certain sandy strata considered to belong to the base of the Great Oolite; consequently while a new edition of the map was issued in 1871, the geological lines were unaltered, but the colouring of the Northampton Sand was modified, and the grouping adopted was as follows:—

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* *See* Morris, Geol. Mag., 1869, p. 104; and Judd, Geol. Rutland, p. 52.

† Conybeare and Phillips, Outlines of Geol. Eng. and Wales, 1822, pp. 216, 237, 246, &c.

‡ Green, Geol. Banbury, p. 12.

Great or Bath Oolite. Upper Zone.
Northampton Sand (Sands, calc. sandstones, ironstones, and limestones)—
Upper part = Lower Zone of Great Oolite.
Lower part = Inferior Oolite.
Inferior Oolite. (Clypeus Grit.)

The construction of a line of railway from Chipping Norton to Banbury has exposed a number of sections, clearly showing the presence of the upper and lower portions of the Great Oolite—the latter comprising the Stonesfield Slate division, which here, as in other places, appears to be intimately connected with the Fuller's Earth. These beds will be described further on, but it may be stated that where fully developed, as west of Bourton-on-the-Water, there is no discordance between them and the Inferior Oolite Series below. In other cases there is considerable unconformity.

Near Chipping Norton, the Inferior Oolite Series comprises a very variable set of beds, the uppermost portion of which is a thick mass of hard oolitic and sandy limestones (Chipping Norton Limestone), while, at lower horizons, we have evidence of the Clypeus Grit, and of beds of white and brown sand, calciferous sandstone, and occasional oolitic beds, the precise relations of which are exceedingly difficult to determine.

It would appear that the divisions of the Inferior Oolite are inconstant in extent, as well as variable in character, overlapping some of the minor divisions, while they are overlaid irregularly by different portions of the Great Oolite Series, which thus rests unconformably on various members of the Inferior Oolite. By the light of recent researches there will be much less difficulty in distinguishing Great Oolite from Inferior Oolite; but this has yet to be done on the Geological Survey Maps in the country around Chipping Norton—portions of the Great Oolite being included in the "Northampton Sand" in some places, and of Inferior Oolite in the "Great Oolite" and "Stonesfield Slate" of other areas, more especially between Chipping Norton and Stonesfield.

The observations of Mr. T. Beesley, and of Mr. E. A. Walford, of Banbury, of Mr. J. Windoes, of Chipping Norton, and of Mr. W. H. Hudleston, have tended largely to elucidate the structure of the district, and to augment our knowledge of the fossil contents of the strata. Many difficulties, however, still remain for future workers. Sections are not sufficiently abundant to clearly show the relations of all the subdivisions of the Inferior Oolite, to demonstrate their lateral variations or attenuation; and, where fossils are rare or absent, it is not always possible to say to which particular division or "zone" of the Inferior Oolite every outlying mass or isolated section of the beds may belong; for faults, as well as irregular overlaps, serve to complicate the geology of this area. Indeed it is not unlikely that some undulations affected the Inferior Oolite prior to the deposition of the Great Oolite; and owing to denudation, the Great Oolite thus rests irregularly on different members of the Inferior Oolite. (*See* p. 325.)

It is, however, clear that the mass of the sandy strata previously grouped, as belonging partly to the Great Oolite and partly to the Inferior Oolite, belongs to the latter series; but until the area has been mapped in detail on the 6-inch scale, it is hardly likely that the remaining doubts with regard to the correlation of particular subdivisions, will be dispelled. There is no more complicated tract among the Oolitic rocks of England than this region of the Inferior Oolite between Chipping Norton, Charlbury, and Banbury. We enter a region of changing sedimentation, which to some extent corresponds with the change in the general strike of the beds. Thus the general northerly strike of the Inferior Oolite, from Dorsetshire to the Cotteswolds, is modified by undulations and faults that appear eastwards of Northleach, and a general easterly or north-easterly strike is maintained for some distance, until the main outcrop again turns in a northerly direction towards the Lincolnshire "Cliff." In the following remarks, the correlations that are indicated, must be taken as provisional.

In passing eastwards across the Vale of Moreton we find that the representatives of the Cotteswold Sands are no longer to be identified, and that the lowest beds of which we have evidence above the Upper Lias Clay, are those containing *Ammonites opalinus* and *Rhynchonella cynocephala*, fossils which characterize the upper stage of the Gloucestershire Cephalopoda Bed. In this area, then, we have a more definite division between Upper Lias and Inferior Oolite, and the name Midford Sand, applied to the passage-beds, is no longer applicable.

We find no evidence of Pea Grit, nor of any mass of the Freestones, nor of the Gryphite Grit, but there are sandy beds at different horizons; and it will be remembered that in the northern portion of the Cotteswolds we find the incoming of sandy conditions, marked by the calcareous sandstones in the Lower Freestone division and by the sands (termed Harford Sands) that are associated with the Upper Freestone. In this area of Oxfordshire we have not only sandy equivalents of the Freestone Series, but sandy beds equivalent to portions of the Ragstone division of the Cotteswold Hills. Moreover we have occasional limestones that belong sometimes to the Freestone Series, sometimes to the very highest portion of the Inferior Oolite

The local divisions of the Inferior Oolite Series may be summarized as follows:—

| | | Ft. In. |
|---|---|---|
| Ragstone Series. | Hard oolitic and sandy limestones (Chipping Norton Limestone); underlaid in some places by iron-shot oolitic beds (Clypeus Grit), in others by white and yellow sands, ferruginous or calcareous sandstones with lignite (Sandy Series with lignite), and sometimes resting directly on limestone of a conglomeratic nature (Trigonia and Coral Bed) with *Astarte minima*, *Lithodomus*, *Trigonia producta*, *T. signata*, *Terebratula globata*, and *Rhynchonella spinosa* - | 10 0 to 50 0 |

| | | Ft. In. |
|---|---|---|
| Oolite Marl. | Pale marly and flaggy oolitic limestones, yielding *Natica cincta*, *Terebratula fimbria*, &c. (local) - - | 15 0 |
| Northampton Beds. | Calcareous sandstones and sands, conglomeratic in places; with *Ammonites corrugatus*, *A. opalinus*, *Rhynchonella cynocephala*, and *Terebratula trilineata* - - | 3 0 to 15 0 |

The Chipping Norton Limestone consists of oolitic and sandy limestones of variable character, some of the beds becoming rather siliceous in places, like certain beds of the Inferior Oolite near Frome, as in a quarry half-a-mile N.E. of Churchill. Here and there the stone is made up of comminuted shells, and it contains small quartz pebbles and rolled pebbles of oolite. Clayey seams occur now and again, and concretionary iron-stone is also present. The stone usually is sharply jointed. In places the beds decompose into a friable sandy loam or marl. In many quarries the exposed faces of the beds become lime-washed or incrusted with a calcareous coating. This is the "Rock Milk" (*Lac Lunæ*) of old mineralogists, sometimes also termed the "Agaric Mineral," from its supposed resemblance to fungoid growth.*

The beds are often much shattered, and the "rifts" or "swillies" are filled with clay and débris from the overlying Great Oolite Series. In some cases the broken beds are due to dissolution of calcareous matter, from the more sandy limestones that occur in the lower part of this division.

The total thickness of this Limestone is probably never more than 30 feet, and is usually less. The beds do not constitute a good freestone, but they are employed for building-purposes, for dry-walling, and for road-metal.

The Chipping Norton Limestone was described under this name in 1878 by Mr. Hudleston.† It forms the highest part of the Inferior Oolite in this district, and has been compared with the White Freestone of the Stroud district, and with certain ferruginous limestones seen in the railway-cuttings between Notgrove and Bourton-on-the-Water (p. 133).

It is overlaid in places by oolitic limestones, and by clays and marls with *Ostrea acuminata*, *O. Sowerbyi*, *Nerinæa Eudesi*, &c. belonging to the Great Oolite Series. It clearly underlies the Stonesfield Series with which is associated the Fuller's Earth, and there is evidence in places of unconformable overlap of the Chipping Norton Limestone by the superincumbent strata. Nevertheless, it has been pointed out by Mr. Walford and others, that the Limestone presents Bathonian characters in its fossils. We are indebted mainly to Mr. James Windoes, of Chipping Norton, for our acquaintance with the Ammonites, which are far from abundant. From the lower portion of the limestone he has

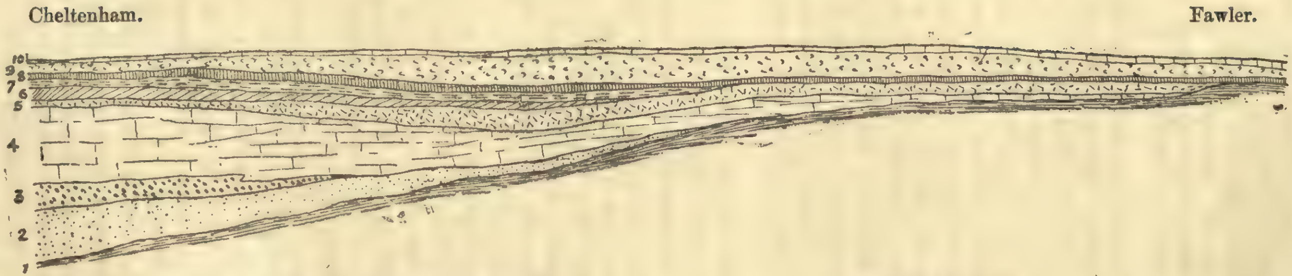
* *See* Kidd, Outlines of Mineralogy, vol. i. p. 39; and Weaver, Trans. Geol. Soc. ser. 2, vol. i. p. 351.

† Proc. Geol. Assoc., vol. v. p. 384.

Fig. 46.

*Diagram-section from the Cotteswold Hills to Fawler in Oxfordshire.*

(Distance, about 25 miles. Vertical scale, 240 feet to an inch.)




10. White Oolite and Chipping Norton Limestone.
9. Clypeus Grit.
8. Upper Trigonia Grit.
7. Gryphite Grit and Lower Trigonia Grit; Notgrove Oolite, &c.
6. Upper Freestone.
5. Oolite Marl.
4. Lower Freestone.
3. Pea Grit Series.
2. Midford (Cotteswold) Sand.
1. Upper Lias Clay.

obtained *Ammonites Parkinsoni*; and from higher beds, species identified as *A. arbustigerus* and *A. bullatus*; but the occurrence of the two last-named species is not accepted by Messrs. Sharman and Newton, who have recently examined the specimens. They recognize only the species noted below.

The following fossils have been obtained by Mr. Windoes from the Chipping Norton Limestone*:—

Strophodus.
Ammonites (near to) Bakeriæ.
—— fuscus.
—— Parkinsoni.
—— —— var. dorsetensis.
Actæonina.
Ceritella.
Cerithium limæforme ?
Littorina Phillipsi.
Monodonta.
Natica canaliculata.
Nerinæa.
Nerita rugosa ?
Patella.
Pleurotomaria.
Trochotoma.
Astarte.
Avicula.
Ceromya undulata.
Corbis.
Gervillia pernoides.
Leda lachryma.
Lima cardiiformis.
Modiola furcata.
—— imbricata.
Myacites.
Nucula.
Opis similis.
Pecten retiferus.
Sowerbya Woodwardi.
Trigonia Painei.
—— producta.
—— v-costata.
Terebratula maxillata.
—— Phillipsi.
Holectypus depressus.
Pseudodiadema depressum.

In places near Langton Bridge, as remarked by Mr. Beesley, the upper part of the Chipping Norton Limestone had the appearance of "old weathered mortar," and this mortar-like limestone has yielded obscure plant-remains, and portions of *Chara*; an identification confirmed by Mr. James Groves, from specimens obtained by Mr. Windoes. Mr. Walford has procured from the same peculiar bed, *Nerinæa Eudesi*, &c.

Stratigraphically we must include the Chipping Norton Limestone with the Inferior Oolite, although it exhibits evidence that would lead us to regard it as forming a passage from that formation into the Great Oolite Series. Perhaps we may be contented with the view that Inferior Oolite conditions endured somewhat longer in this area than was the case elsewhere in the south-western counties; or, in other words, it may be a case, such as not unfrequently occurs, where a stratigraphical formation trangresses the limits of a zone.

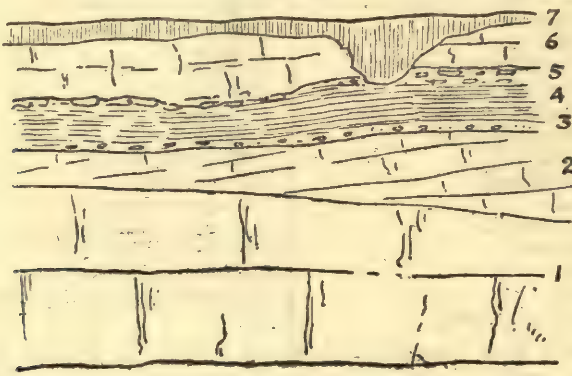
The Chipping Norton Limestone has been well exposed in quarries between Chipping Norton and Churchill; in the railway-cutting west of Langton Bridge, about 1¾ miles north of Chipping Norton church, and in a quarry to the north of the cutting; in another (Padley's) quarry, east of Chipping Norton, an opening known as the "Cetiosaurus quarry" (*see* p. 327); and on the Burford Road, south-east of the Toll Gate near Chipping Norton. At Langton Bridge, the top-bed of the Limestone, which contains fragments of shells and Echini, and quartz grains, is considered by Mr. Beesley to exactly resemble the material of the so-called

* See also Walford, Quart. Journ. Geol. Soc., vol. xxxix. pp. 234, 237; and Hudleston and Wilson, Catalogue of British Jurassic Gasteropoda.

Druidical, but doubtless sepulchral "Rollrich (or Rollright) stones," situated on the hill north-east of Little Rollright village.* I have noticed similar beds in quarries north-west of Little Rollright, and again near Heythrop. Mr. Beesley also referred to the decomposition of the sandy limestone as resulting in a reddish sand. (See Fig. 92, p. 329.)

FIG. 47.

*Section south-west of Chadlington Down Farm, south of Chipping Norton.*




| | | Ft. | In. |
|---|---|---|---|
| | 7. Brown loamy soil - - - - - | 0 | 9 |
| Great Oolite Series. | 6. Compact grey and slightly oolitic limestone; with rubbly bed (5) at base, that may be due to the subterranean action of springs flowing over the surface of the clay beneath - - - | 2 | 6 |
| | 4. Grey clay, passing down into brown clay; with layer at base (3) containing lumps of hard and rather cherty limestone, probably derived from beds below - - - - - | 2 | 0 |
| Chipping Norton Limestone. | 2. False-bedded limestone, shelly and oolitic in places. | | |
| | 1. False-bedded brown sandy limestone, crinoidal and finely oolitic in places; some layers more sandy than others - | 10 | 0 |

Proceeding southwards we find the Chipping Norton Limehouse exposed beneath the Great Oolite Series south-west of Chadlington Down Farm. Some curious bee-hive shaped excavations are occasionally found in the surface-strata (2 to 7) at this locality.† They are probably pre-historic. Here the Chipping Norton Limestone is shelly, oolitic and crinoidal in

* Proc. Geol. Assoc., vol. v. p. 179; and Hudleston, *Ibid.*, p. 380. *See also* Phillips, Geol. Oxford, p. 55. Some blocks of similar rock have been employed for the monument erected at Churchill by the Earl of Ducie in memory of William Smith, who was born at that village; *see* Geol. Mag., 1892, p. 94.

† See Essex Naturalist, vol. i. p. 265.

places, but much of it is a finely oolitic and calcareous sandstone. (*See* Fig. 47.) Some of the layers, as shown in a quarry east of Sarsgrove, are remarkably false-bedded.

North of Castle Barn, south-east of Sarsden, the lower beds of stone, which appear to belong to the Chipping Norton Limestone, contain an impersistent bed of soft grey oolitic marl, 1 ft. 8 in. thick, yielding Gasteropods, (*Natica ?* and others) very poorly preserved. (*See* p. 326.) I feel, however, some doubt with regard to the correlation of these beds, for comparing them with those at North Aston, they might belong to the Great Oolite.

South of Lyneham Barrow,[1] and by the Camp, there are quarries showing false-bedded sandy and oolitic limestones, and sandy rock with hard concretions, resembling beds elsewhere associated with the Collyweston Slate. It is difficult to correlate the beds that are exposed in this neighbourhood.

The Chipping Norton Limestone is quarried for road-metal, &c. near Handbrake on Chastleton Hill, near the Cross Hands Inn, and north-west of Little Rollright.

The Clypeus Grit may be traced at the base of the Chipping Norton Limestone in a quarry by the main road east of Adlestrop, and again above the Upper Lias clay in the disused brickyard west of Salford, as observed by Mr. Walford. It is from 10 to 20 feet thick. The sequence proved in this neighbourhood is as follows:—

| | | | Ft. | In. |
|---|---|---|---|---|
| | Great Oolite Series. | Flaggy oolitic limestones and marly clay, with *Ostrea acuminata*, *O. Sowerbyi*, &c. | | |
| Inferior Oolite. | Chipping Norton Limestone. | Oolitic limestones, fissile when near the surface, passing down into less oolitic and somewhat sandy beds, and into thick, fine-grained, oolitic limestones below; with lignite in places, rolled fragments of oolite and tiny quartz pebbles - - about | 12 | 0 |
| | Clypeus Grit. | Coarse and rubbly oolite, iron-shot in places, with *Clypeus Ploti*, *Trigonia*, *Terebratula globata*, &c. - about | 10 | 0 |
| | Northampton Beds. | Brown calcareous sandstone - - | 1 | 8 |
| | | Brown sands, with pebbly layer at base | 1 | 2 |
| | Upper Lias - | Grey clay. | | |

The Clypeus Grit, as I am informed by Mr. James Windoes, has been proved in several places in the neighbourhood of Chipping Norton, more especially in the escarpment between the town and Churchill. It has also been proved beneath the town itself, where its thickness must be nearly 20 feet, judging by one well sunk to a depth of 55 feet.

A trace of the division has been exposed, faulted against the Chipping Norton Limestone, in a quarry south-east of the town, on the Burford Road; and an exposure of sandy and ferruginous limestone (classed by Mr. Windoes with the Clypeus Grit) occurs in the deep road-cutting by the cross roads, south of Lime-kiln

Farm.* It is also exposed in a deep road-cutting through Bright Hill east of the Five Knights.

The following species, collected from the Clypeus Grit by Mr. Windoes, have been recorded by Mr. Hudleston:—†

Ammonites Parkinsoni.
Actæonina. (H. B. W.)
Cardium citrinoideum.
Homomya gibbosa.
Lima duplicata.
Pecten.
Pholadomya Dewalquei.
—— Heraulti.
Trigonia costata.
Trigonia signata.
Rhynchonella angulata.
—— concinna.
Terebratula globata.
Clypeus Ploti.
Holectypus depressus.
Anabacia complanata (orbulites).
—— hemisphærica.
Montlivaltia trochoides.

North of Chipping Norton the Clypeus Grit appears to die out, or, if not, it merges into the sandy beds which at Hook Norton directly underlie the Chipping Norton Limestone, and yield but few fossils. Nor do we find this bed anywhere distinctly represented to the east. Southwards, Prof. Hull records a thickness of about 20 feet at Sarsden, but only a trace at Enstone.‡

At Fawler we have the following section of beds:—§

| | | | Ft. | In. |
|---|---|---|---|---|
| Inferior Oolite. | Chipping Norton Limestone. | Oolitic limestone of variable texture, with occasional marly layers. The beds, which are quarried for lime-burning, are much tumbled, shattered, and lime-washed. Few fossils occur; but *Pholadomya* and Echini may be found - 12 0 to | 15 | 0 |
| | Clypeus Grit. | Rubbly oolitic marls and coarse marly oolites, with *Clypeus Ploti*, *Ammonites Parkinsoni*, *Pholadomya Dewalquei*, *Terebratula globata*, &c. - - - 8 0 to | 12 | 0 |
| | Lower Beds of Ragstone. | Marly limestones - - - 5 0 to | 6 | 0 |
| | | Coarse oolitic, and almost pisolitic, limestones, with *Gervillia*, *Isocardia*, *Lima gibbosa*, *Modiola Lonsdalei*, *Myacites*, *Pecten vagans*, *Rhynchonella concinna*, *R. obsoleta*, *R. varians*, *Serpula*, &c. - - | 4 | 0 |
| | | Hard iron-shot limestone, with pebbly layer at base; Corals, *Echinobrissus clunicularis*, *Rhynchonella spinosa*, *Terebratula globata*, and *T. maxillata* (smooth form) - - - - | | |

Upper Lias.—Blue Clay.

From the basement-bed (above the Upper Lias Clay) Mr. Walford obtained small blocks of limestone covered with *Plicatulæ*

* Proc. Geol. Assoc., vol. v. p. 386; and Walford, Quart. Journ. Geol. Soc., vol. xxxix. pp. 236, 238.

† Proc. Geol. Assoc., vol. v. p. 384.

‡ Geol. Country around Woodstock, p. 13.

§ *See also* Proc. Geol. Assoc., vol. iv. p. 95; Hull, Geologist, vol. iii. p. 304; Hull, Geol. Woodstock, p. 15; Walford, Quart. Journ. Geol. Soc., vol. xli. p. 39; F. A. Bather, *Ibid.*, vol. xlii. p. 144.

and pierced with *Lithodomi;* and he records the occurrence of *Trigonia producta, T. angulata, Rhynchonella quadriplicata ?,* &c.

The basement-bed of the Inferior Oolite (Ragstones) at Fawler indicates that, in this southerly direction, the upper beds of the Inferior Oolite overlap the lower beds and rest directly on the Upper Lias, as is also the case near Burford (p. 145).

The same basement-bed appears to be represented (as pointed out by Mr. Walford), in the pebbly beds with bored-stones, *Trigonia,* and Corals, at Hook Norton, and in the sections north of Dunthrop, at Otley Hill, and at Sharpe's Hill.

The cutting at Hook Norton, east of the tunnel, has afforded a good section of the strata, which have been described by Mr. T. Beesley, and more particularly by Mr. Walford, in whose company I have had the opportunity of examining the beds, and on whose authority most of the fossils are enumerated.* The following is a summarized account of the beds :—

| | | Ft. | In. |
|---|---|---|---|
| | Soil and rubble of Great Oolite. | | |
| Ragstones. | Flaggy white oolitic limestone - - | 2 | 0 |
| | Hard concretionary calcareous sandstone and yellow and white sand; *Ostrea* - - - - - | 3 | 6 |
| | Hard close-grained slightly oolitic and sandy limestone, with *Ostrea* on surface - - - - | 1 | 9 |
| | Ferruginous and sandy beds, with lignite and plant-remains - 10 0 to | 12 | 0 |
| | Shelly and iron-shot limestones, with rolled fragments of limestone: *Astarte minima, Lima, Lucina despecta, Pecten lens, Trigonia producta, T. gemmata, T. signata,* and *Rhynchonella spinosa* - - 3 0 to | 4 | 0 |
| | Conglomeratic iron-shot limestone, with bored stones: *Ostrea, Trigonia, Rhynchonella spinosa, Serpula, Isastrœa,* and *Thamnastrœa* - 0 10 to | 1 | 2 |
| Northampton Beds. | Hard grey sandy limestone, oolitic in places: *Ammonites opalinus, Terebratula perovalis,* &c. - 2 8 to | 3 | 0 |
| | Marly bed. | | |
| | Brown shelly and calcareous sandstones: *Belemnites gingensis, Goniomya, Gresslya, Rhynchonella cynocephala, Terebratula plicata,* &c. - ; Brown sandy clay with pebbles - | 3 | 6 |
| | Upper Lias.—Blue clay. | | |

The Chipping Norton Limestone is no doubt represented in the upper strata, while lower down the Clypeus Grit and the Trigonia Grit of the Cotteswolds may be represented in point of time. (*See* Fig. 92, p. 329.)

* Walford, Quart. Journ. Geol. Soc., vol. xxxix. p. 229; Beesley, Proc. Warwickshire Field Club, 1876, p. 29, and Proc. Geol. Assoc., vol. iv. p. 170; Hudleston, *Ibid.*, p. 389, and Gasteropoda of Inf. Oolite, p. 71; Tomes, Proc. Geol. Assoc., vol. vi. p. 157.

Over the country east and north-east of Hook Norton, the evidence tends to show that both upper and lower portions of the Inferior Oolite are represented in a sandy series that passes into the Northamptonshire area. Over portions of that area the general divisions comprise the Lower Estuarine Beds resting on the Northampton Sands.

Prof. Judd remarks that outliers of the Oolites cap a number of more or less isolated hills in the north of Oxfordshire, such as Brailes Hill, Mine Hill, Tysoe Hill, Shenlow Hill, Epwell Hill, Long Hill, and the high grounds above Epwell, Sibford, and Whichford. "The variable beds of limestones, sands, ironstones, &c., which form these outliers, have been classed with the Northampton Sand, and indeed they can be traced from this point northward and eastward almost continuously with that series of more or less ferruginous beds. * * * Tracing the same beds to the southwards, we find in the outlier above Whichford and Long Compton, thick beds of white freestone underlaid by sands; beneath these occur beds of calcareo-siliceous stone with but few well-preserved fossils." From these beds Mr. Walford has recorded *Astarte elegans* and *Trigonia signata.** Near Long Compton a specimen of *Ammonites garantianus,* was obtained from the "Northampton Sand."†

A section at Sharpe's Hill, south-west of Hook Norton Leys and north-west of Hook Norton, showed the following section :—

| | | | Ft. | In. |
|---|---|---|---|---|
| Great Oolite Series | | Brown clay and rubble - <br> Greenish marly clay - <br> Band of limestone - <br> White marl with *Gervillia* - <br> Dark clay - - | 3 0 to 4 | 0 |
| Inferior Oolite. | Ragstones | Ferruginous marly bed. | | |
| | | Hard false-bedded oolitic and shelly limestone - - - | 6 | 0 |
| | | Gritty oolitic and conglomeratic limestone; with lignite, *Trigonia signata,* &c. - - | 0 8 to 1 | 0 |
| | Northampton Beds ? | Brown ferruginous sands and calcareous sandstone (blue-hearted) with shelly beds - - - | 6 | 0 |

The upper beds in this quarry show resemblances to beds seen north of Lower Tadmarton: they belong to the Great Oolite Series. The Oolite below is the Chipping Norton Limestone. The sandy beds may represent the Northampton Sands; at any rate they are equivalent to beds seen at Newbottle Spinney and near Bloxham. Mr. Walford records from the lower beds *Avicula braamburiensis, Gervillia, Ostrea,* and *Trigonia costata*;‡ and he recognizes no strata older than the zone of *Ammonites Parkinsoni.*

North-west of Nill Farm, and west of Hook Norton Lodge, the following section was exposed :—

* Quart. Journ. Geol. Soc., vol. xxxix. p. 233.
† Judd, Geol. Rutland, pp. 13, 17, 21.
‡ Quart. Journ. Geol. Soc., vol. xxxix. p. 233.

| | | Ft. | In. |
|---|---|---|---|
| Ragstones | Brown sandy and loamy soil - - | 3 | 6 |
| | Yellowish-brown and white sands - | 2 | 6 |
| | Hard flaggy oolitic limestone; with lignite and plant-remains - - | 6 | 0 |
| | Brown oolitic limestone, becoming sandy and conglomeratic (?) at the base - - - - - | 1 | 3 |
| Northampton Beds? | Slightly oolitic and shelly limestone *Trigonia* and lignite - - - | 0 | 7 |

From limestones beneath the sandy beds of Tadmarton Camp and Milcomb Hill, Mr. Walford records *Pecten demissus*, *P. lens*, *P. personatus*, *Trigonia Brodiei*, *Montlivaltia lens*, &c.* Possibly the bottom layer of limestone (above noted) may belong to this lower portion of the Inferior Oolite Series; the section at any rate may be compared with that in the Hook Norton railway-cutting (p. 155).

At "Otley Hill" on the west of Hotley Hill Farm, and on the western side of the road leading towards Traitor's Ford, the following section was shown:—

| | | | Ft. | In. |
|---|---|---|---|---|
| Inferior Oolite. | Ragstones | Rubbly oolitic beds - - <br> Hard sandy and oolitic bed with bored stones and Corals; pebbly at base - | 3 | 0 |
| | Northampton Beds. | Hard sandy and ferruginous limestones - - | 4 | 0 |

Prof. Judd, Mr. Walford, and Mr. J. Windoes have obtained a number of fossils from this pit, but the horizons have not in all cases been clearly stated.† *Isastræa Conybearei*, *Lithodomi*, &c. occur in the pebbly bed, an equivalent to which is seen beneath the Clypeus Grit at Fawler. The lower beds have yielded the following species:—

Ammonites corrugatus.
—— opalinus.
Nerinæa cingenda.
—— pisolitica.
Pholadomya fidicula.
Trigonia Brodiei.
—— striata.
Rhynchonella cynocephala.
Acrosalenia.
Montlivaltia lens.

Large specimens of *Nautilus* also occur. The assemblage compares well with that recorded from Brailes.

Prof. Judd states that in the pits opened at the summit of Brailes Hill, there are beds of white oolitic freestone (slightly siliceous), which by weathering assume a somewhat fissile character. Among these upper beds there is a white, coarsely oolitic rock, graduating into a regular freestone undistinguishable from that of the Lower Freestones of Gloucestershire; in its upper part this bed becomes shelly and contains numerous Corals and fragments of Echinoderms. Below, there is an irregular bed of brown sand and good ironstone, presenting the usual features of the

* Quart. Journ. Geol. Soc., vol. xxxix. p. 228.

† Judd, Geol. Rutland, p. 21; Walford, Quart. Journ. Geol. Soc., vol. xxxix. pp. 234, 242, 244; S. S. Buckman, Inf. Ool. Ammonites, pp. 52, 53.

Northampton Sand. Beneath the sand and ironstone, a thickness of about 8 feet of calcareo-siliceous rock is exposed, one bed near the bottom being crowded with fossils, among which Prof. Judd recognized the following*:—

| | |
|---|---|
| Ammonites corrugatus. | Hinnites abjectus. |
| —— Murchisonæ. | Pecten articulatus. |
| Belemnites aalensis. | —— demissus. |
| —— ellipticus. | —— personatus. |
| Astarte elegans. | Trigonia costata. |
| —— minima. | Pentacrinus Milleri. |
| Ceromya bajociana. | Latimæandra Davidsoni. |
| Cucullæa oblonga. | Montlivaltia trochoides. |
| Gresslya peregrina. | Thamnastræa defranciana. |

The Limestones here may belong to the Chipping Norton Limestone. From the lower beds, similar assemblages of fossils were collected by Prof. Judd, at Mine Hill and Tysoe Mill Hill.

Prof. Judd refers to a pit, about 20 feet deep, on the hill on which Tysoe Mill stands; this exhibited siliceous limestones with ironstone-bandings, in some places passing into loose calcareous sands, in others into the ordinary iron-ore of the Northampton Sand. At this place marine fossils were rare in the beds, but fragments of lignite and plant-remains were very abundant. He further states that "In the long spur capped by Northampton Sand, which stretches northwards as far as Compton Winyate, we find many illustrations of the variable character of the beds which lie upon the Upper Lias Clay. Sometimes, as near White House Warren, white sands with numerous bands of carbonaceous matter occur; in some places these white sands are found passing into hard sand-rock, at others into ferruginous sand, and at others again, as near Broomhill Farm, into cellular ironstone rock. At not a few points the sands graduate, within very short distances, into a more or less fissile calcareo-siliceous rock traversed by hard ferruginous bands. The same rapid variations—so characteristic of the Northampton Sand throughout its whole range—from arenaceous to more or less ferruginous and calcareous rocks, is seen in the numerous outliers to the east of this spur, one of which, Epwell Hill, rises to an elevation of 836 feet, and constitutes the highest point in the county of Oxford."†

A pit north-east of White House, north-west of Epwell, showed the following section:—

| | | Ft. | In. |
|---|---|---|---|
| Northampton Beds? | Grey sandy soil - - 0 6 to | 1 | 0 |
| | White quartzose sand, here and there slightly indurated; passing down into bed below - - - | 2 | 6 |
| | Brown sand with ferruginous veins, and layers only slightly indurated; with patches of white sand - 4 6 to | 5 | 0 |

The sand resembles that east of Newbottle Spinney, and may perhaps be grouped with the Northampton Beds. It is, however,

* Geol. Rutland, pp. 17, 18.
† Geol. Rutland, p. 20.

hazardous to speak with certainty of the correlation of such beds of sand, detailed mapping on the 6-inch scale being needful to determine their stratigraphical relations. Similar sands occur at a higher horizon, as noted in a section west of Hook Norton Lodge (p. 156).

Brown and white sands, probably equivalent to those seen in the Epwell section, have been dug near Tadmarton Camp, and these beds have been again exposed beneath the Great Oolite Series on Constitution Hill, near Withycombe Farm, Banbury. Mr. Walford says "all that remains of the Inferior Oolite is from 12 to 20 feet of white and fawn-coloured sands with occasional bands of stone." From these he obtained plant-remains, and some fossils, including *Avicula braamburiensis, Corbicella bathonica, Gresslya abducta, Ostrea gregaria, Pecten articulatus, Trigonia angulata, T. v.-costata,* an Alga, &c.* These beds probably belong to the lower division grouped with the Northampton Beds.

It has been noted that to the south of Chipping Norton there is a variable set of sandy and oolitic limestones, underlaid by more decidedly sandy rock, with hard concretionary nodules; but these lower sandy beds are overlapped in the direction of Fawler.

To the north-east of Chipping Norton, in pits near the Priory Farm, Heythrop Common, north of Showell Farm, near Pomfret Castle, and thence to Great Tew, and in the west of Swerford, we find evidence of the same general sequence.

On top we find in places the irregular capping of clays and rubbly stone, belonging to the Great Oolite Series. At Swerford these beds resemble those seen above the Inferior Oolite Series at Newbottle Spinney: the section is as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite Series. | 7. Brown clay - - - - <br> 6. Grey and blue-black clay - - | 3 | 0 |
| | 5. Bluish grey rubbly sandy and shelly limestone and clay, with *Ostrea acuminata* - - - - | 2 | 0 |
| Inferior Oolite Series. | 4. Calcareous sandy and shelly stone - | 1 | 0 |
| | 3. Clay seam - - - - <br> 2. Flaggy sandy, shelly, and (in places) slightly oolitic limestone - - <br> 1. Yellow sands with small concretionary nodules of calcareous sandstone; piped where at the surface, and passing into harder stone - - | about 10 | 0 |

The rubbly bed 5, appears to be in part decomposed or reconstructed portions of the bed below. It is termed the "Rift Bed" by Mr. Walford, for it sometimes fills rifts or crevices in the underlying strata. A fuller account of this section, differing somewhat in detail, is given by him.† Here there is evidently a break between the Great Oolite Series and underlying strata, for

* Quart. Journ. Geol. Soc., vol. xxxix. p. 228; see also Beesley, Proc. Geol. Assoc., vol. v. p. 174.

† Quart. Journ. Geol. Soc., vol. xxxix. pp. 230, 232, 234.

elsewhere in the neighbourhood there is to be found 6 feet of flaggy oolite representing the Chipping Norton Limestone.

It is difficult to fix horizons in the beds in this neighbourhood, and it is likely that more than one zone of the Inferior Oolite may be represented in the calcareous sandy beds, some of which are obscurely oolitic. Fossils are not abundant; we may find *Ostrea* and *Trigonia signata, Galeolaria socialis,* and Lignite, but otherwise our search may be unrewarded by any zonal species, for *Trigonia signata* does not appear to characterize any definite horizon. Very fine examples of this fossil were obtained by Mr. Windoes and the late S. Stutterd from a pit near Priory Farm, on Heythrop Common. It locally forms a *Trigonia*-bed, that occurs in the upper part of the sandy limestones, which have been exposed to a depth of about 12 feet, at Swerford Park and Great Tew.

The lower portion of this sandy development of the Inferior Oolite Series, comprises layers of hard blue-hearted calcareous sandstone, like the Lower Calcareous Grit, and in places it is conglomeratic. These beds have been quarried to the N.W. of Little Tew and S.W. of Great Tew, where they are shown to a depth of 12 feet. The section north of Heythrop Common is as follows:—

| | | FT. | IN. |
|---|---|---|---|
| | Brown clay. | | |
| Inferior Oolite Series. | Rubbly oolitic stone with *Ostrea* - - | 1 | 0 |
| | Marly *Ostrea*-bed, with small concretionary nodules of calcareous sandstone at the base - - - - - | 1 | 0 |
| | Flaggy calcareous sandstone, with *Trigonia signata* - - - 1 0 to | 1 | 6 |
| | Sandy and flaggy, false-bedded calcareous sandstone, with nodules of similar rock in upper part - - - - | 6 | 0 |

North of Showell Farm, and again eastwards near the turning to Little Tew, we find flaggy and marly oolite, 6 to 8 feet thick, with *Ostrea* and Gasteropods; these beds rest on calcareous sandstone and sand, the former sometimes obscurely oolitic.

By the park-drive, a little north-west of Heythrop Church, there are extensive quarries, where beds of coarse-grained and more or less shelly oolite have been worked to a depth of nearly 20 feet. The beds contain spines of Echini, *Ostrea*, and very small pebbles of quartz: they are more massive at the base and rubbly on top, and have furnished much building-stone for the neighbourhood. The beds are very irregular and false-bedded. In places a thick Oyster-bed is to be seen in the quarries on the north-eastern side of the drive. It occurs in irregular masses, 5 feet thick in places, and composed of pale marly oolite crowded with *Ostrea,* with occasionally *Lima cardiiformis* and pebbles of oolite: it dies away more or less abruptly into loose marly oolite. It is overlaid by 8 or 10 feet of oolite, part of which is worked for building-stone, and it is underlaid by 4 feet of stone, also worked.

The upper portion of this division is seen in a quarry north-east of Enstone, where about 12 feet of fissile and false-bedded oolite and sandy oolitic limestone have been opened up. The beds contain *Trigonia* and *Lima*, and are overlaid by about 3 feet of clay with fragments of *Ostrea*. South of Enstone (east of the 69th milestone) the beds were again exposed; and the Giant's Stone or Hoar Stone, a block about 11 × 7 × 3 feet, is formed of the rock. In character these beds correspond with the Chipping Norton Limestone; but they may include strata on a lower horizon.

About one-third of a mile north of Dunthrop the following section was exposed :—

| | | Ft. | In. |
|---|---|---|---|
| | Brown clayey soil - - - - | 0 | 6 |
| Ragstones | Flaggy oolite - - - - | 1 | 3 |
| | Coarse marly oolite with *Ostrea* [? = Clypeus Grit] - - - - - | 1 | 0 |
| | Shelly oolite with pebbles of oolite and numerous casts of shells, especially *Trigonia costata;* with *Ammonites* (rare), *Lima*, *Ostrea*, and Corals, *Isastræa Richardsoni*, &c. - - - - | 1 | 9 |
| Oolite Marl? | Hard false-bedded marly oolitic limestone, with *Ostrea:* passing down into coarse shelly, pisolitic and oolitic limestone, with *Lima cardiiformis* - - - | 13 | 0 |

These beds may be compared with those opened up north-west of Heythrop Church; in the quarries east of Sarsgrove on the road from Burford to Chipping Norton: and in a quarry on the Banbury Road about 3¼ miles from Chipping Norton. The junction with the sandy series below was shown, in a quarry about a quarter of a mile to the eastwards of the one last-mentioned, on the road to Little Tew.

These sections at Dunthrop and Heythrop are important, for here it would appear that we have evidence of two limestone divisions—the upper portion of which represents the Chipping Norton Limestone, perhaps the Clypeus Grit, and the Trigonia Bed at Fawler and the Coral Bed of Hook Norton: the lower portion may represent beds parallelled with the Oolite Marl and with portions of the Lincolnshire Limestone. Precise correlation is however very hazardous,

Proceeding further east we come, near Deddington, to the two important sections described by Prof. Judd. The lists published by him suggest that we have representatives there, not only of the Oolite Marl or Upper Freestone of the Cotteswolds, but of higher stages, indicated by *Clypeus Ploti*, *Terebratula globata*, &c.

Judging also from the fossils obtained from the Lincolnshire Limestone in certain places, as at Tinkler's quarry, Stamford,* it would seem that the upper portion of the Inferior Oolite is to some extent represented in that division.

About a mile north-west of Deddington, in the parishes of Little Barford (or Barford St. John) and Great Barford (or

* See Judd, Geol. Rutland, p. 160.

Barford St. Michael), there are two small outliers which have been preserved, in consequence of the Inferior Oolite having been let down by faults. In the small outlier north of the River Swere (Combe Hill), Prof. Judd found about 15 feet of white oolitic limestone, some of the beds being very shelly; at the time of my visit only about half that thickness of rock was exposed. Many fossils have been collected from the beds, by Mr. Beesley, Mr. R. Gibbs, Prof. Judd, and Mr. Walford:* they include the following species:—

× Strophodus.
× Ammonites Murchisonæ.
× Belemnites ellipticus.
× Nautilus.
× Natica cincta.
× Patella rugosa.
Arca Pratti.
× Astarte elegans.
× Hinnites abjectus.
× Lima cardiiformis.
—— electra. (H. B. W.)
× —— pectiniformis. (H. B. W.)
Lucina Wrighti.
× Ostrea flabelloides.
× Pecten lens.
× —— personatus.
× Perna rugosa, var. quadrata.
× Trigonia beesleyana.
—— pullus.
Terebratula fimbria.
—— globata.
× —— maxillata (submaxillata).
× —— perovalis.
—— plicata.
× Galeolaria (Serpula) socialis.
× Pentacrinus Milleri.
× Pygaster semisulcatus.
× Stomechinus germinans.
× Montlivaltia trochoides.
Thamnastræa defranciana.
Thecosmilia Wrighti.

Those marked × occur also in the pit next mentioned.

Prof. Judd also states that "On the south side of the River Swere, at a place known as Blackingrove, we find a pit opened in beds of stone similar to that on the other side of the river at Combe Hill; as we go lower in the series, however, the oolitic limestones are seen passing down into beds of a more siliceous and shelly character, and finally into the hard siliceo-calcareous rock, which occurs so commonly in the Northampton Sand. The whole of these beds are crowded with shells which have been collected both by the late [Charles] Faulkner, of Deddington, and the officers of the Geological Survey; thus we have been made acquainted with a very large and interesting fauna from this locality, which enables us to refer the beds without doubt to the base of the Inferior Oolite. The strata representing the Northampton Sand here, as at many other places, contain numerous rounded pebbles of argillaceous limestone; it is in places banded with brown oxide of iron in its lower part, and rests directly upon the Upper Lias Clay."

The following fossils have been collected at Blackingrove in the sandy limestone of the Northampton Sand:—

Mesodon (Pycnodus).
Strophodus.
Ammonites corrugatus.
—— Murchisonæ.
Belemnites aalensis.
Gresslya peregrina.
Pholadomya fidicula.

* Judd, Geol. Rutland, p. 25; Beesley, Proc. Warwickshire Field Club, 1872, p. 28, and Proc. Geol. Assoc., vol. iii. p. 204; Walford, Quart. Journ. Geol. Soc., vol. xxxix. pp. 227, 239.

Prof. Judd also mentions *Clypeus Ploti* from this locality. The beds (according to Mr. Beesley) have been worked since the Roman occupation, but the quarry has now for many years been closed.

The general succession of the strata at Steeple Aston, south-east of Deddington, was given as follows by William Smith, in 1805*:—

| | | Feet. |
|---|---|---|
| [Great Oolite.] | White Stone [shelly oolite underlaid by marly clay]. | |
| [Inferior Oolite.] | White sand - - - - | 6 |
| | Oven stone or soft sandstone - - | [7] |
| [Upper Lias.] | Wet clay - - - - | [35] |
| [Middle Lias.] | Rock - - - - - | 20 |
| | Sandy clay. | |

A general section in the same area was afterwards given by Prof. Phillips,† whose measurements are given in square brackets. The thickness of the Upper Lias in this neighbourhood is in places reduced to 10 or 15 feet.‡

At Worton, between Steeple Aston and Banbury, the following section, showing details of the Inferior Oolite, was noted in 1854 by Prof. Phillips:—

| | Ft. | In. |
|---|---|---|
| Shelly and sandy layers, with patches of calcareous flagstone ("plank") - - - - - | 4 | 0 |
| Iron-ore (oolitic) in undulated and folded masses - | 0 | 6 |
| Stony bands, with plant-remains - - - - | 1 | 0 |
| Sands, with nodules of iron-ore and shells - - | 5 | 6 |
| Calcareous band - - - - - - - | 2 | 0 |
| | 13 | 0 |
| Ferruginous clay (top of Upper Lias) - - - | | |

This section is suggestive of the Northampton Beds; and it is interesting to know that the bands of iron-ore above the Upper Lias, as well as those beneath it (Middle Lias), were formerly worked near Steeple Aston, by means of a shaft 90 feet deep.§

Phillips remarks that in the country about Sandford the above beds become white and yellow sand (16 or more feet thick) with irregular laminæ of calcareous sandstone, blue in the centre, and called "plank." This is sometimes covered by 6 feet of clay. Strickland mentioned that near Lower Heyford "about a mile south of Rousham the [Great Western] railway again cuts into a hill and exposes some beds of siliceous sand of various colours. Above this is a bluish clay with numerous small oblong Ostreæ."|| The clay doubtless belongs to the Great Oolite Series.

Yellow ferruginous sands passing upwards into the calcareous sandstone, and resting on the Upper Lias clay, were noticed by Prof. Hull in the valley of the Dorne east of Steeple Barton, where

* Life of William Smith, by J. Phillips, p. 61.
† Quart. Journ. Geol. Soc., vol. xvi. p. 116; Geol. Oxford, p. 145.
‡ Hull, Explan. of Hor. Sec., Sheets 71 and 72, p. 4.
§ R. Meade, Coal and Iron Industries, 1882.
|| Memoirs of H. E. Strickland, p. 184.

they are 30 feet thick; and he observed that they could be traced as far south as Linch Farm. He considered that the sandy beds here and at Heyford represented the "Upper Lias Sands" of Gloucestershire; but he subsequently deferred to the opinion of Mr. T. R. Polwhele that they belonged to the base of the Great Oolite.* The original view was the more correct one. (See Fig. 91, p. 324.)

On the hill above Beesley's Barn, about one mile N.W. of Bloxham, the following section was exposed:—

| | | Ft. | In. |
|---|---|---|---|
| Inferior Oolite Series. | Brown sandy loam | 0 | 6 |
| | Flaggy beds of oolite, and calcareous sandstone with plant-remains | 1 | 0 |
| | Calcareous and mortar-like beds, with ferruginous veins | 3 | 6 |
| | Sandy ferruginous and concretionary bed | 0 | 7 |
| | Hard pebbly oolitic bed | 0 | 8 |
| | Hard ferruginous and marly sandstones, pale and bluish; *Pecten* at top | 1 | 10 |

These beds are probably on the same horizon as those at Newbottle Spinney. (See p. 176.)

* Geol. Woodstock, p. 17; see also Hull, Explan. of Hor. Sec., Sheets 71 and 72, p. 4.

# CHAPTER VI.

## INFERIOR OOLITE SERIES—(LOCAL DETAILS *continued*).

### 3. NORTHAMPTONSHIRE, RUTLANDSHIRE, AND LINCOLNSHIRE.

#### GENERAL ACCOUNT OF THE STRATA.

IN the tracts now to be described, the beds admit of the following divisions, but these are not everywhere represented :—

| | | |
|---|---|---|
| Inferior Oolite Series. | Lincolnshire Limestone. | |
| | Collyweston Slate. | |
| | Lower Estuarine Series | Northampton Beds. |
| | Northampton Sand | |

Some of these divisions have been recognized in areas already described, but a fuller account of them may now be given.

#### NORTHAMPTON BEDS.

The term "Northampton yellow and brown Sandstone and Sand" was employed as early as 1815 by John Farey;* but the name Northampton Sand was not extensively used until it was adopted in 1860 by the Geological Survey.† At that time the beds were taken to be the equivalent of the Stonesfield Slate: a supposition supported by the similarity between that stratum and the Collyweston Slate (See p. 170.)

The Rev. P. B. Brodie, however, in 1853, recognized that the Northamptonshire Ironstone belonged to the Inferior Oolite;‡ and Morris in 1869 showed that the "Ferruginous Sand and Sand-rock" (Northampton Sands) were probably equivalent in part to the Yorkshire "Dogger." He also concluded that the Collyweston and Whittering Slates, and part if not all of the overlying oolite of Ponton, Corby, Stamford, Barnack, &c., represented the beds overlying the Dogger, or higher portions of the Inferior Oolite.§

Our detailed knowledge of the beds, as will be pointed out, is mainly owing to the researches carried on during the course of the Geological Survey by Prof. Judd, and to the observations of the late Samuel Sharp, of Dallington Hall.

The Northampton Beds, which attain a maximum thickness of about 70 or 80 feet, were divided by Prof. Judd, as follows :—

Lower Estuarine Series.
Northampton Sand.

* Supp. Index to Sowerby's Mineral Conchology, vol. i.
† W. T. Aveline and R. Trench, Geol. part of Northamptonshire, p. 8.
‡ Proc. Cotteswold Club, vol. ii. p. 132.
§ Geol. Mag., 1869, p. 104.

The LOWER ESTUARINE SERIES consists of white, brown, and grey sands with plant-remains, and "vertical markings" of their rootlets, with inconstant beds of clay, ferruginous nodules, &c. The beds are 10 or 20 feet thick. *Cyrena* occurs rarely; and other fossils are seldom found. Like the Upper Estuarine Series, there is evidence of the alternation of fluvio-marine, and terrestrial conditions; while the Northampton Sand below is essentially marine. In many localities however it is not possible to fix any plane of division between the strata; and where a boundary can be taken, it is likely to vary in horizon at different places.

The NORTHAMPTON SAND comprises beds of hard calcareous sandstone, ironstone, and occasional oolitic sandy limestone; these pass, often within short distances, into beds of white sand or ironstone. As Prof. Judd remarks, "Sometimes the whole thickness of the Northampton Sand is made up of white sands with occasional beds of clay; . . . but in the majority of instances a greater or less portion of its mass, usually towards its lower part, is converted into a solid bluish or greenish ironstone rock of oolitic structure, exactly resembling many parts of the Dogger and Middle Lias ironstones of Yorkshire; this rock, by weathering action set up from its joint planes, assumes a brown colour and a banded or cellular structure of a very peculiar and striking character. . . . This structure is due to the chemical action set up in the mass by the atmospheric waters, which, penetrating from the joint and bedding planes, have caused the concentration of hydrated peroxide of iron along surfaces having a general parallelism with those planes. The hard bands are often concentrically arranged. Frequently the change by weathering from blue and green carbonate and silicate to brown hæmatite has only partially taken place, and the centres of the blocks consist of the former while their outer portions are constituted by the latter, displaying the usual hard bands. The brown ore, when examined microscopically, is often seen to retain the same oolitic structure which is found in the unweathered rock."* (See Fig. 137, p. 494).

The thickness of the Northampton Sand is variable; as Professor Judd remarks, it probably never exceeds 40 feet, while it is frequently reduced to very insignificant proportions, and sometimes, as about Luffenham, almost entirely disappears, being there represented by thin beds of white sand, clay, and ironstone. These beds apparently die out for a space east of Barrowden and Wakerley, where they are from 2 to 3 feet thick, and then the Lincolnshire Limestone rests on the Upper Lias Clay.†

Fossils are not, as a rule, very abundant, and they are for the most part in the condition of surface casts and internal moulds. Occasionally, however, they are well preserved, as in a stratum at Aldwinkle, where "the substance of the shell usually remains, sometimes even, when first exposed, retaining the nacreous lustre."‡ In this case the rock is calcareous sandstone.

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* Judd, Geol. Rutland, pp. 32, 83, 90, 91, 101.

† *Ibid.*, pp. 91, 95.

‡ *Ibid.*, p. 98.

List of Fossils from the Northampton Sand :—

Ammonites corrugatus.
—— insignis (Fig. 4).
—— jurensis (Fig. 3).
—— Murchisonæ (Fig. 16).
—— opalinus (Fig. 6).
—— Wrighti.
Nautilus multiseptatus.
—— obesus.
Belemnites aalensis.
—— Blainvillei.
Nautilus jurensis.
Natica canaliculata.
Nerinæa cingenda (Fig. 22).
Pleurotomaria.
Astarte elegans (Fig. 12).
—— excavata (Fig. 20).
—— minima.
Avicula braamburiensis (Fig. 13).
—— inæquivalvis.
—— Münsteri.
Cardium Buckmani.
—— cognatum.
Ceromya bajociana (Fig. 21).
Cucullæa cancellata.
—— oblonga.
Cypricardia bathonica.
—— cordiformis (Fig. 19).
Gervillia acuta.
—— Hartmanni.
—— lata.
Goniomya angulifera.
Gresslya abducta.
—— peregrina.
Hinnites abjectus.
—— tumidus (velatus).
Isocardia cordata.
Lima cardiiformis.
—— duplicata.
—— impressa.
—— incisa.
—— Lycetti?
—— pectiniformis.
—— pontonis.
—— rigida.
—— strigillata.
Lucina bellona.
—— Wrighti.
Macrodon hirsonensis.
Modiola cuneata.
—— gibbosa.
—— imbricata.
—— Leckenbyi.
Myacites calceiformis.
Myoconcha crassa.
Ostrea flabelloides.
Pecten articulatus.
—— demissus.
—— lens.
—— personatus.
Pholadomya fidicula.
—— Heraulti.
Pinna cuneata.
—— Hartmanni.
Pteroperna plana.
Quenstedtia lævigata.
—— oblita.
Tancredia axiniformis.
Trigonia compta.
—— costata.
—— formosa.
—— Phillipsi.
—— signata.
—— v. costata.
Unicardium gibbosum.
Rhynchonella angulata.
—— cynocephala.
—— Lycetti.
Terebratula Buckmani.
—— fimbria.
—— maxillata (submaxillata).
—— perovalis.
—— trilineata.
Galeolaria socialis.
Serpula convoluta.
Acrosalenia Lycetti.
Clypeus.
Echinobrissus clunicularis.
Galeropygus agariciformis.
Pygaster semisulcatus.
Pentacrinus.
Isastræa Richardsoni.
Latimæandra Davidsoni.
Montlivaltia trochoides.
Thamnastræa defranciana.
Thecosmilia gregaria.

Other species have been recorded, but some of these require confirmation. See Morris, Geol. Mag., 1869, pp. 101, &c.; Sharp, Quart. Journ. Geol. Soc., vol. xxvi. p. 354, vol. xxix. p. 296; Judd, Geol. Rutland, pp. 276, &c.; E. T. Newton, Geol. Mag. 1891, p. 493; and S. S. Buckman, *Ibid.*, 1892, p. 258.

The Northampton Sand, where fully developed, represents the upper part of the zone of *Ammonites jurensis*, the zone of *A. opalinus*, and portions of the zone of *A. Murchisonæ*. There is at any rate no evidence of the beds with *A. striatulus*, so that, as remarked by Sharp, we may have only a portion of the passage-beds between the Upper Lias and Inferior Oolite represented in these strata.

In most localities there is evidence of erosion on top of the Upper Lias clay, and the base of the Northampton Sand contains pebbles of argillaceous limestone and ironstone, sometimes covered with Serpulæ and Polyzoa or bored by Lithodomi. With these pebbles, as pointed out by Prof. Judd and Mr. Beeby Thompson, we occasionally find examples of *Ammonites bifrons*, evidently due to the destruction of Upper Lias beds with septaria and cement-stones.

The Lower Estuarine Beds, as Prof. Judd has suggested, may represent in part the Lower Freestones of the Cotteswold Hills; but owing to the absence of distinctive fossils, we are not in a position to state the zones that may in places be represented in the sub-division. Over considerable tracts in North Oxfordshire and South Northamptonshire, these strata are directly overlaid by the Upper Estuarine Beds.*

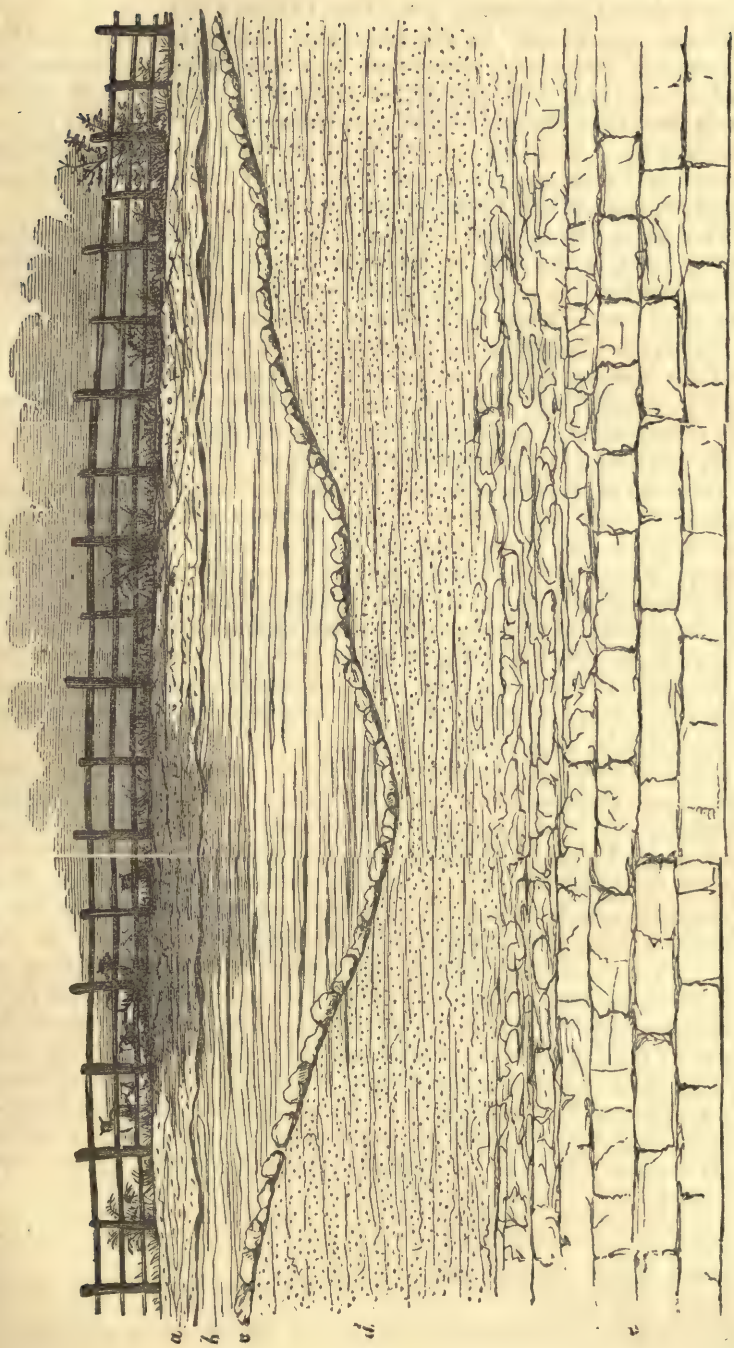
Prof. Judd has pointed out many instances of unconformity where the junction of the Upper and Lower Estuarine Series can be examined. "The bottom-bed of the Upper Estuarine Series, whenever this formation is distinctly developed, is found to be a band of ironstone-nodules, and these always rest on an eroded surface" of the underlying strata. This band however is not always present, and it is difficult sometimes to separate the two Estuarine Series. Moreover some of the irregular junctions may be attributed, partially at any rate, to subsequent erosion or dissolution of the underlying strata. As an example of the appearance presented by the junction of these two series of beds, the illustration of a pit near the Race-course at Northampton was given by Prof. Judd. "Here we have, in the lower part of the pit, beds of well stratified white sand with vertical plant-markings, and sandrock (the latter quarried as a building-stone), passing downwards into a dark brown sandstone with a very thin representative of the Northamptonshire ironstone at its base. On the eroded surface of these beds lie the light-blue, and often highly carbonaceous, clays of the Upper Estuarine Series, with the very constant layer of nodules ('ironstone junction-band') at its base." (Fig. 48. See also Figs. 51, p. 188, and 53, p. 191.)

"Bearing in mind the existence of an unconformity between these two series of estuarine beds, we are not surprised to find that, in the country to the north, a thick series of beds (the Lincolnshire Oolite) comes in like a great wedge between them. Thus in the northern part of the county of Northampton, along the valley of the Nene, the succession of beds is the same as that which we have already pointed out as presented in the neighbourhood of Northampton, while along the valley of the Welland, and in the country to the westward and northward, we have the same series of beds, with the addition of a new formation, to which the Geological Survey has given the name of the

* Judd, Geol. Rutland, pp. 39, 90, 92; Sharp, Quart. Journ. Geol. Soc., vol. xxvi. p. 375.

Fig. 48.

*Section in a pit at the Race-course, Northampton* (Prof. J. W. Judd).




*a.* Drift and soil.
*b.* Sandy clays, &c.
*c.* Ironstone Junction-band. } Upper Estuarine Series.
*d.* White sand.
*e.* Sand-rock } Lower Estuarine Series and Northampton Sand.

Lincolnshire Oolite Limestone," now generally spoken of as the Lincolnshire Limestone.* (See Fig. 112, p. 399.)

These divisions of Lower Estuarine Series and Lincolnshire Limestone, frequently shade one into the other by insensible gradations; and occasionally, at their junction, beds of fissile sandy limestone occur, which constitute the Collyweston Slate. We pass thus from Estuarine Beds to those exhibiting shallow marine or littoral conditions, and thence into the somewhat deeper-water deposits of the Lincolnshire Limestone.

The term COLLYWESTON SLATE is adopted from the name in common use, in the district between Stamford and Rockingham, where "slates" have been worked since the time of Henry VII. The chief localities are Collyweston, Easton, Dene, and Kirby.

The term "Collyweston Limestone and Grey Slate" was used by John Farey;† the earlier name of "Northamptonshire Lime" used by Michell in 1788, referring mainly to the Great Oolite. The stratigraphical position of the beds, overlying Ironstone and Lias, was noted in 1831 by John Phillips.‡

The base of the Lincolnshire Limestone becomes more or less arenaceous, and we find a gradual passage through the Collyweston Slate and its equivalents into the Lower Estuarine Series below. These junction-beds consist of sands alternating with sandy limestones, both often containing concretionary masses. The larger forms are known to the quarrymen as "Pot-lids." Where these beds become sufficiently fissile, after exposure to frost, to be utilized for roofing purposes, they constitute the Collyweston Slate: but in many places we find only indurated sandy layers. They are from 2 to 10 feet thick.

These beds, as remarked by Prof. Judd, exhibit ripple-markings, worm-tracks, and burrows, and numerous plant-remains.§ It is most interesting to observe (and the fact has been noted by others)|| that in lithological characters the Collyweston Slate exhibits nearly all the features of the Stonesfield Slate, although it is not so oolitic as some of the older beds. Moreover there is a striking general similarity in some of the fossils, as for instance in the occurrence in both formations of *Belemnites bessinus*, *Gervillia acuta*, *Trigonia impressa*, and *Placunopsis socialis*. Vertebrate remains are however comparatively scarce in the Collyweston Slate, and no remains of Insects and Crustacea have been recorded from it; although a few specimens of Saurians and Crustacea have been obtained from the Northampton Sand. One of the most characteristic fossils of the Collyweston Slate is the Gasteropod, *Malaptera* (*Pterocera*) *Bentleyi*.

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* Geol. Rutland, pp. 33, 90, 140.

† Agric. Derbyshire, 1811, p. xxix; and Supp. Index to Sowerby's Mineral Conchology, vol. i. 1815.

‡ Geikie, Life of Murchison, vol. i. p. 182. See also Brodie, Proc. Cotteswold Club, vol. i. p. 53.

§ Geol. Rutland, pp. 140, 157.

|| J. Phillips, Geol. Yorkshire, Part 1, ed. 2, 1835, p. 131.

List of Fossils from the Collyweston Slate:—

Fish-remains.
Belemnites bessinus.
Alaria hamus, var. Phillipsi.
Malaptera (Pterocera) Bentleyi.
Natica canaliculata.
—— cincta.
Patella rugosa.
Astarte elegans.
—— excavata.
Avicula braamburiensis (Fig. 13).
—— Münsteri.
Cardium Buckmani.
—— cognatum.
Ceromya bajociana (Fig. 21).
—— concentrica.
Cucullæa cancellata.
—— cucullata.
Gervillia acuta.
Goniomya literata.
Hinnites abjectus.
—— tumidus.
Homomya crassiuscula.
Lima pectiniformis.
—— Lycetti?
Lucina orbigniana.
Lucina Wrighti.
Macrodon hirsonensis.
Modiola gibbosa.
—— sowerbyana (Fig. 10).
Myacites scarburgensis.
Ostrea flabelloides.
—— rugosa.
Pecten articulatus.
—— demissus.
—— lens.
—— paradoxus.
—— personatus.
Perna rugosa.
Pholadomya fidicula.
—— Heraulti.
Pinna cuneata.
Placunopsis socialis.
Pteroperna costatula.
—— plana.
Trigonia compta.
—— costata.
—— hemisphærica.
—— impressa.
Unicardium gibbosum.
Phlebopteris polypodioides.

The age of the LINCOLNSHIRE LIMESTONE was settled mainly through the labours of Samuel Sharp and Prof. Judd. The Rev. P. B. Brodie, in 1850, had published opinions on the Inferior Oolite age of certain beds near Grantham, a view supported at the time by Lycett.* John Phillips in 1860 mentions the probable Inferior Oolite age of the Lincolnshire Oolite, but adopted (not without hesitation) a different correlation; probably because the Yorkshire equivalents were then regarded as of Great Oolite age.† For the same reason, no doubt, the specimens collected by Mr. Howell from the Lincolnshire Limestone in the Northampton area, during the original Geological Survey of the district, were considered to be Great Oolite species.

As pointed out by Prof. Judd, the chief difficulty seems to have arisen from the confusion between the Stonesfield Slate and the Collyweston Slate, shared by Lonsdale, Morris, and Ibbetson, and adopted by Brodie; but Phillips had in 1835 rightly compared the Collyweston and Whittering Slates with those of Brandsby in Yorkshire, and the Lincolnshire Oolite with the Grey Limestone of Scarborough. Subsequently Samuel Sharp of Dallington near Northampton, and Mr. Thomas Beesley of Banbury, were, by the study of the fossils in their respective areas, independently led to the conclusion that the Northampton Sand and Lincolnshire Oolite belonged to the Inferior Oolite.

While studying the general relations of the Lincolnshire strata and the characters of their faunas, in 1866 and subsequent years,

* Proc. Cotteswold Club, vol. i. pp. 55, &c.; Rep. Brit. Assoc. for 1850, Sections, p. 74.

† Quart. Journ. Geol. Soc., vol. xvi. pp. 17 (Address) and 119; see also Geol. Yorkshire, Part 1, ed. 2, pp. 3, 124.

Professor Judd was induced on stratigraphical and palæontological grounds to regard the great calcareous series in that county, and also the ferruginous beds below, as belonging undoubtedly to the Inferior Oolite.* From 1867 to 1871 he was actively engaged on the Geological Survey in Rutlandshire, and parts of Northamptonshire and Lincolnshire, and the results of his detailed work fully established the classification that has since been generally adopted.

In describing the main features of the Lincolnshire Limestone it will be proper to quote largely from Prof. Judd's Memoir :—

"The beds of the Lincolnshire Oolite display very various characters in different localities. Two aspects which it assumes, however, may be specially characterised."

"The first of these we have called the 'coralline facies' and it is characterised by beds of slightly argillaceous limestone, of compact, sub-crystalline, or but slightly oolitic texture, abounding with corals, which are usually converted into masses of finely crystallized carbonate of lime." The shells, which by their great abundance specially characterize this facies, often occur in the form of casts only, and consist of several species of *Nerinæa*, *Natica cincta*, *Pholadomya fidicula*, and *P. Heraulti*, *Ceromya bajociana*, *Pinna cuneata*, *Modiola sowerbyana*, several species of *Lima*, and *Terebratula maxillata*. "The patches of limestone rock constituted in this manner afford ample evidence of having once been coral-reefs (see p. 36 ); near Castle Bytham a pit is opened in a rock seen to be almost wholly made up of corals."

"The other variety of the Lincolnshire Oolite, which we have called the 'shelly facies,' consists almost wholly of small shells or fragments of shells, sometimes waterworn and at other times encrusted with carbonate of lime. The shells belong to the genera *Cerithium*, *Trochus*, *Monodonta*, *Turbo*, *Nerinæa*, *Astarte*, *Lima*, *Ostrea*, *Pecten*, *Trigonia*, *Terebratula*, *Rhynchonella*, &c.; and spines and plates of Echinoderms, joints of Pentracrinites, and teeth of Fishes also occur abundantly in these strata, which exhibit much false-bedding. The Gasteropods are usually waterworn, and the specimens of Conchifera and Brachiopoda usually consist of single valves often broken and eroded. These beds it is clear were originally dead-shell banks, accumulated under the influence of constantly varying currents."

"The rocks of the two facies of the Lincolnshire Oolite do not maintain any constant relations with one another; at some places, as Barnack and Weldon, beds of the shelly facies occur almost at the base of the series, while at others, as about Geddington and Stamford, the strata with the coralline facies occupy that position. Sometimes, as at Ketton and Wansford, we find beds in the Lincolnshire Oolite entirely made up of fine oolitic grains, and these constitute some of the most valuable freestones. Very rarely the grains of which the rock is composed are very coarse, and it becomes a pisolite."

* Geol. Rutland, p. 4.

"Its horizontal extent is, however, by no means commensurate with its great thickness and importance, for it is found to thin away rapidly southwards, eastwards, and northwards; it should probably be considered as the eastern portion of a great lenticular mass of marine limestones intercalated between the Upper and Lower Estuarine Series."

At Stamford the Lincolnshire Oolite is about 80 feet thick, and northwards it increases to about 100 feet: At Geddington, it is only 12½ feet thick, and it thins out entirely a few miles further south near Harrington and Maidwell. As we go eastward we also find it rapidly thinning out, between Thrapston and Fotheringhay; and at Water Newton Brickyard, Wansford Tunnel, Wood Newton, near Cross Way Hands Lodge, and Stone-pit Field Lodge, it is seen as a bed only a few feet in thickness separating the Upper and Lower Estuarine Series; these beds a little further to the east being found in actual contact.* Probably therefore the Lincolnshire Limestone is not present below Peterborough.

The Lincolnshire Limestone has been regarded as belonging mainly to the upper part of the zone of *Ammonites Murchisonæ;* it was referred by Prof. Judd to the sub-zone of *A. Sowerbyi*, and considered by him as an extension of the Oolite Marl of the Cotteswolds. Whether however the entire mass of the beds belongs to this restricted horizon may fairly be questioned. Prof. Judd points out that the Upper Estuarine Clays which rest unconformably on the Northampton Sand, maintain similar relations with the Lincolnshire Limestone near Weekley, north-east of Kettering. Here indeed the Limestone was upheaved and to some extent denuded prior to the deposition of the Upper Estuarine Series. In the neighbourhood of Brigstock, Stanion, and Little Oakley he noticed similar evidence of unconformity. "Further —at some points, as for example the Ketton Quarries, the upper surface of the Lincolnshire Oolite is seen to be not only water-worn and denuded, but to have been bored by *Lithodomi* before the deposition of the beds of the Great Oolite series." † Such borings as remarked by Prof. Morris indicate a period of arrested deposition, and show that the rock was already partly consolidated.‡

The evidence all tends to show that some unconformity exists between the Great Oolite and Inferior Oolite Series in Lincolnshire; and as we proceed in a south-westerly direction to Kettering, Northampton, and Towcester, this unconformity is more and more marked. Proceeding towards Lincoln, however, there is no such distinct evidence of a break in the series.

Mr. Hudleston has remarked that the Gasteropoda of the Lincolnshire Limestone have Bathonian affinities; and he adds, that while regarding the Lincolnshire Limestone as being in the Lower Division of the Inferior Oolite (zone of *Ammonites Murchisonæ*), an exception should have been made as regards the

* See Judd, Geology of Rutland, pp. 139, &c.
† Geol. Rutland, pp. 36–38.
‡ Geol. Mag., 1869, p. 102; see also Sharp, Quart. Journ. Geol. Soc., vol. xxix. p. 241.

fossiliferous beds of Weldon and Great Ponton,* which appear to be high in the Inferior Oolite Series.

The stratigraphical evidence shows that there are various shelly horizons in the Lincolnshire Limestone; thus the rag or shelly bed of Barnack is quite low in the series; that of Weldon and the Great Ponton shell-bed are higher. It is possible that the fossils may in some places be *remanié*, as suggested by Mr. Hudleston; but it is very difficult to fix any definite subdivisions other than very local ones.

The recorded occurrence in the Lincolnshire Limestone of such species as *Ammonites subradiatus*, and *A. Blagdeni;* of *Terebratula globata, T. sphæroidalis*, and *Rhynchonella spinosa;* and of *Clypeus Ploti*, suggest that the upper division of the Inferior Oolite is represented in some localities. More attention however needs to be given to the local stratigraphical horizons from which these fossils have been obtained.

The principal beds in the Inferior Oolite Series (Lincolnshire Limestone, Collyweston Slate, and Northampton Beds), may be roughly arranged as follows:—

Ponton Upper Shelly beds, Wansford, Ketton, Stamford, Casterton, Clipsham, Castle Bytham, and Ancaster freestones, Hibaldstow Beds.
Ponton oolite and gasteropod-bed, Houghton freestone, Stamford Marble, Weldon freestone and shell-beds, Kirton clay-bed.
Barnack Rag, Lincoln silver-bed, Kirton Beds.
Collyweston Slate, Whittering Pendle.
Duston Beds.

List of Fossils recorded from the Lincolnshire Limestone:—

Asteracanthus ornatissimus.
Strophodus.
Ammonites Blagdeni.
—— Murchisonæ (Fig. 16).
—— polyacanthus.
—— subradiatus.
Belemnites bessinus.
—— Blainvillei.
Nautilus polygonalis.
Actæonina glabra.
Alaria pontonis.
Ataphrus (Monodonta) lævigatus.
Cerithium attritum.
—— Beani.
—— —— var. weldonis.
—— limæforme, var. pontonis.
—— wansfordiæ.
Cylindrites turriculatus.
Littorina (Turbo) Phillipsi.
Natica adducta.
—— canaliculata.
—— cincta.
—— punctura.
Nerinæa cingenda (Fig. 22).
Nerinæa cotteswoldiæ.
—— Eudesi, var.
—— weldonis.
Onustus ornatissimus.
Patella inornata.
Pleurotomaria armata.
—— ornata.
Rissoina obliquata.
Trochotoma calix.
Trochus spiratus.
Arca Pratti.
Astarte elegans.
—— excavata.
—— minima.
—— pontonis.
—— rhomboidalis.
Avicula braamburiensis (Fig. 13).
—— inæquivalvis.
—— Münsteri.
Cardium Buckmani.
—— cognatum.
Ceromya bajociana (Fig. 21).
—— concentrica.
Cucullæa cancellata.

* Inf. Ool. Gasteropoda, pp. 196, 215.

Cucullæa cucullata.
—— oblonga.
Cypricardia bathonica.
Gervillia acuta.
—— Hartmanni.
—— lata.
Goniomya literata.
—— v. scripta.
Gresslya latirostris.
Hinnites abjectus.
—— tumidus.
Homomya crassiuscula.
Isocardia cordata.
Lima cardiiformis.
—— duplicata.
—— gibbosa.
—— impressa.
—— pectiniformis.
—— pontonis.
—— rigida.
—— rodburgensis.
—— rudis.
—— strigillata.
Lucina bellona.
—— despecta.
—— Wrighti.
Macrodon hirsonensis.
Modiola cuneata.
—— gibbosa.
—— imbricata.
—— sowerbyana (Fig. 10).
Myacites calceiformis.
—— securiformis.
Myoconcha crassa.
Opis gibbosus.
Ostrea flabelloides.
—— palmetta, var. montiformis.
Pecten aratus.
—— articulatus.
—— demissus.
—— lens.
—— paradoxus.
—— personatus.
—— texturatus.
Perna rugosa.
Pholadomya fidicula.
—— Heraulti.
—— ovalis.
—— ovulum.
Pholas oolitica.
Pinna cuneata.
Placunopsis socialis.
Plicatula tuberculosa.
Pteroperna costatula.
—— gibbosa.
—— plana.
—— pygmæa.
Quenstedtia lævigata.
Tancredia axiniformis.
—— donaciformis.
Trigonia costata.
—— hemisphærica.
—— Phillipsi.
—— pullus.
—— striata (Fig. 9).
Unicardium depressum.
Rhynchonella cynocephala.
—— plicatella.
—— quadriplicata.
—— spinosa.
—— sub-tetrahedra.
Terebratula Buckmani.
—— fimbria.
—— globata.
—— maxillata.
—— Phillipsi.
—— sphæroidalis.
—— perovalis.
Entalophora straminea.
Galeolaria socialis.
Acrosalenia Lycetti.
Clypeus Ploti.
—— Michelini.
Echinobrissus clunicularis.
Galeropygus agariciformis.
Pedina rotata.
Pseudodiadema depressum
Pygaster semisulcatus.
Stomechinus germinans.
Anabacia complanata.
Isastræa limitata.
—— Richardsoni.
Latimæandra Davidsoni.
Thamnastræa defranciana.
—— Lyelli.
Thecosmilia gregaria.
Nilssonia compta.
Phlebopteris polypodioides.
Ptilophyllum acutifolium.

## Local Details.

### *King's Sutton to Towcester and Stony Stratford.*

Two of the more important sections in this district, to which my attention was directed by Mr. E. A. Walford, are those exposed in a sand-pit and stone-quarry at Newbottle Spinney, between King's Sutton and Newbottle.

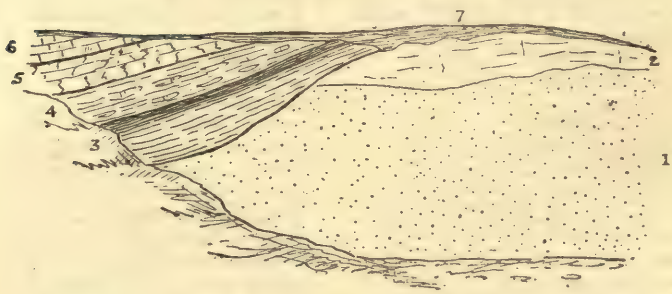
In the sand-pit, situated about a quarter of a mile south-west of Newbottle Church, the following section was exposed (see Fig. 49):—

| | | Ft. | In. |
|---|---|---|---|
| | 7. Brown clayey soil. | | |
| Great Oolite | 6. Flaggy beds of brown shelly and oolitic limestone, and gritty limestone - - - - | 2 | 0 |
| | 5. Pale marly, and slightly oolitic, limestone, with spines of Echini, *Modiola*, &c. - - - | 2 | 6 |
| | 4. Brown shelly marl (Oyster Bed), with nodules of earthy limestone: *Ostrea Sowerbyi, Cyprina, Modiola, Trigonia, Rhynchonella* - 2 0 to | 2 | 6 |
| Upper Estuarine Series. | 3. Black, bluish-grey, brown and greenish clay (resting irregularly on beds below) - - - | 2 | 6 |
| Lower Estuarine Series. | 2. White and grey clay and sand. | | |
| | 1. White brown and purplish-coloured sand, with ochreous nodules, seen to depth of - - - | 9 | 0 |

In the Spinney, apparently on a slightly lower horizon, the following beds were shown:—

| | | Ft. | In. |
|---|---|---|---|
| Northampton Sand. | Brown ferruginous and micaceous false-bedded sandy limestone, often blue-hearted. Some beds are very hard and fissile, others are softer, more calcareous, and slightly oolitic, in some places, with shelly layers and plant-remains and lignite. Hard pebbly concretions or pebbles occur in places. Exposed to depth of - | 10 | 0 |

Fig. 49.




*Section south-west of Newbottle, near King's Sutton.*

The sequence here indicated, and the general character of the beds, so well compare with the series near Northampton, that the grouping above noted may on stratigraphical grounds be adopted with confidence. Fossils are not abundant nor well-preserved, but I have obtained *Avicula braamburiensis, Lima, Ostrea, Pecten, Rhynchonella*, Crustacean remains, &c. Mr. Walford informed me that he had obtained casts of *Trigonia signata;* and he is disposed to place the beds in the Upper Division of the Inferior Oolite.

The same beds have been opened up to the south and north-west of Croughton. The sands were dug east of Warren Farm, and the stone-beds a little further north. There we find calcareous and obscurely oolitic sandy limestones, some layers splitting up so as to form flags that might be used for tiling, like the "slates" of Duston. Slaty beds of this character evidently favoured the notion that these beds, and associated sands, belonged to the Stonesfield Slate. Beds of sand and slaty sandstone were observed by Prof. Green, above the Upper Lias, in the railway-cutting north-west of Brackley Station.*

At the Brickyard north-east of Brackley, the following beds were exposed :—

| | | Ft. | In. |
|---|---|---|---|
| | Loamy soil - - - - | 1 | 6 |
| Lower Estuarine Series and Northampton Sand. | Purplish loam and clay and white and brown sand - - - - | 8 | 0 |
| | Greenish and dark sand and slightly calcareous sandstone, very hard and ferruginous: *Avicula braamburiensis*, *Pecten*, *Ostrea*, pebbles of hardened Upper Lias clay bored: (rusty springs) - - - - | 3 | 6 |
| Upper Lias - | Blue pyritic clay with *Ammonites fibulatus*: the clay is worked for the manufacture of red bricks, tiles, and drain-pipes - - - - | 8 | 0 |

The junction of Great Oolite and Inferior Oolite has been exposed in quarries south of Helmedon, and between Brackley and Radston. In the latter neighbourhood the following section was observed by Prof. Green :—

| | | Ft. | In. |
|---|---|---|---|
| [Upper Estuarine Series.] | Soft whitish sandstone - - - | 2 | 0 |
| | Clayey sand with *Ostrea* - - | 2 | 0 |
| | Dark blue clay - - - - | 1 | 6 |
| [Northampton Beds.] | Hard rubbly sand full of fossils - | 2 | 6 |
| | Hard blue limestone - - - | 2 | 0 |
| | Flaggy or slaty sandstone. | | |

It is often difficult, where the Upper and Lower Estuarine Beds come together, to fix a divisional-line between them. In the above section it appears most likely that the Upper Estuarine Beds have overlapped the Lower Beds, so as to rest unconformably on the Northampton Sand.

Helmedon (according to Morton) was long celebrated for its extensive freestone-quarries : the stone, "which lies next underneath a *stratum* of clay," having been used for the mansions of Stowe and Woburn; but even in his time the stone was no longer worked for the purpose. The same writer gives the following details of a stone-pit at Eydon,† and these indicate that the beds belonged to the Northampton Sand :—

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* See Green, Geol. Banbury, pp. 12, 19.

† John Morton, Natural History of Northamptonshire, 1705, pp. 108, 126, &c.

| | | Ft. | In. |
|---|---|---|---|
| Northampton Sand. | Reddish sandy soil - - - | 1 | 0 |
| | Sand with a small Mixture of Earth in it, about - - - - | 4 | 0 |
| | Ordinary Reddish Walling-Stone, in several thin courses - - - | 3 | 0 |
| | Freestone [sandstones], in five courses - | 6 | 0 |

At Thorpe Mandeville the rock, which has been quarried for building-stone, consists of a calcareous and slightly micaceous sandstone. Many outliers of Northampton Sand are met with on Burton Dassett Hills, and between Wardington and Daventry. As a rule they furnish little evidence beyond more or less ferruginous sands and thin-bedded sandstone, with occasional ironstone and lignite, but some fossil shells have been obtained from the sands at Dane's Hill, east of Daventry.* Iron-ore was at one time worked at Culworth.

A fine series of sections showing the sequence from the Northampton Sand to the Oxford Clay has been opened up at Stowe-Nine-Churches; the beds seen below the Great Oolite were as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Upper Estuarine Series. | Grey and bluish clay - - - | 3 | 0 |
| Lower Estuarine Series and Northampton Sand. | White and brown sands, with vertical plant-markings - - - | 9 | 0 |
| | Building-stone (poor) passes laterally into Ironstone - - - | 5 | 0 |
| | Ironstone-beds; ferruginous and concretionary sandy beds - - | 20 | 0 |
| Upper Lias Clay | (Not exposed). | | |

These beds are faulted against the Great Oolite. The strata have been described very fully by Mr. Beeby Thompson,† under whose guidance I examined the sections.

A large brickyard, east of Towcester, belonging to the "Easton Estate and Mining Co.," showed the following section:—

| | | Ft. | In. |
|---|---|---|---|
| Northampton Beds. | Ferruginous beds, with nodules of pale argillaceous ironstone near base - | 6 | 0 |
| Upper Lias - | Grey clay, with two or three impersistent bands of ironstone, to depth of about - - - - - | 10 | 0 |
| | Bluish-grey clay - - - - | 30 | 0 |
| | (Well sunk 14 feet deeper in clay.) | | |

Red Drain-pipes, Bricks, Slabs, Ridge-tiles, Paving-tiles, and Chimney-pots are here manufactured.

The above section is of interest as affording some evidence of conformity between the Northampton Sand and the Upper Lias Clay. Even if the iron-ore itself is due to infiltration or replacement after the accumulation and consolidation of the strata, the material replaces bands that tend to show conformity.

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* Aveline, Geol. part of Northamptonshire, p. 11.

† Journ. Northamptonshire Nat. Hist. Soc., vol. vi. p. 294; see also Phillips, Geol. Oxford, &c., p. 146.

By the wood, to the north of the brickyard, a sand-pit has been opened to obtain material for moulding bricks. This pit exposed 10 feet of white, grey, and brown, carbonaceous and ferruginous sand, with loamy and clayey beds here and there; and towards the top ochreous veins, while the beds are tinged purple in places.

Mr. R. Trench observed that in the railway-cutting south-east of Blisworth, the Northampton Sand is exceedingly thin, so that eastward, but a single layer of stone represents the rock.

At the south end of Blisworth Canal Tunnel the sand is only 5 feet thick, resting on Upper Lias Clay, and overlaid by blue clay of the Great Oolite (= Upper Estuarine). This was also the case at Gullet Coppice brick-kiln, south-east of Towcester.

Underlying the Great Oolite at Deanshanger, west of Stony Stratford, there is a stiff bluish-black and greenish-coloured clay with lignite and (according to the workmen) also bones. This division belongs to the Upper Estuarine Series; it was exposed to a depth of 3 ft. 6 ins. at the brickyard at Deanshanger, and was said to have been proved in an adjoining well to a depth of 18 feet. White Sand (Lower Estuarine Series), yielding water, was met with below; but the overlying clay was said to get white and sandy towards the base, so that the Upper Estuarine division was probably rather less than 18 feet in thickness.*

These attenuated representatives of the Northampton Beds do not appear to be fossiliferous, and they suggest that the formation does not extend much farther to the south-east. As remarked by Prof. Judd, "It is probable that at some points the extremely variable beds, constituting the Northampton Sand, thin out altogether, and that the higher beds of the Great Oolite series lie directly upon the Lias."† This is the case probably at Olney, where the Upper Estuarine clays may rest directly on Upper Lias Clay.

### *Duston and Northampton to Maidwell.*

Iron-ore is largely worked in the Northampton Sand of Northamptonshire, pits being opened to a depth of 10 or 20 feet, or even more, at Gayton and Blisworth, Hunsbury Hill, Duston, Spratton and Brixworth, Wellingborough, Finedon, Kettering, between Burton Latimer and the Cranfords, Twywell, Slipton, Gretton, and Easton near Stamford.

The frequent changes undergone by the Northampton Sand render the actual extent of the profitable ironstone in each locality a matter of considerable uncertainty, and one that needs to be proved by trial-holes. Throughout the whole of the district from

* H. B. W., Explanation of Horizontal Section, sheet 140, p. 5.
† Geol. Rutland, p. 31.

Blisworth to Thrapston, Stamford, and Market Overton, beds of ironstone of variable character and thickness occur; but in many cases the ore is too thin or too poor to work, while the beds in some places are represented only by sands or by ferruginous and calcareous sandstone.

In the case of the Middle Lias ironstone, the ore, in Leicestershire and other parts of the midland area, is not worked beneath a covering of Upper Lias clay; but the Northampton ironstone is obtained often beneath thick coverings of Lower and Upper Estuarine Beds and Great Oolite, for in these cases, through the overlying beds being largely of a porous nature, the rock has been weathered to a considerable distance underground. The fact is that the brown iron-ore can be worked more profitably than the unweathered rock (carbonate of iron).

Ironstone has been worked also in the outliers of Neville Holt and Uppingham, Ridlington and Preston, between Gretton and Bulwick, west of Oundle, at Southwick, &c. Traces of ironstone are also met with in the outliers of Whadborough, Robin-a-Tiptoes, and Barrow Hill. Near Normanton the ironstone is 8 feet thick, but at Ufford, south-east of Stamford, it is reduced to 1 foot.

According to Sharp's estimates, the ferruginous rock and associated sandstones must be nearly 50 feet thick in places, but the sections vary much in detail, and the thickness of the unprofitable green beds at the base, is also subject to variation in different localities. The beds containing ironstone do not attain a thickness of more than 30 feet, and these as a rule do not yield more than about 10 or 12 feet of profitable ore. These ironstone-beds pass laterally to some extent into the "Variable beds" of Sharp, and these again into the White Sands, &c. of the Lower Estuarine Series. He noted the following local subdivisions *:—

| | Ft. |
|---|---|
| White Sands - - - - - - - | 12 |
| Variable Beds, with "Slate" at the base - - - | 34 |
| Ironstone - - - - - - - | 35 |

These estimates of thickness are no doubt excessive if we add together the maximum thickness of each division.

On Dane's Hill, near Northampton, the beds exposed were as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Northampton Beds. | Rubble with bright red and pink staining in places - - 5 0 to | 6 | 0 |
| | White sand - - - - - <br> Rubbly iron-sandstone with "boxes" of iron ore: the beds becoming thicker deeper down - - - <br> Yellow ochreous iron-ore - - | 12 | 0 |

The following section was noted at one of the Duston ironstone-pits:—

* See Sharp, Quart. Journ. Geol. Soc., vol. xxvi. pp. 358, 380; vol. xxix. p. 228.

| | | Ft. | In. |
|---|---|---|---|
| Northampton Beds. | Ironstone - Sandy Bed - Bedded ironstone, oolitic in places; with *Astarte, Lima, Nautilus,* Gasteropods - | 10 | 0 |
| | Green and brown ironstone - Concretionary ironstone, with occasional small nodules - | 1 0 to 2 | 0 |
| | Earthy and sandy ironstone - | 1 | 0 |
| Upper Lias - | Clay - | 1 | 0 |
| | Grey and brown clay with thin bands of ironstone. | | |
| | Blue clay. | | |

The pits at this locality show from 10 to 12 feet of ironstone and sandy beds, some of them oolitic, and all fairly well bedded. Not more than 10 feet of brown ironstone is worked, the lower beds for about 2 feet are usually rejected, although here and there good ironstone occurs down to the bottom of the beds. These include certain green beds, which are tinted by silicate of iron and are more or less phosphatic. The oxidation of the beds has been irregular, and green-tinted ironstone is found in patches at higher levels. The ironstone rests on the blue clay of the Upper Lias, consequently the pits are usually wet at the base.

Many fossils may be obtained, and these occur sometimes in particular layers, so that there is locally an *Astarte*-bed with *A. elegans*. Among other fossils are *Ammonites insignis, Nautilus multiseptatus, Cardium, Ceromya bajociana, Cucullæa, Lima, Pecten, Trigonia, Terebratula maxillata, T. trilineata,* &c.

When the ironstone has been worked out the ground is partially filled up and levelled with the waste material. This was the case with the Danes Camp at Hunsbury Hill, the centre of which has been excavated for iron-ore and levelled. Near Duston there are several picturesque old quarries both in the ironstone and building-stone: the excavations varying in depth from 25 to 35 feet.

Northwards of the Duston ironstone-pits, the beds undergo a considerable change, similar indeed to that of the Middle Lias between Kings Sutton and Hornton. Thus the Northampton iron-ore of Duston (in a much shorter distance) passes into a useful building-stone.

The section at the New Duston Stone-pit, which I visited in company with Mr. B. Thompson, was as follows:—

| | Ft. | In. | | Ft. | In. |
|---|---|---|---|---|---|
| White sands, &c. - Sandy clay - | 3 | 0 | to | 4 | 0 |
| Dark grey carbonaceous clay - | 1 | 6 | to | 2 | 0 |
| Yellow clayey sand with rootlets - | 0 | 6 | to | 1 | 6 |
| Ochreous yellow sandstone (Roylands, &c. - | 10 | 0 | to | 12 | 0 |

| | | Ft. In. | Ft. In. |
|---|---|---|---|
| Northampton Beds | Fissile and somewhat oolitic slaty beds (White Pendle or Duston "Slate") with *Belemnites* [*Lima*, *Hinnites abjectus*]: more or less current-bedded - - - | 4 0 to | 6 0 |
| | Even layers of brown calcareous sandy rock (Yellow and Best Brown Hard building-stone). *Cardium cognatum* - - | - about | 12 0 |
| | Blue-hearted calcareous sandstone (Rough Rag and Hard Blue Rag), the blue portion more distinctly oolitic than the outer brown portions; *Astarte elegans* (with shell preserved), *Lima*, lignite, *Trigonia*, [*Ceromya bajociana*, *Gervillia*, *Pholadomya fidicula*, *Cardium cognatum*], *Ammonites opalinus*, *Nautilus* | 6 0 to | 7 0 |
| | [Ironstone] - - | - about | 3 0 |

All the beds are more or less calcareous and sandy, with ferruginous veins. Where protected the top-beds are massive. Occasionally broken-beds may be observed, and they appear to be due to the dissolution and removal of calcareous matter. Sharp has given a detailed account of this section, and the local names and other remarks in square brackets, as well as some of the thicknesses, are given on his authority.

He mentions that at the "Old Slate-quarry Close," a stone-pit was opened some years ago, and there were then exposed several of the old workings that had been carried on, at some unknown and distant time, for the obtaining of slate alone. The old process was that called "foxing," still sometimes adopted at Collyweston; shafts were sunk, and the "slate" was extracted from beneath the overlying beds by means of adits.*

At Harleston there is a quarry showing the stone-beds, which are worked to a limited extent and are rather more sandy than at Duston. The upper strata present a broken appearance in a sort of "Gully," features evidently produced by dissolution of the carbonate of lime.† Beneath come "slaty" beds of sandy rock, locally termed the "White bed." Below come the main stone-beds (Harleston Stone), which are used for building-purposes. *Astarte elegans* and other fossils are to be found.

West of Duston and near Harpole, white sands are met with, attaining a thickness of 30 feet;‡ and these beds with the ferruginous rock and building-stone of Duston, may be compared with those seen at Newbottle Spinney (see p. 176).

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* Quart. Journ. Geol. Soc., vol. xxvi. p. 370.

† Similar features have been noticed by Sharp, Quart. Journ. Geol. Soc., vol. xxvi. p. 363.

‡ Aveline, Geol. part of Northamptonshire, p. 11.

The following sections on the northern side of Northampton, well show the local character of the beds :—*

1. Bass's Pit, on the Common, was as follows :—

| | | | Ft. | In. |
|---|---|---|---|---|
| | Boulder Clay, with piped soil. | | | |
| Northampton Beds. | Ferruginous sandy stone | 3 0 to | 4 | 0 |
| | Yellow sands | | 3 | 0 |
| | False-bedded oolitic and crinoidal stone, massive in places | | 6 | 0 |
| | *Rhynchonella* - bed (*R. cynocephala*) | a few inches to | 1 | 6 |
| | Ferruginous sandy beds, yielding poor ironstone | 8 0 to | 10 | 0 |
| Upper Lias | Blue Clay. | | | |

2. The Shittlewell or Nursery quarry :—

| | | | Ft. | In. |
|---|---|---|---|---|
| Northampton Beds. | Fissile sandy ironstone | | 6 | 0 |
| | Sandy bed | 2 0 or | 3 | 0 |
| | Thin and false-bedded oolitic stone; forms a hard building-stone. The upper layers have irregular calcareous nodular bands, giving a banded appearance to the rock | | 9 | 0 |
| | Calcareous sandy stone, yielding better building-stone | about | 6 | 0 |
| | Rotten ironstone (with water) | 4 0 or | 5 | 0 |
| Upper Lias | Blue Clay. | | | |

The lower beds were not exposed at the time of my visit, the information respecting them being given by the workmen.

The irregular concretions are somewhat similar to those seen at Collyweston and are probably of secondary origin. (See p. 198).

At Boughton Green the Northampton Beds are worked as building-stone for local purposes. The beds exposed to the depth of about 20 feet, are much like those at Duston: fissile layers at the top (and when the stone has been weathered at the outcrop), then a sandy layer and massive false-bedded stone beneath.

At Wooton Brickyard, south of Northampton, the following section showed the junction with the Upper Lias clay :—

| | | | Ft. | In. |
|---|---|---|---|---|
| | Sandy soil. | | | |
| Northampton Sand. | Rubbly ferruginous sandstone. | | | |
| | Ironstone, with a few nodules. | | | |
| Upper Lias | Brown and blue ferruginous clay. | | | |
| | Sandy ferruginous band | 0 3 or | 0 | 4 |
| | Blue clay. | | | |

Here and at Duston (p. 181), as well as at a few other localities, there may be noticed the occurrence of ferruginous bands that tend to link the Upper Lias Clay with the Northampton Sand.

At the Kingsthorpe Sand-pit (Stephen Cox's), known also as the "White Stone pit," the following beds were exposed, and at one time (according to Sharp) the Upper Estuarine clays were shown on top :—

* These sections have been described by Sharp, Quart. Journ. Geol. Soc., vol. xxvi. pp. 362, 366.

| | | Ft. | In. |
|---|---|---|---|
| Lower Estuarine Beds. | Soft white and ferruginous sands, shaly in places - - - about | 10 | 0 |
| | Pale and yellow (ferruginous) sand-rock - - - - - | 9 | 0 |

The sand-rock hardens on exposure in dry weather and with heat, but crumbles with moisture. It has been used as a building-stone in Kingsthorpe, and also in Northampton in some of the old buildings (Union Infirmary, Barrack wall, &c.). About 16 cubic feet weigh 1 ton. It is not however a very durable stone, and is seldom used now for building-purposes.

It was formerly sent away for building furnaces. The sand is now employed for making mortar, while the white sand is sold for scouring purposes, for kitchen floors, farm utensils, and stables.

The section was evidently somewhat different when described by Sharp. The main mass of the white stone was then obtained from the upper portion of the series, and he observed a plant-bed with vertical rootlets near its base, and above the yellow (or brown) sandstone. He noted also a similar section near the Stand on the Race-course at Northampton.* (See Fig. 48, p. 169.)

The junction of the Northampton Beds with the Upper Lias clay was well shown in the railway (Towcester line) near Blisworth. At the base of the Ironstone-beds, nodules or pebbles of argillaceous ironstone occur; and lower down there is another band (3 or 4 inches thick) with similar rolled nodules, some of them bored. The section is as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Northampton Sand. | Ironstone-beds, with nodules at base 10 0 or | 12 | 0 |
| | Greenish clayey sand, with veins of iron-ore - - - - - | 2 | 0 |
| | Band of clay, with nodules; some bored - - - 0 3 to | 0 | 4 |
| Upper Lias - | Grey clay. | | |

Lithologically we seem here to have a kind of passage upwards from the Upper Lias clays to the Ironstone of the Northampton Beds: but on the whole the evidence favours the view that there has been some destruction of the Upper Lias clay, materials from which are incorporated in the basement-beds of the Northampton Sand (see also p. 168). The overlying Lower Estuarine Beds, &c. were shown at the Blisworth Ironstone-pit.†

In the Kingsthorpe brick-pit the junction of the beds was also shown, and there above the Upper Lias we have 6 to 8 feet of rubbly brown sandstone and ironstone, with pebbles and rolled nodules.‡

Along the Nene valley, between Northampton and Thrapston, as pointed out by Prof. Judd, the Lower Oolites are cut through, and the streams flow over the Upper Lias clay. The Northampton Sand, which is thin along the outcrop, forms the only representative of the Inferior Oolite in this tract as far as Oundle, for the

* Quart. Journ. Geol. Soc., vol. xxvi. pp. 362, 365.

† Sharp, Quart. Journ. Geol. Soc., vol. xxvi. p. 379.

‡ Sharp, *Ibid.*, p. 363.

Lincolnshire Limestone has disappeared. Hence the structure corresponds with that to the south and south-west of Kettering. Ironstone has been observed near Irchester and Raunds, but it is evidently liable to much local diminution in thickness, for the Northampton Sand is not everywhere present along the outcrop. This absence may be due to irregular overlap of the Great Oolite Series. Northwards along the valley of the Nene and of its tributary the Willow Brook, the Lincolnshire Limestone reappears near Southwick and Wood Newton, as a wedge between the two Estuarine series, the beds of which, westward and northward, gradually assume great thickness and importance.

Prof. Judd further states that "at Wadenhoe, just above the level of the river, we have sections illustrating the extremely attenuated condition of the Lower Oolites. It is only in very good sections that the exact limits between the Upper and Lower Estuarine series can be traced, both being often greatly reduced in thickness; wherever a clear section, however, can be traced, the ironstone junction-band is more or less distinctly exposed, and the Upper or Great Oolite beds are found to repose on an eroded surface of the Lower or Inferior Oolite beds." He notes the succession of strata seen at Wadenhoe, as follows:—

| | | Ft. | In. |
|---|---|---|---|
| | Cornbrash - } Traceable in slopes above the pit. | | |
| | Great Oolite Clay - | | |
| | Great Oolite Limestone | | |
| Upper Estuarine Series. | White clays - - - - | 1 | 0 |
| | Yellow, sandy Clay - - - | 1 | 0 |
| | Dark, laminated, sandy clay - - | 1 | 6 |
| | White clays, with vertical plant-markings - - - - - - | 0 | 9 |
| Lower Estuarine Series. | Dark, carbonaceous clays - - | 0 | 6 |
| | White clays, with vertical carbonaceous markings and ferruginous stains - | 2 | 0 |
| Northampton Sand.—Ironstone beds, to bottom of pit | | 8 | 0 |

Here it is evidently difficult to fix the junction between the Upper and Lower Estuarine Series, for the ironstone-band at the base of the former has not been noticed.

Fine sections of the Northampton Sands were exposed at the Spratton Ironstone-workings south of Brixworth.

The following species occur at this locality:—

†Ammonites insignis.
†‡—— jurensis.
†—— Murchisonæ.
†—— opalinus.
†Nautilus.
†Belemnites.
‡Pleurotomaria.
‡Ceromya bajociana.
‡Pecten.
†Tancredia axiniformis ?
†Trigonia compta.
†—— v. scripta.
‡Terebratula trilineata.
‡—— maxillata.
‡—— (near to) globata.

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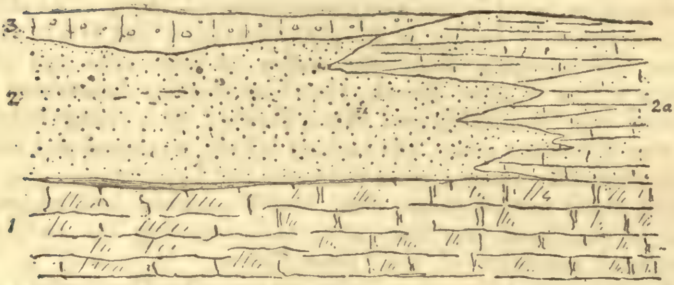
* Judd, Geol. Rutland, pp. 98, 99, 143, 169.

† Obtained by Mr. T. Jesson, and identified by Mr. E. T. Newton, Geol. Mag. 1891, p. 493; see also S. S. Buckman, *Ibid.*, 1892, p. 258. Mr. Buckman regards one form here named *A. jurensis*, as the mutation "*Lytoceras Wrighti*," and one variety or mutation of *A. insignis* he would name "*Hammatoceras Newtoni*."

‡ Obtained by H. B. W., and named by Messrs. Sharman and Newton.

FIG. 50.

*Section at the Spratton Ironstone-workings, near Brixworth, Northamptonshire.*




| | | Ft. | In. | | Ft. | In. |
|---|---|---|---|---|---|---|
| | 3. Boulder Clay - - | 3 | 0 | to | 4 | 0 |
| Northampton Sand | 2. White sand, passing into 2A. Brown sandstone and sandy ironstone: with impersistent seam of clay at base - - | 12 | 0 | to | 14 | 0 |
| | 1. Ironstone (6 to 8 ft. worked) | 10 | 0 | to | 12 | 0 |

Mr. Aveline has remarked that the beds in the area north-west of Northampton, (near E. and W. Haddon, Guilsborough, Naseby, &c.), "do not lie flat on the tops of the hills, but cover them like a saddle, every ridge being an anticlinal axis, and every brook running on a synclinal axis."* He noticed the same feature at Hunsbury Hill. He however observes that the sands generally rest on an uneven surface of the Upper Lias clay, a section illustrating this, being exposed in a cutting of the railway near Brampton station. It is possible that the features may to some extent be due to the subterranean wearing away of the Lias clays by springs.

Over the area to the north-west, there are sections, here and there, of yellow ferruginous sands and sandstone, and east of Long Buckby, a brickyard showed "sand with layers of good ironstone." About a mile north of Naseby, by the road leading to Clipston, a ferruginous rock with fossils was noticed by Mr. Aveline. Much of the ground is however covered with Drift.

Mr Aveline states that east of Hazlebeech, thin flaggy oolitic strata, similar to beds at Duston, have been opened up; they were overlaid by ferruginous sands, and evidently formed part of the Northampton Beds.

Nearer to Maidwell, however, we have the first indications (in passing north-eastwards from Towcester) of beds grouped with the Lincolnshire Limestone. Mr. Aveline describes the rock as hard, fine and compact, white, flaggy limestone, which is said to burn into "tolerable white lime,"† though it evidently contains a large proportion of silica. The only fossil found in it, so far as

* Geol. parts of Northamptonshire and Warwickshire, pp. 8-10.
† Geol. part of Northamptonshire, p. 10.

I know, is a *Trigonia.* The following section was shown at the Lime-kiln at Maidwell:—

| | | Ft. | In. |
|---|---|---|---|
| Glacial Drift | Brown stony soil | 1 | 0 |
| | Chalky Boulder Clay - - - 3 0 to | 4 | 0 |
| | Brown ferruginous sandy layer 0 1 to | 0 | 3 |
| | White and brown sand - - 1 0 to | 1 | 6 |
| | Rubble of limestone, oolite, ironstone, &c. | 2 | 6 |
| Lincolnshire Limestone. | Brown limestone; Pale earthy, and obscurely oolitic, limestone; Brown sandy limestone (like Chipping Norton Limestone) | 3 | 0 |

The term Maidwell Limestone was used by Farey, and Parkinson in 1811, as one of the divisions of our strata.*

There are few sections in the country to the east, but areas of limestone have been traced between Draughton and Harrington, and to the south-east, near Old or Wold. Calcareous beds also occur in the Northampton Sand; and near Draughton, these beds have been burnt for lime.†

### *Wellingborough, Kettering, and Rockingham.*

North-west of the Midland Station, at Wellingborough, ironstone has been worked over the ground south of the Finedon road; it is now nearly exhausted. About 4 feet of ironstone was worked (1889), there being about 4 feet of useless stone below, and then blue clay (Upper Lias). The stone worked is at the surface, and is itself poor in places, and joggled with gullies, &c. The best stone, 10 to 11 feet thick, was formerly worked about a mile N.N.W. of the railway-station. This had no "cover," and indeed the covering of Estuarine beds seems to make little or no difference to the quality of the ironstone.

At the Kettering Ironstone quarries the following section was exposed:—

| | | Ft. | In. |
|---|---|---|---|
| Soil | Brown clay and rubble | 1 | 6 |
| Lower Estuarine Series and Northampton Sand. | Yellow and white sand | 3 | 0 |
| | Grey bedded sand and sand-rock, carbonaceous and ferruginous | 1 | 6 |
| | Grey carbonaceous sand | 3 | 0 |
| | Dark grey clay and sand | 1 | 6 |
| | Grey sand passing down into laminated carbonaceous sand and clay, and thence into dark grey clay (1 foot) | 4 | 0 |
| | Grey clay and sand | 1 | 0 |
| | Yellow and white sand with plant-remains | 6 | 0 |
| | Sand-rock - - - 3 0 to | 4 | 0 |
| | Ironstone, about 6 feet worked; the green beds considered useless; Ironstone-beds, not used, 3 or 4 feet; with nodular bed at base - 10 0 to | 12 | 0 |
| Upper Lias | Blue Clay. | | |

* Farey, Agric. Derbyshire, p. 114; Parkinson, Organic Remains, vol. iii. p. 445.
† Judd, Geol. Rutland, p. 30.

FIG. 51. *Section in Sand-pit west of Weekley, Northamptonshire* (Prof. J. W Judd).


Upper Estuarine Series.
- *a.* Soil, 1 to 2 ft.
- *b.* Blue, stratified, carbonaceous clays becoming lighter coloured towards base, and passing into *c*, 1 ft. 6 in.
- *c.* White sandy clay with carbonaceous markings, 4 ft.
- *d.* More or less ferruginous bands, in places containing ironstone nodules ("Ferruginous junction-band"), 0 to 3 in.

Lower Estuarine Series.
- *e.* Ash-coloured, and white, stratified sands, containing seams of light-blue clay (up to 2 inches thick), 6 to 8 ft.
- *f.* White sands with much carbonaceous matter, generally in thin seams, 4 to 5 ft.

Northampton Sand.
- *g.* "Bed-rock." The Northamptonshire iron ore with usual characters, to bottom of pit.

The talus possibly hides a small fault with a downthrow to the East.

The beds are faulted at one point, and the Lower Estuarine beds are brought against the Upper Lias Clay, the downthrow being from 12 to 15 feet. The fault ranges from N.W. to S.E.

The identification of the beds at the Kettering quarries with the Lower Estuarine Series, is proved by the important sections at the Lime-kiln quarry and Ironstone-workings at Glendon, west of Weekley Hall Wood. The beds shown were as follows (see Fig. 52.):—

| | | Ft. | In. |
|---|---|---|---|
| Drift Soil | 12. Rubble and brown clay with pebbles; and *Belemnites*, *Gryphæa arcuata*, specimens of which are occasionally washed into fissures of the underlying rock | 3 | 0 |
| Lincolnshire Limestone. | 11. Pale earthy and oolitic limestone; net-work of Serpulæ (*Galeolaria socialis*), and some Mollusca | 2 | 0 |
| | 10. Brown oolitic limestone, with *Nerinæa* and Lamellibranchs | 4 | 0 |
| Lower Estuarine Series | 9. White, yellow, and brown sand and sand-rock | 3 | 0 |
| | 8. Brown sand-rock; Grey carbonaceous sand; Ferruginous sand | 3 | 6 |
| | 7. Stiff blue carbonaceous clay | 3 | 0 |
| | 6. Grey and brown sand | 0 | 8 |
| | 5. Blue clay | 0 | 8 |
| | 4. Grey and greenish-yellow carbonaceous sand | 2 | 0 |
| | 3. Blue clay - - - 1 0 to | 1 | 6 |
| | 2. Brown and grey clayey sand, with vertical plant-markings; passing down into white sand (2 feet) | 7 | 6 |
| Northampton Sand. | 1. Ironstone: brown-bedded sandstones, more or less raddled with iron-ore; fissile and false-bedded in places; with green cores towards the base — worked to depth of | 10 | 0 |

The quarry in the Lincolnshire Limestone at Glendon Wood, was visited on a celebrated occasion in the summer of 1869, by Sir A. C. Ramsay, Mr. Etheridge, Mr. Howell, Prof. Judd, and the late Samuel Sharp.* They then obtained a number of fossils, which proved the strata to belong to the Inferior Oolite. The following are among the species that occur:—

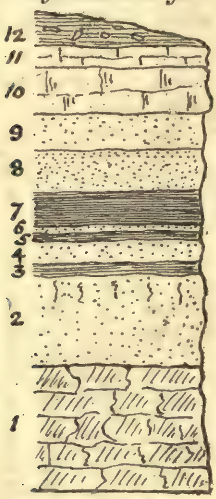
Natica cincta.
Nerinæa cingenda (Fig. 22).
Cardium Buckmani.
—— cognatum.
Ceromya bajociana (Fig. 21).
Gervillia acuta.
Lima pectiniformis.
Lucina bellona.
—— despecta.
Myacites scarburgensis.
Pecten personatus.
Pholadomya fidicula (Fig. 11).
Pinna cuneata.
Tancredia axiniformis.
Trigonia hemisphærica.
Galeolaria (Serpula) socialis.
Acrosalenia Lycetti.
Pygaster semisulcatus (Fig. 25).
Corals.

* Sharp, Quart. Journ. Geol. Soc., vol. xxvi. p. 381; vol. xxix. p. 231; and Judd, Geol. Rutland, p. 145.

The limestone in the quarry is burnt for lime. One of the workmen dug down to the sandy beds at my request. In the same field, however, about 4 feet of yellow brown and white sand was exposed; while at the adjacent ironworks, the section showed (on top) 3 feet of limestone-rubble, resting on 3 feet of white and yellow sand, and then brown sand-rock, &c. as recorded. The thickness of the Lower Estuarine Beds is greater than that noted by Mr. Etheridge.

FIG. 52.

*Section at Glendon, north of Kettering.*




12. Drift Soil.
10, 11. Lincolnshire Limestone.
2–9. Lower Estuarine Series.
1. Northampton Sand.

Borings at Weekley and Weekley Hall Wood, proved from 15 to 18 feet of "sand," resting on from 14 to 22 feet of "rock," before clay was reached. This evidence tends to show that the "rock" (Northampton Sand) is rather thick in this neighbourhood. (See Figs. 51 and 53, and p. 173.)

At Geddington the thickness of the Lincolnshire Limestone is from 15 to 20 feet. Many fossils have been obtained at Rushton, where at the base of the limestone there is a thin layer of sandy limestone (1 foot) that represents the Collyweston Slate.

Prof. Judd states that at Desborough the ironstones and overlying sands and clays were well exposed in a deep cutting near the railway-station, where they are covered by Boulder Clay; and also in the numerous large pits at which the iron-ore is very extensively dug for the purpose of being sent away by rail into Staffordshire, Derbyshire, and Yorkshire. Near this place we have an interesting example of the development of calcareous beds in the midst of the Northampton Sand. These calcareous beds form a band of hard, blue, ferruginous and very shelly limestone in the midst of the ironstone beds; this ferrugino-calcareous rock is dug for road-metal. In the country to the southwards, however, the Northampton Sand often locally assumes calcareous characters, and passes, sometimes throughout the greater part of its thickness, into an impure limestone of oolitic structure.*

Prof. Judd gives the following section of the strata exposed in a pit below Cottingham Church:—

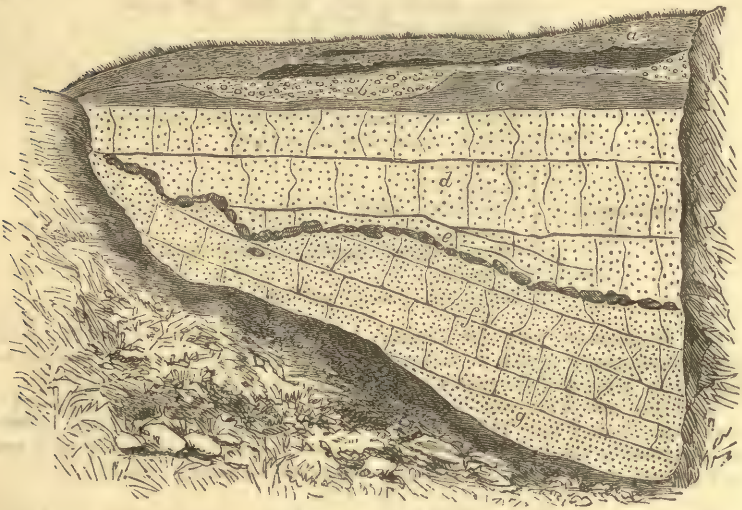
| | | FT. | IN. |
|---|---|---|---|
| Collyweston Slate | Light brown, sandy beds at the bottom of the Lincolnshire Oolite - 2 0 to | 3 | 0 |
| Lower Estuarine Beds. | Dark bluish-black marl, full of plant-remains - - - - | 0 | 4 |
| | Marl of lighter bluish-black colour, with plant-remains running through it ("plant-bed") - - - | 3 | 0 |
| | Whitish and drab laminated sands - | 2 | 6 |
| | Dark-blue clay - - - - | 3 | 0 |
| | White sand - - - - | 2 | 0 |

* Geol. Rutland, pp. 94, 95.

| | | Ft. In. | |
|---|---|---|---|
| Northampton Sand. | Ironstone - - - 6 0 to | 8 | 0 |
| | Hard red rock, with greenish centres (rock used for building-purposes) - | 20 | 0 seen |

Fig. 53.

*Section at Old Head Wood, north-east of Kettering, Northamptonshire* (Prof. J. W. Judd).




*a.* Soil.
*b.* Gravelly Drift.
*c.* Light-blue estuarine clays. } Upper Estuarine Series.
*d.* White marly clays. } Upper Estuarine Series.
*e.* Ironstone junction-band. } Upper Estuarine Series.
*f.* Soft, much jointed oolitic rock. } Lincolnshire Limestone.
*g.* Harder oolitic rock. } Lincolnshire Limestone.

The Lower Estuarine Beds in the neighbourhood of Rockingham and Gretton, are from 10 to 15 feet thick, and the ironstone beneath them is largely worked at Gretton.

At Great Weldon the Lincolnshire Limestone has long been quarried, and many "hills and holes" remain to show the extent of the old excavations. I visited this locality in company with Mr. Beeby Thompson. The stone is now worked at quarries belonging to the Earl of Winchilsea and Nottingham.

The following section down to the base of the freestones was exhibited:—

| | | Ft. | In. |
|---|---|---|---|
| Soil - - | Clay, with fragments of limestone, &c., resting on irregular and "piped" surface of beds below - - - | 1 | 6 |
| | Rubbly and decomposed rock - - | 2 | 0 |
| | Fissile limestone - - - | 1 | 0 |
| | False-bedded oolitic limestones with rolled fragments: cavernous in places. (These and overlying beds are not utilized) - - - | 7 | 0 |

| | | Ft. | In. |
|---|---|---|---|
| Lincolnshire Limestone. | Hard shelly limestone, blue-hearted; known as the Rag or Weldon Marble (used for walling, road-stone, landings, steps, &c., and occasionally polished) - - - 2 0 to | 3 | 0 |
| | Oolitic freestone, current-bedded in places (known as the A. bed) - | 2 | 6 |
| | Oolite: bottom-freestone (known as the A. 1 bed) - - 3 9 to | 4 | 6 |
| | Fine oolite (easily worked, but local, known as the B. bed) - - | 1 | 6 |
| | Rough shelly limestone, with moulds and casts of shells - - - | 3 | 0 |
| | Fine pink-coloured oolitic freestone - | 4 | 0 |
| | Fossil-bed (known also as the Marble Bed—takes a good polish) - - | 2 | 0 |
| Northampton Beds. | Ironstone - - - - | 2 | 6 |
| | Sandy clay - - - - | 0 | 6 |
| | Greenish sand, passing down into bluish-grey sand - - - | 8 | 0 |
| | "Fossil-bed" passing down into bed below - - - 2 0 to | 3 | 0 |
| Upper Lias . | Blue clay (known as "Gault"). | | |

The freestones vary in places, becoming sometimes more shelly. Annelide-borings occur in some of the layers; and they are faulted and joggled in places, with open gullies generally running east and west.

The thickness from the bottom-freestone to the "Gault" (Upper Lias Clay) was 24 ft. 9 in. The information respecting the lower beds is based on statements made by the foreman, partly from the evidence of a well-sinking, water being obtained from the greenish sandy beds.*

North-east of Great Weldon, a small opening by the road-side, showed false-bedded oolitic and shelly beds with many Gasteropods. These are decomposed limestone-beds, and many specimens were obtained by R. Gibbs, formerly the fossil-collector on the Geological Surey. The following species have been recorded† :—

Actæonina glabra.
Ataphrus (Monodonta) lævigatus.
Bourguetia elegans.
—— (Phasianella) latiuscula.
Brachytrema subvaricosum.
Ceritella lindonensis.
Cerithium attritum.
—— Beani var. weldonis.
—— latisulcatum.
—— polystrophum.
Exelissa strangulata var. ovalis.
—— weldonis.
Fibula angustivoluta.
Natica cincta.
Nerinæa altivoluta.
—— brevivoluta.
—— Eudesi, var.
—— gracilis.
Nerinæa pseudocylindrica.
—— (cf.) Stricklandi.
—— weldonis.
—— zonophora.
Rissoina obliquata.
Trochus.
Cardium.
Corbicella bathonica.
Myoconcha crassa.
—— striatula.
Mytilus lunularis.
Ostrea flabelloides.
Pecten articulatus.
Trigonia pullus.
Rhynchonella Crossi.
Terebratula maxillata.
Acrosalenia.
Pseudodiadema depressum.
Thecosmilia.

* A section is given by Sharp, Quart. Journ. Geol. Soc., vol. xxix. p. 235; see also Judd, Geol. of Rutland, &c., p. 151.

† Judd, Geol. Rutland, p. 151; Hudleston, Inf. Ool. Gasteropoda, pp. 72, 215; Hudleston and Wilson, Catalogue of Jurassic Gasteropoda, 1892.

Prof. Judd remarks that "A long narrow inlier of the Northampton Sand is seen in the upper part of the valley of the Willow Brook, near Dene, Bulwick, and Blatherwycke, but there are seldom good exposures of the strata. At Dene brickyard we have the following section:"—

| | | Ft. | In. |
|---|---|---|---|
| Lincolnshire Limestone. | Marly limestone - - 1 0 to | 2 | 0 |
| | Whitish caclareous sands - - | 1 | 6 |
| | Hard, blue-hearted, sub-crystalline limestone - - - - | 1 | 6 |
| | Brownish, calcareous sand, becoming indurated into stone at its base - | 2 | 0 |
| | Hard and compact, coralline limestone, full of *Nerinæa*, with partings of clay - - - - - | 3 | 0 |
| | Irregular bed of siliceous concretions with mammillated surfaces below. This bed is intensely hard; between its laminæ are contained numerous plant-remains; it appears to be the representative of the Collyweston Slate - - - - - | 1 | 0 |
| Lower Estuarine Series and Northampton Sand. | Irregularly stratified and false-bedded, variegated sand - - 6 0 to | 8 | 0 |
| | Black, carbonaceous, sandy clays, with nodules of pyrites, and many fragments of wood converted into the same mineral - - - - | 6 | 0 |
| | Bed of hard sandstone of a dark-grey colour ("kale" of the workmen) - | 1 | 0 |
| | Clay, similar to bed above, but lighter coloured and more sandy - - | 3 | 0 |
| | Sandy ironstone (dug in a well) 3 0 to | 4 | 0 |
| Upper Lias Clay. | | | |

"This section is of great interest as presenting another type of the Northampton Sand, namely that in which a great part of the formation is represented by beds of dark-coloured clay. These beds have in some instances been mistaken for the Upper Lias, and have, indeed, been sometimes mapped as such. A close inspection, however, soon convinces the observer that the resemblance is a very superficial one, and is confined almost entirely to colour. The clays in question are totally wanting in the tenacious character of the Upper Lias, and indeed they are composed quite as largely of arenaceous as of argillaceous materials; their dark colour appears to be due to the large quantity of organic (vegetable) matter which they contain."*

Slates are occasionally worked to the south of Dene Wood, and they were formerly worked west of Kirby Lodge to the north. A section which I saw in 1889, by Dene Wood, was as follows:—

| | | Ft. | In. |
|---|---|---|---|
| | Boulder Clay - - - 2 0 to | 4 | 0 |
| Lincolnshire Limestone. | Compact brown gritty limestone used for road-metal - - - | 3 | 0 |

* Judd, Geol. Rutland, pp. 101, 102, 152; Sharp, Quart. Journ. Geol. Soc., vol. xxix. p. 236.

| | | | Ft. | In. |
|---|---|---|---|---|
| Collyweston Slate. | Sand | - about | 1 | 0 |
| | "Slate" | - about | 2 | 0 |
| | Sand. | | | |

The pit was partially filled with water, but I was informed that "slates" were worked during the previous winter.

At Wakerley the Lincolnshire Limestone attains a thickness of about 30 feet, and has been quarried in numerous places. A bed 6 to 8 feet thick of shelly rag, like the Weldon Rag, occurs near the base of the formation. Prof. Judd observes that some of the beds are entirely made up of drifted shells, usually of small size, the valves of the Brachiopods and Conchifera being almost always disunited, and the Gasteropods exhibiting equal signs of drifting in their broken spires and other marks of attrition. Many of the shells are coated with a deposit of carbonate of lime, and the beds exhibit much false-bedding.* Hard mammillated and sandy beds representing the Collyweston Slate occur in this neighbourhood.

Prof. Judd states that near Morcott there are a number of quarries in the Lincolnshire Oolite, one of which showed the following succession of beds :—

| | |
|---|---|
| Lincolnshire Limestone. | White, oolitic limestone with some shells and Echinoderms, and a few plant-remains (stone burnt for lime). |
| Collyweston Slate and Lower Estuarine Series. | Calcareous sands.<br>Hard, blue, siliceous limestone, with few shells but many plant-remains, the latter sometimes well preserved (ferns, &c.) (stone used for road-metal).<br>Fine, white sands (used for mortar). |

Much of the limestone at Morcott is compact and marly, and devoid of oolitic grains. From this locality Prof. Judd obtained a very fine example of *Ceromya bajociana*, 6½ inches in length and 4½ inches in breadth; also the following characteristic forms :—

| | |
|---|---|
| Natica cincta. | Pinna cuneata. |
| Lima. | Galeropygus agariciformis. |
| Modiola sowerbyana. | Pygaster semisulcatus. |

*Uppingham to Stamford.*

The following notes are from Prof. Judd's Memoir :—

At Bisbrook the line of junction of the Northampton Sand and the Upper Lias is indicated by numerous springs. The lowest beds of the former series were at one time dug at this place for lining ovens, a purpose for which they are said to be admirably adapted.

At Glaston there occurs, at the base of the Northampton Sand, a very hard, somewhat calcareous band, which is crowded with a shell which closely resembles, if it is not actually identical with, *Rhynchonella cynocephala.*

* Judd, Geol. Rutland, pp. 153, 154, 178; Sharp, Quart. Journ. Geol. Soc., vol. xxix. pp. 237, 238; Morris, Geol. Mag., 1869, p. 103.

South of Uppingham, near Lyddington and at Glaston, hard beds of a calcareous nature, approaching in character those which are seen at Desborough and which make so conspicuous a feature in the country to the southwards, are seen at the base of the Northampton Sand. At Uppingham these calcareous beds are about 2 feet thick.

The lowest beds at Uppingham, as at many other points in the area, appear to be considerably less ferruginous than those above them, and are extensively quarried for building-purposes. A large quarry near the town gave the following section:—

| | | Ft. | In. |
|---|---|---|---|
| Northampton Sand. | "Bearing" (ironstone rock with the usual characters) - - - | 8 | 0 |
| | Hard building-stone, of a blue colour - | 8 | 0 |
| | Mass of concretions or pebbles embedded in a blue ironstone matrix - | 0 | 6 |
| | Upper Lias Clay. | | |

The following section was obtained in a well at the town of Uppingham:—

| | | Ft. | In. |
|---|---|---|---|
| Lower Estuarine Beds. | Sand and Clay - - - - | 12 | 0 |
| Northampton Sand. | Good ironstone rock - - 5 0 to | 6 | 0 |
| | "Rock," building-stone - - | 3 | 0 |
| | Upper Lias Clay - - dug to | 4 | 0 |

A stone-pit just outside Uppingham, on the road to Stockerston, illustrates very admirably the gradual passage from the unweathered blue rock at the base, up to the perfectly weathered, deep brown, "cellular" ironstone above, and the transition upwards of this ironstone into loose sands (Fig. 54). The thickness of the beds is about 20 feet.*

The following section was noted by myself in the road-cutting on Black Swan Hill, near Thornhaugh:—

| | | Ft. | In. |
|---|---|---|---|
| Lincolnshire Limestone. | False-bedded shelly rag (like Barnack Rag) - - - - - | | |
| | Ferruginous brown oolite weathering rubbly - - - - - - | 5 | 0 |
| | Fine brown oolitic stone, with large and coarse particles and crinoidal fragments - - - - | | |

At Whittering (or Wittering), east and west of the high-road, flaggy beds of oolite and of tough flaggy calcareous sandstone (yielding the slabs known as "Whittering Pendle") were formerly worked. The beds came out in thick slabs adapted for piggeries, paving, &c. The shallow quarries have since been closed and levelled.

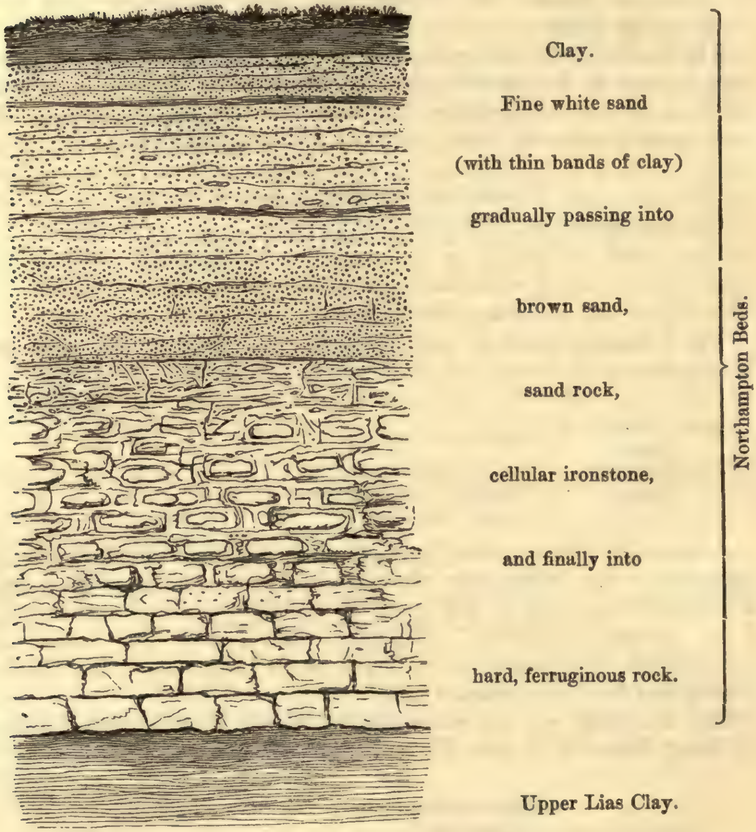
S. Sharp recorded from the Whittering Pendle, *Belemnites bessinus*, *Gervillia*, *Hinnites*, *Lima*, *Lucina*, *Perna*, *Pecten*, &c.†

* Judd, Geol. Rutland, pp. 108, 109.

† Quart. Journ. Geol. Soc., vol. xxix. p. 274. The organism named *Aroides Stutterdi*, at one time regarded as a Coral, then as a Plant, has since been considered to be a portion of an Echinoderm, J. S. Gardner, Geol. Mag., 1886, p. 200.

Fig. 54.

*Stone-pit near Uppingham, on the road to Stockerston, Rutlandshire* (Prof. J. W. Judd).




A section east of Thornhaugh, showed sands and calcareous sandstones on the horizon of the Collyweston Slate: it was as follows:—

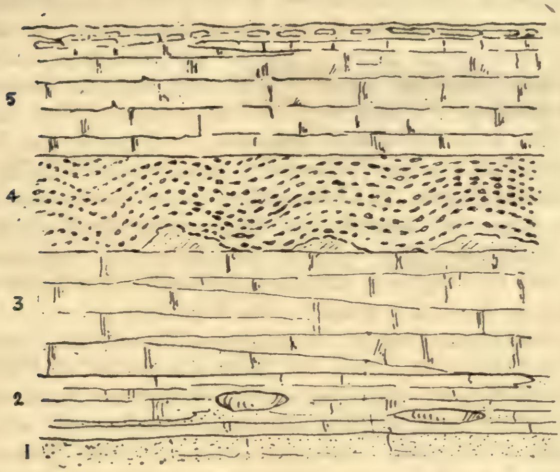
| | | Ft. | In. |
|---|---|---|---|
| Lincolnshire Limestone. | Rubbly and fissile oolite - - - | 3 | 0 |
| Collyweston Slate. | Sands and irregular beds of calcareous sandstone, more or less concretionary, with pot-lid structure: a thick bed (18 in.) occurs near the base - - - - about | 10 | 0 |

The concretionary beds much resemble those in the Collyweston slate-quarries.

The lithological characters of the beds at Collyweston are exceedingly variable, but the following section affords a good notion of the general sequence:—

FIG. 55.

*Section at "Slate-mine," Collyweston, Stamford.*




| | | FT. | IN. |
|---|---|---|---|
| Lincolnshire Limestone. | 5. Marly and oolitic limestones with occasional sandy beds - 10 0 or | 12 | 0 |
| | 4. Sand with curious concretionary nodules and thin irregular slabs, that occur in undulating layers (in one place to the number of 37) and coalesce with oolitic and sandy stone at base [Top Sand] - - | 3 | 0 |
| | 3. Hard brown oolite; passing down into pale gritty limestone and calcareous sandy stone (forming roof-bed of mine) - - - | 6 | 0 |
| Collyweston Slate - | 2. "Slate"; fine-grained calcareous sandstone - - - 3 0 to | 3 | 3 |
| Lower Estuarine Series. | 1. Soft yellow calcareous sand and sandstone. | | |

The "Slate" is here mined, and the galleries are supported by piled slabs of stone. A more particular account of the "slates" will be given in the chapter on Economic Products, p. 483.

The strata above the slaty beds comprise oolitic freestones, and hard beds with scattered oolitic grains, that recall to mind the lower beds of the Great Oolite that are worked at Througham Field, near Bisley. The pot-lid structure so familiar at Stonesfield, is repeated at Collyweston. Altogether the beds are exceedingly variable in character.

Full particulars of the strata have been published by Sharp, who has noted the quarrymen's names of the beds, and the fossils obtained from them.

The bed No. 3 has yielded *Natica cincta, Gervillia acuta, Hinnites tumidus, Ceromya concentrica, Pecten aratus,* Ferns, &c. Some of the layers are used as building-stone: they are known in ascending order as the Bitch, Hard Limestone, Hard Sand, and Brood. The upper beds, No. 5, also yield *Natica cincta*

*Hinnites tumidus, Pecten aratus, P. lens,* &c. These beds include the Ringstone, White and Red Cale.*

The curious nodules of sandstone that occur in this district and elsewhere (see p. 153), have been noticed by Capt. Ibbetson and Prof. Morris: they speak of "a concretionary bed of sand with irregular cylindrical ramose bodies of sandstone, resembling fucoid stems, assuming sometimes a very singular arrangement, as at Wittering [Whittering]."† It seems to me that these nodules, like the "pot-lids," indicate a stage in the formation of sandstone—a process that may in some cases be going on now. The undulating layers at Collyweston have most probably been disturbed since the formation of the nodules, perhaps by dissolution of calcareous matter from the subjacent stratum (which presents here and there a hummocky surface), and by mechanical movements in the sandy mass. (See Fig. 55.)

Prof. Judd states that at Duddington there are a number of old pits near the river which still bear the name of "the Slate-pits"; according to tradition, slates similar to those of Collyweston were once dug there, and their abandonment was due to their being "drowned" by the waters of the Welland.‡ At Easton also, I was informed that at times the water rises in the pit so that the men are "drowned out."

The section on the north side of the road at Easton, near Stamford, was as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Lincolnshire Limestone and Collyweston Slate. | Rubbly fine-grained oolite - - | 6 | 0 |
| | Even layers of oolitic freestone, with closely packed oolite grains - - | 7 | 0 |
| | Hard grey and pinkish shelly limestone, with scattered oolite grains 1 8 to | 2 | 0 |
| | Yellow sands, with irregular nodules of calcareous sandstone - - | 4 | 0 |
| | Tough brown sandy limestone, packed with oolite grains in the upper and lower portions, and with scattered grains in the middle - - | 1 | 6 |
| | Sand with nodules (as above) - - | 1 | 0 |
| | Irregular calcareous sandstone, with scattered oolite grains, and plant-remains. (Water rises to this bed) - | 2 | 0 |
| | "Slate-beds." Banded calcareous and micaceous sandstone, showing Pot-lid structure - - 2 0 to | 2 | 6 |
| Northampton Beds. | Sands, about 6 feet § - - | (not seen). | |
| | Ironstone beds - - - - | | |

The Slates here yield *Malaptera* (*Pterocera*) *Bentleyi* (known to the quarrymen as "Bird's Claws"), *Gervillia, Lucina Wrighti, Pecten,* &c. The Limestone is used for walling, and is burnt for lime. The sand is employed in making mortar, and for foundry-purposes.

* Sharp, Quart. Journ. Geol. Soc., vol. xxix. pp. 243–245.
† Rep. Brit. Assoc. for 1847, sections, p. 129.
‡ Geology of Rutland, p. 154.
§ See also Judd, Geol. Rutland, p. 156.

Prof. Judd remarks that "Between Easton and Stamford the hard, siliceous rock forming the base of the Lincolnshire Oolite and representing the Collyweston slate, is exposed. At several points near the bed of the River Welland at Stamford, it has been observed; and here Sharp procured his interesting specimen of *Astropecten cotteswoldiæ*, var. *stamfordensis*. A fragment of the same beautiful starfish has recently been found at Collyweston."

At Easton Woodside, north-west of Easton near Stamford, the Northampton Beds have been worked for ironstone. This comprises bedded sandy ironstone, showing here and there "cellular" or "box-structure" like the Northampton ironstone at Duston. It is worked in places to a depth of 9 feet. The junction with the Upper Lias was not shown: but the full thickness of the ironstone is estimated to be about 15 or 20 feet.*

Turning now to the celebrated district of Barnack, south-east of Stamford, it will be interesting to quote the following passage from Prof. Judd's Memoir:—

"In the neighbourhood of Barnack the very extensive 'hills and holes' show what enormous quantities of the celebrated 'Barnack-rag' were quarried in former times. Indeed almost all the beautiful ecclesiastical edifices of the Norman, Transition, Early English, and Decorated periods in North Northamptonshire and South Lincolnshire, and especially those of the adjoining Fenland, appear to have been constructed of stone derived from these extensive quarries, around which a very considerable population of quarrymen appears in early times to have been established. Far earlier, even in Roman times, the value of this building material seems to have been recognised; but before the perpendicular period (15th century) the use of the stone appears to have been abandoned, probably from the exhaustion of the quarries. The excavations of the 'hills and holes' of Barnack, now filled up and grass-grown, are continued in Walcot Park, where some of the pits still remain open. Several pits in the Lincolnshire Oolite are still worked near Barnack, but in none of them is a rock of exceptionally fine quality found; and the general opinion that the Barnack-rag (a freestone of excellent quality almost made up of small shells and other drifted organisms, and containing a few scattered oolitic grains) is now wholly exhausted, is probably the correct one."

Prof. Judd also notes the following section in a pit near Barnack:—

| | | |
|---|---|---|
| | Soil. | |
| Lincolnshire Limestone. | Rubbly oolite.<br>Rock, made up of small shells and fragments of shells, Echinoderms, Corals, &c.; plates and spines of *Cidaris*, with joints of *Pentacrinus*, and many specimens of the minute variety of *Rhynchonella spinosa* (*R. Crossi*), abound - | 4 feet seen. |
| | Ordinary white, oolitic limestone, not shelly - - - - - | 8 feet. |
| Collyweston Slate Beds. | Beds of yellow and white sand, containing hard siliceous concretions - | Base not seen. |

* Judd, Geol. Rutland, p. 103.

The shelly rock is regarded as part of the celebrated "Barnack-rag." It is interesting to notice that the shelly facies of the Lincolnshire Oolite occurs at Barnack near the base of the series.* The Gasteropoda include the following species† :—

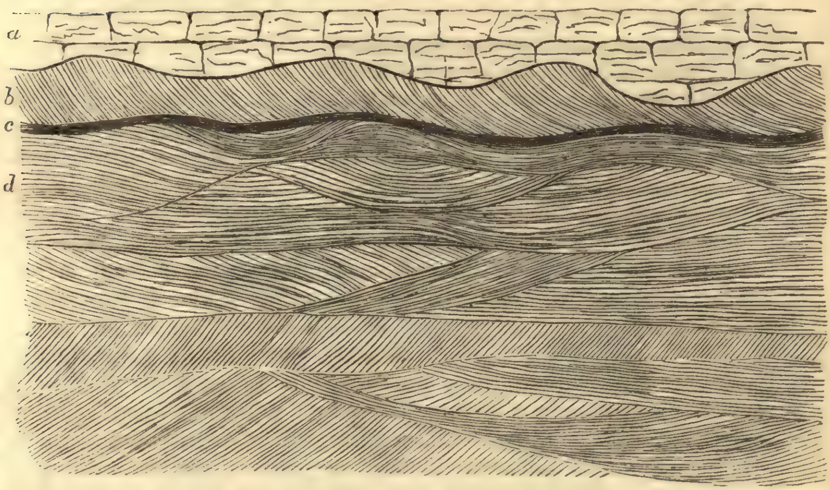
| | |
|---|---|
| Bourguetia (Phasianella) elegans. | Littorina Phillipsi. |
| Ceritella Sowerbyi. | Nerinæa pseudopunctata. |
| Cerithium Georgei. | Onustus ornatissimus. |
| —— wansfordiæ. | |

There is a specimen of *Natica cincta* from Barnack, in the Northampton Museum.

The above section shows the character of the strata now visible near Barnack; old quarries, more or less obscure, are to be seen by the road south-west of the village, and west of the southern windmill.

FIG. 56.

*Pit in the Northampton Beds, between Ufford and Marholm, Northamptonshire.* (Prof. J. W. Judd.)




| | |
|---|---|
| (*a.*) Siliceous limestone ("pendle") with mammillated surfaces below - - - - - - | Collyweston Slate, and Lower Estuarine Series. |
| (*b.*) Obliquely-laminated, fawn-coloured sand, 1 ft. - - | |
| (*c.*) Purplish finely laminated clay, 3 in. - - - | |
| (*d.*) Finely-laminated, fawn-coloured sands, with much oblique lamination, 5 ft. exposed - - - - | |

It may be questioned if the Barnack Rag is entirely exhausted; the stone has been opened up, for local use, immediately to the north-west of the village, and there blocks weighing 3 tons were obtained by means of cranes. I was informed that the stone, when first raised, can be readily sawn, but on exposure it becomes

* Judd, Geol. Rutland, pp. 172, 173; see also Sharp, Quart. Journ. Geol. Soc., vol. xxix. p. 269.

† Hudleston and Wilson, Catalogue of Jurassic Gasteropoda, 1892.

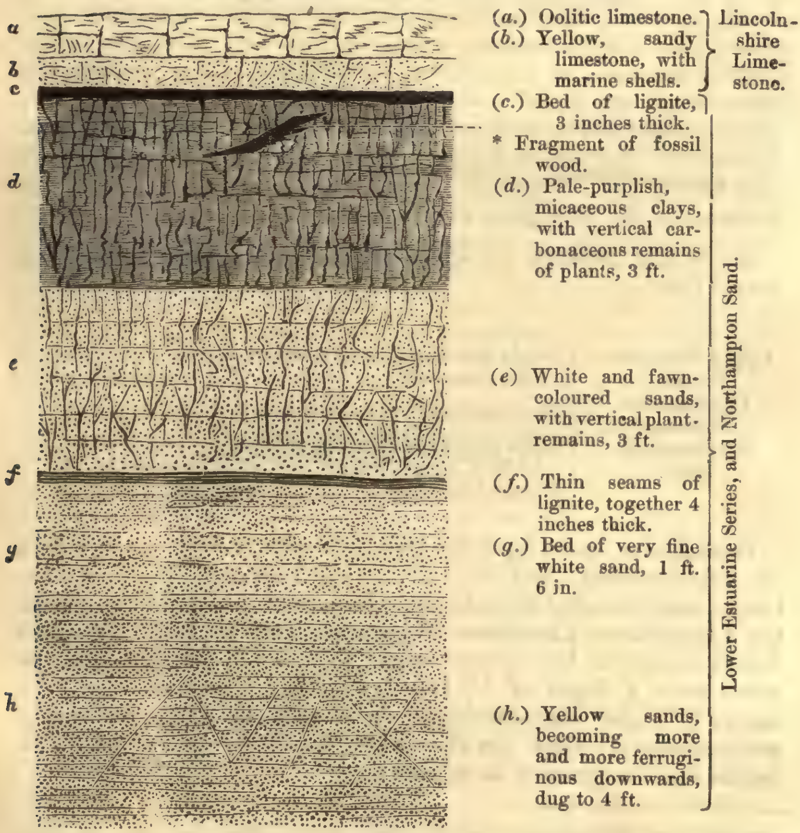
"as hard as iron," turning the edges of tools. On this account masons do not like it, and the stone is not sought for by them. The oolite beneath the rag, furnishes a good workable freestone;* but beds of variable quality are associated with it. South-west of Barnack, where the rag-beds occur in a decomposed form at the surface, they are 6 feet thick, and underlaid directly by a thin band of compact limestone with scattered oolitic grains: free-stone occurs below.

A well sunk to a depth of 26 feet, through these rocks into the sandy beds below, obtained a good supply of water.

Prof. Judd remarks that at Ufford, south-east of Barnack, the white sands of the Lower Estuarine Series are highly micaceous, and contain many thin layers of lignite and fragments of wood. One of the pits afforded the following section (Fig. 57):—

FIG. 57.

*Section of Northampton Beds in a pit east of Ufford, Northamptonshire.* (Prof. J. W. Judd.)




(b) is similar to and corresponds with (a) of the section, Figure 56, on page 200.

* See note on microscopic characters, by Mr. Teall, p. 11.

Prof. Judd states that the plant-markings which occur in the beds (*d*) and (*e*), appear to indicate that plants actually grew upon the spot, and were embedded as they stood, by the quiet deposition of fine sediment around them. The beds called "root-beds" by Prof. Morris, which occur in the Upper Estuarine Series, greatly resemble (*d*). The clay of (*d*) is very fine-grained, and the surfaces of its laminæ are covered with scales of mica: in it the carbonaceous matter is always preserved, while in the sands below (*e*) it is more frequently removed, and the sides of the empty tubes are stained with oxide of iron. In descending through the lower beds of sand (*h*) we find them more and more impregnated with oxide of iron, which exists as a coating around the individual grains; when this coating is removed by the action of acid, a white sand remains similar in every respect to that forming the bed (*g*). From the statements of workmen it appears that this ferruginous character still increases in going deeper, and that the bed which rests directly on the Lias Clay is a thin band of the ordinary ferruginous rock of the Northampton Sand.

Another section, between Ufford and Marholm, is shown in Fig. 56.

Near Helpstone Heath Farm the sands have been well exposed. They are much false-bedded, and contain (according to Prof. Judd) in some layers, *Pinna cuneata*, *Ostrea acuminata*, *Trigonia pullus*; and in others, numerous *Cyrenæ*. The base of the sands is not seen in this pit, but in another in the vicinity, the white sands are found resting directly on the Upper Lias clay, without the intervention of any ferruginous rock. The total thickness of the Northampton Beds at this place is rather more than twenty feet. Towards the west and south of Helpstone, the thickness of the ferruginous rock increases.*

At Water Newton brickyard the following beds have been proved†:—

| | | Ft. In. | Ft. In. |
|---|---|---|---|
| Upper Estuarine Series. | Sands and clays, with nodular ironstone at base | 3 0 | to 9 0 |
| Lincolnshire Limestone. | Fine grained oolitic limestone | 1 3 | to 4 0 |
| Northampton Beds. | Clays and sands with ironstone beds at base | 16 0 | to 18 0 |
| | Upper Lias Clay. | | |

Both Lower and Upper Estuarine clays have been worked here for brick-making, and the Roman potteries of Durobrivæ or Castor were situated hereabouts. Eastwards as before mentioned the Lincolnshire Limestone disappears; and at New England, Peterborough, a boring was made to a depth of 428 feet, the strata after a depth of 78 feet being blue clay and stone. No supply of water was obtained. It is probable that the boring was commenced after the Cornbrash had been excavated. The details may be grouped as follows:—‡

* Judd, Geol. Rutland, pp. 104–106; Sharp, Quart. Journ. Geol. Soc., vol. xxix. p. 272.

† Judd, Geol. Rutland, pp. 99, 100, 171, 189.

‡ See also Porter, Geol. Peterborough, p. 98.

| | | Thickness. | | Depth. | |
|---|---|---|---|---|---|
| | | Ft. | In. | Ft. | In. |
| Great Oolite Clay. | Sandstone and clay - | 10 | 0 | — | |
| | Blue clay and shells - | 10 | 0 | 20 | 0 |
| Great Oolite Limestone. | Hard blue rock - - | 10 | 0 | 30 | 0 |
| Upper Estuarine Series. | Hard brown clay - - | 25 | 0 | 55 | 0 |
| | Rock, hard clay and shells - | 6 | 3 | 61 | 3 |
| Northampton Beds. | Sand and shells - - | 7 | 9 | 69 | 0 |
| | Hard clay shells and sand - | 6 | 6 | 75 | 6 |
| | Rock - - - - | 2 | 6 | 78 | 0 |
| Upper Lias | Blue Clay - - - | 85 | 0 | 163 | 0 |
| Middle and Lower Lias. | Rock - - - - | 3 | 0 | 166 | 0 |
| | Clay with occasional layers and bands of stone - | 262 | 4 | 428 | 4 |

In Burghley Park the following beds were opened up during workings for ironstone:—*

| | | Ft. | In. |
|---|---|---|---|
| | Remnants of Collyweston Slate. | | |
| Lower Estuarine Series. | Pale yellow sand - - - | 5 | 0 |
| | Blue clay, with vertical plant-markings - - - - - - | 1 | 6 |
| Northampton Sand. | Ferruginous beds. Ironstone with nodular band at base - - - | 8 | 9 |
| | Upper Lias Clay. | | |

Prof. Judd states that to the west of the Park, the Lower Estuarine clay overlying the Ironstone, has been dug for the manufacture of Terra-cotta. Here the clay (from one to four feet thick) is of a pale-blue colour and somewhat sandy, and according to Mr. Lumby, the proprietor, it is composed of almost pure silicate of alumina with a little free sand in very fine grains. Sandy lumps also occur in the mass, and are ground up with the clay in the mill. This admixture of the clay with fine sand is said to greatly improve its quality. Mixed with a very small quantity of the white clay from Poole, Dorsetshire, these clays of the Lower Estuarine Series make an excellent cream-coloured terra-cotta. Similar clay is found at other places in the same bed, and is largely used in the well-known terra-cotta works of Mr. Blashfield of Stamford.†

* Sharp, Quart. Journ. Geol. Soc., vol. xxix. p. 273.

† Judd, Geol. Rutland, pp. 103, 165.

# CHAPTER VII.

## INFERIOR OOLITE SERIES—(LOCAL DETAILS *continued*).

### *Ketton and Stamford to Cottesmore.*

The Ketton Stone is one of the most famous of the building-stones of the Inferior Oolite, and this occurs in the highest portion of the Lincolnshire Limestone that is exposed in the area.

The rocks have been opened up alongside the railway-cutting by Ketton Station (Geeston), for the Ketton Lime-works; but the principal quarries were situated to the north of the village, on a part of Ketton Heath known as "Ketton Stones." Here, as in other localities, the stone dug by the old quarrymen was obtained near the surface and not beneath coverings of clay. Hence the stone was to a large extent naturally seasoned.

Pits have of late years been re-opened in the old quarry-ground of the Ketton Stones, and freestone has been dug in places beneath a considerable covering of the refuse from old workings. The freestone is a good deal shattered. The best section that I saw in this district was situated on the western side of the outlier of Upper Estuarine Series, &c., west of Ketton Stones: it was as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Upper Estuarine Series. | Grey and brown clay - - - | 3 | 0 |
| | Grey banded clay with "race," ferruginous gritty nodules, and calciferous gritty layers; *Ostrea Sowerbyi* - | 10 | 0 |
| | Blue carbonaceous clay - - - | 6 | 0 |
| | White sand and grey clay with rootlets; ironstone nodules at the base - | 7 | 0 |
| Lincolnshire Limestone. | Oolitic freestone—the upper portion stained red to a depth sometimes of 2 ft. 6 in., this portion is known as the "Crash bed"; the lower portion yields a good freestone, and forms a part of the Ketton Stone - - | 6 | 0 |
| | Irregular bed of tough sparry blue-hearted oolite showing "lustre-mottling"; this bed is known as "Rag," and does not furnish good freestone. It passes down into yellow freestone, that is quarried as a lower bed of Ketton Stone - - - | 6 | 0 |

No lower beds were exposed, but they were formerly shown in the railway-cutting at Geeston, near Ketton.*

With regard to the stone-beds, Prof. Judd makes the following remarks† :—

* Morris and Ibbetson, Rep. Brit. Assoc. for 1847, sections, p. 128; Sharp, Quart. Journ. Geol. Soc., vol. xxix. p. 243.

† Geol. Rutland, p. 155; see also Sharp, Quart. Journ. Geol. Soc., vol. xxix. p. 240.

"The 'Crash-bed' is a coarse oolite full of fragments of shells, which lie on its planes of bedding. When first dug this rock is very soft, but by exposure it acquires extreme hardness. It is of a purplish red colour, but varies greatly in the depth of the tints which it exhibits. It is only used locally for rough purposes, such as field-walls, &c. A very interesting circumstance in connexion with the 'Crash-bed' is that its upper surface often exhibits the vertical burrows of *Lithodomi*, indicating the long pause which ensued between the deposition, and probably partial denudation of the Lincolnshire Oolite, and the formation of the Estuarine strata which lie immediately above it."

"The celebrated Ketton freestone is a beautiful, oolitic limestone of good colour, combining great freedom of working with remarkable powers of resisting crushing force and wonderful durability. It is almost wholly made up of very uniform oolitic grains, exhibits scarcely any trace of bedding-planes, and can be placed indifferently in any position in buildings without exhibiting any [special] tendency to weathering."

The following species of fossils have been recorded from the Ketton quarries :—

Nerinæa pseudocylindrica.
Cypricardia bathonica.
Cyprina nuciformis.
Lima pectiniformis.
Lucina Wrighti.
Perna rugosa, var. quadrata.
Pholadomya fidicula.
Trigonia pullus.
Unicardium.
Terebratula maxillata.
Isastræa Richardsoni.

The Upper Estuarine Series, and underlying Ketton Stone, were again shown in excavations at "the Deeps" on the southern side of the Ketton Stones; but the junction was much obscured by a downwash of the clays.

A good section of the junction was shown in a quarry near the Stamford brickyard, north-west of Stamford. The top beds of the Lincolnshire Limestone (or Stamford freestone), were in a crumbly state where exposed, sometimes even to a depth of 7 or 8 feet, but solid blocks were obtained 2 or 3 feet down in most places. The rock is a closely packed oolite, stained red irregularly, like the Rag of Ancaster. Galls and pockets of the Upper Estuarine clays occur in the upper layers of stone. (See Fig. 115, p. 418.)

The general section in this neighbourhood may be stated as follows :—

| | | Ft. | In. |
|---|---|---|---|
| | Upper Estuarine Beds. | | |
| Lincolnshire Limestone. | Oolitic freestone, occasionally pisolitic 10 0 or | 12 | 0 |
| | Softer beds of rubbly oolite and marl, with Corals - - - - | 8 | 0 |
| | Grey oolite - - - - - | 2 | 0 |
| | Fissile marly and shelly limestone and (locally) layers of calcareous sandstone - - - - 2 0 to | 3 | 0 |
| | Hard, compact blue-hearted limestone, with scattered oolite grains (Stamford Marble); passing down into buff limestone, with brown oolite grains (including "Stamford Stone") about | 12 | 0 |

A well-section, noted by S. Sharp, showed a further thickness of about 20 feet of coarse oolitic limestones, &c., down to the representative of the Collyweston Slate. He estimated the total thickness of the beds at about 65 feet. He has also recorded a number of fossils from a well sunk into the Northampton Sand at Little Casterton.* From a fissure in the rock at Tinkler's Quarry, Stamford, some Pleistocene Mammalian remains were obtained.†

The Stamford Marble is a hard white or pale-buff blue-hearted limestone, with scattered oolitic grains. It was formerly used for mantel-pieces, being smoothed but not polished, and sometimes blackened. Specimens of this rock (one containing *Nerinœa*), which I obtained at Stamford, are placed in the Museum at Jermyn Street. Sharp also mentions a fine cream-coloured stone under the name of Stamford Stone, which formerly was much used for chimney-pieces, and for the interior carved work of churches. This seems to belong to the same set of beds as the Marble: it contains *Natica, Nerinœa, Lima*, and some plant-remains.

The freestones in the upper part of the Lincolnshire Limestone have been quarried by the high road to Great Casterton, near the turning to Little Casterton. The Casterton Stone, like that of Stamford and Ketton, is of good repute. The marly beds below the freestone have yielded a number of fossils, recorded by S. Sharp.‡

Referring again to Prof. Judd's Memoir, we learn that "At Clipsham Quarries the beds of the Lincolnshire Oolite are extensively wrought for building-purposes. The stone is quarried from beneath a considerable thickness of the Estuarine Clays forming the base of the Great Oolite Series. The sections are similar to those of Ketton and Stamford brick-yard (Torkington's pit), but not so complete. The ironstone junction-bed is present, but does not seem to be so persistent as is usually the case. The Clipsham sections are, however, somewhat obscure. The Clipsham freestone which, like that of Ketton and Weldon, is associated with other beds of more or less coarse shelly rag, is an oolitic limestone similar to that of Ketton, but less even in grain, and with a few shells scattered through its mass. Its characters more closely resemble those of the extensively worked stone of the same age about Ancaster."

"At the cross-roads between Greetham and Thistleton, there are extensive quarries, exhibiting the Lincolnshire Oolite as a compact, sub-crystalline limestone, presenting many of the shells, &c. characteristic of the coralline facies of the formation." § Rock of this character does not furnish durable building-stone.

South of Luffenham brickyard there is a fault which lets down the Collyweston Slate and Ironstone about 13 feet, on the south, where the beds appear much disturbed. The section was as follows:—

| | | |
|---|---|---|
| | Collyweston Slate. | |
| Lower Estuarine Series. | Grey and purplish clay and yellow sand - - - - - | 6 feet. |
| Northampton Sand. | Ironstone (top exposed at one part, and base in another) - - - | 6 feet seen. |
| Upper Lias. | Blue clay with septaria and ferruginous nodules. | |

The junction of the Ironstone with the Upper Lias was tolerably well marked, but there was no evidence of unconformity in the relations of the strata.

* Quart. Journ. Geol. Soc., vol. xxix. pp. 251, 255.
† *Ibid.*, p. 254.
‡ *Ibid.*, p. 252.
§ Geology of Rutland, p. 167.

The general section of the beds, as noted by Prof. Judd, near Edith Weston, Whitwell, and Exton is as follows:—

| | |
|---|---|
| Lincolnshire Limestone. | Oolitic limestone.<br>White siliceous limestone with mammillated surfaces (equivalent of Collyweston Slate). |
| Lower Estuarine Series. | White and fawn coloured sands.<br>Light blue clays. |
| Northampton Sand. | Ironstone beds - - - - 10 to 12 feet. |
| Upper Lias Clay. | |

Prof. Judd states that from Burley, for some distance northwards, the Lincolnshire Limestone does not reach the edge of the escarpment, the Northampton Sand forming a tract, about a mile wide, at the top of the ridge on which stand the villages of Cottesmore and Market Overton. The junction of the Limestone and Sand in this part of the district is often greatly obscured by Drift; the boundary between the latter and the subjacent Upper Lias Clay is, however, very distinct and easily traceable until we get to Wymondham, where the great Boulder Clay sheet overlaps the edge of the escarpment on to the Lias plateau below. In the neighbourhood of Cottesmore, Barrow, and Market Overton, numerous small sections of the ironstone-rock and of the overlying Estuarine sands and clays can be seen, but they afford only a repetition of the characters noted, at many points to the south. The greatest thickness of ironstone is 9 feet, and much of it is oolitic. The escarpment along this line, from Burley-on-the-hill to Market Overton, is nearly as bold and striking in appearance as that between Rockingham and Harringworth.*

*Waltham-on-the-Wolds, Great Ponton, Ancaster, and Sleaford.*

At Waltham-on-the-Wolds the general succession of the beds has been summarized by Mr. A. J. Jukes-Browne, as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Lincolnshire Limestone. | Oolitic limestones, &c. - - 20 0 to | 30 | 0 |
| [Collyweston Slate.] | Shaly sandstone - - - | 1 | 0 |
| Lower Estuarine Series. | Soft yellow sand - - - | 3 | 0 |
| | Bluish-grey laminated clays - about | 13 | 0 |
| Northampton Sand. | Ironstone (best red stone) - - | 3 | 0 |
| | Ironstone ("curly") a mass of fossil casts - - - - - | 3 | 0 |
| | Ferruginous "sandstone" - - | 5 | 0 |

Here the Ironstone beds were at one time extensively worked; but the ore is not of good quality, analyses showing an average amount of 20 per cent. of iron, with 50 per cent. of silica. The workings were discontinued in 1885.†

The shaly sandstone on top of the Lower Estuarine Series may be taken as a representative of the Collyweston Slate. The large

* Geology of Rutland, p. 97; and Kendall, Iron Ores of Great Britain, 1893, p. 239.

† Geol. S.W. Lincolnshire, p. 47.

quarries east of Waltham, show about 25 feet of compact earthy limestone, coarse-grained oolite, shelly and oolitic limestone. These contain a band of yellow micaceous sand or sandstone (1 ft. thick) and an occasional band of grey shaly clay.*

The full thickness of the Lower Estuarine Beds in this locality is about 20 feet; but, at Croxton Kerrial, the thickness proved in a well was 12 feet.

The cuttings on the new railway between Saxby and Bourn, showed sections of the Lincolnshire Limestone, which I examined in 1892. South-west of South Witham, there were shallow cuttings in compact limestones with scattered oolitic grains and bands of coarse-grained and somewhat argillaceous oolite. Here I obtained a large specimen of *Ammonites* "*Sowerbyi*," *Gresslya*, &c. The beds are much shattered, and occur at a lower horizon than the freestone division, which was not exposed along the railway in this neighbourhood; indeed for a mile or more further east the cutting traverses only Boulder Clay. Beds of oolite with Corals have been worked by the windmill, west of South Witham, and freestone was formerly quarried on the eastern side of the village. Other quarries may be seen adjoining the railway about 2 miles east of South Witham. It is not however until we approach Castle Bytham that sections of freestone were exposed in the cuttings.

At Potter's Hill, west of Castle Bytham, the eastern end of the cutting showed false-bedded oolitic freestone, overlaid by the Upper Estuarine Series, with its layer of ironstone-nodules at the base; and these beds were covered by Boulder Clay.

Proceeding eastwards to Castle Bytham and thence to near Little Bytham, there were fine sections showing, beneath the Upper Estuarine clays, the following beds:—

| | | Ft. | In. |
|---|---|---|---|
| Lincolnshire Limestone. | False-bedded oolite, in part very fine-grained with coarser and almost pisolitic bands below: the stone stained pink in places - - - - | 16 | 0 |
| | Compact limestone, with scattered oolite grains, some layers resembling Stamford Marble; seen to depth of - | 3 | 0 |

Near the surface the freestone was much broken up, and in places there were wide fissures or joints that had been enlarged by water-action. At Castle Bytham, where the Upper Estuarine Clays had been cleared off the surface of the freestone, it exhibited a hummocky appearance, and although the inclined layers of false-bedded oolite terminated abruptly beneath the clay covering, there was no positive evidence of unconformity, and no traces of lithodomous borings were visible.

The general section at Great and Little Ponton, as described by John Morris,† is as follows:—

* Geol. S.W. Lincolnshire, p. 54.

† Quart. Journ. Geol. Soc., vol. ix. pp. 324, &c.; Sharp, *Ibid.*, vol. xxix. p. 265; Jukes-Browne, Geol. S.W. Lincolnshire, p. 54.; Brodie, Rep. Brit. Assoc. for 1850, sections, p. 76.

*Great Ponton Cutting.*

| | | Ft. | In. |
|---|---|---|---|
| Lincolnshire Limestone (upper beds). | Rubbly and shelly oolites, with numerous fossils: *Terebratula maxillata*, *Lima*, &c. | 20 | 0 |
| | Soft marl, with *Ostrea* - 0 4 to | 1 | 0 |
| | Marly limestone, with Corals, *Nerinæa*, and *Turbo*: irregular | 2 | 0 |
| | Coarse shelly oolites and freestones | 15 | 0 |

*Little Ponton Cutting.*

| | | | |
|---|---|---|---|
| Lincolnshire Limestone (lower beds). | Rubbly oolite, rag, and compact shelly beds, thick-bedded, some pisolitic about | 25 | 0 |
| | Clay - 0 2 to | 0 | 3 |
| | Compact marly and shelly rock, with *Lucina*, *Pinna*, *Ostrea*, *Avicula*, *Trichites*, Corals | 5 | 0 |
| | Marly and oolitic limestones; *Gervillia acuta* | 12 | 6 |
| | Grey sandy clay | 1 | 6 |
| | Marly oolite, with *Pecten* | 0 | 6 |
| | Compact marly and sandy rock, with *Gervillia acuta*, and *Trigonia Phillipsi* | 3 | 6 |
| | Ferruginous sandy oolite, with fragments of shells; resting on sandy beds - about | 30 | 0 |

It is difficult to decide how far the above may represent a continuous section, whether there be a break in the series or a duplication. I am disposed to take the latter view. The railway-cuttings are isolated and the beds are variable; and between the two main cuttings there are two shallow sections consisting of shelly pisolite with *Cerithium*, *Nerinæa*, and other univalves. At one point, as mentioned by Morris, the oolite rocks were pierced to a depth of about 60 feet in a well sunk close to the line of railway.

East of the Witham river, between Great and Little Ponton, the Northampton Sand (brown ferruginous sandstone) was exposed in ditch-sections. Ironstone was shown for some distance along a narrow valley north of Ponton Park Woods, although not so represented on the Geological Survey Map.

In the railway-cuttings there is little to be seen that was not recorded by Morris. The uppermost beds of Great Ponton show irregular dark and pale bands, the former being mainly oolite and the latter shelly limestone: the beds are more or less false-bedded. They rest on massive and rather marly oolitic freestone that is quarried to a depth of 10 feet by the railway. The more shelly beds are quarried by the lime-kiln south of Great Ponton railway-station; and the freestones have again been extensively quarried at Houghton for building-stone and lime-burning.

Most of the fossils obtained by Morris, were taken from the "Upper Shelly Beds at Ponton," and the rock "whence the majority of specimens were obtained was a soft pisolite, the shells being generally well preserved and rarely broken. Associated with them were rolled fragments of marly rock and casts of shells in a similar matrix (chiefly *Nerinæa* and *Cerithium*), much rolled and eroded, some of them being slightly encrusted with calcareous matter." His lists evidently include species not only from Great Ponton cutting but also from the shallow cuttings, between the two larger ones. Among the species of Gasteropoda the following have been recorded*:—

Actæonina glabra.
Alaria hamoides.
—— pontonis.
Amberleya gemmata.
Ataphrus Belus.
—— discoideus.
Bourguetia (Phasianella) elegans.
—— pontonis.
Brachytrema binodosum.
—— subvaricosum.
Ceritella lindonensis.
—— Sowerbyi.
Cerithium Georgei.
—— limæforme, var. pontonis.
Cylindrites turriculatus.
Exelissa pulchra.
Littorina Phillipsi.
Monodonta Lyelli.
Nerinæa bacillus.
—— cotteswoldiæ.
—— pseudopunctata.
—— (cf.) Stricklandi.
—— subglabra.
Onustus ornatissimus.
Patella.
Rissoina obliquata, and var. parcicostata.
Trochotoma extensa.
Trochus Acis.
—— Ibbetsoni.
—— monilitectus.

The Lincolnshire Limestone has been well exposed at Denton, and from the lower beds *Malaptera Bentleyi* has been recorded.

From the neighbourhood of Grantham to Ancaster, the thickness of the Lincolnshire Limestone appears to increase to a total of about 100 feet, while the underlying Lower Estuarine Beds and Northampton Sand, have been estimated to have a thickness of 40 feet at some localities, but usually this does not exceed 20 or 30 feet.†

A good section of the lower beds was noted as follows, by W. H. Holloway, in Syston Park, N.E. of Grantham‡ :—

| | | Ft. | In. |
|---|---|---|---|
| Lincolnshire Limestone. | Soil and rubbly oolite - - - | 3 | 8 |
| | Sandy limestone - - - | 1 | 2 |
| Lower Estuarine Series. | Sandy marls; red, white, and greenish sands; white, purplish, black and grey clays - - - | 12 | 6 |

The sandy limestone, no doubt, represents the Collyweston Slate: a similar bed was shown in the railway-cutting west of Ancaster railway-station. There also the details were measured by Holloway. The Lower Estuarine Beds consist of alternations of white sands and laminated clays, as in the above section, and attain a thickness of 7 or 8 feet; they rest on a ferruginous and sandy rock, with thin calcareous bands, exposed to a depth of 4 feet. This last-named bed represents the Ironstone of the Northampton Sand, and rests on the Upper Lias Clay. The thickness of the Northampton Sand at Belton Ashes was proved to be 15 feet.

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* Morris, *op. cit.*, p. 327; see also Hudleston, Gasteropoda of the Inferior Oolite, pp. 72, &c; Hudleston and Wilson, Catalogue of Jurassic Gasteropoda, 1892.

† Sharp, Quart. Journ. Geol. Soc., vol. xxix. p. 266; Morris, Geol. Mag., 1869, p. 103; Jukes-Browne, Geol. S.W. Lincolnshire, p. 45.

‡ Geol. S W. Lincolnshire, pp. 50, 51.


FIG. 58.—*Section in the Railway-cutting west of Ancaster.* (W. H. Dalton.)

Scale, 3 chains to an inch.

| | | Ft. | In. |
|---|---|---|---|
| c. Lincolnshire Limestone | | 15 | 0 |
| b. Northampton Beds. | Sands with band of ferruginous clay | 3 | 0 |
| | Blue clay | 1 | 6 |
| | Ironstone, &c. (partly obscured) | 14 | 0 |
| a. Upper Lias clay. | | | |

Passing on to Ancaster we again come to one of the more celebrated localities for freestone, belonging to the Lincolnshire Limestone.

The general section of the stone-beds at Ancaster is as follows*: —

| | | Feet. |
|---|---|---|
| Upper Estuarine Series. | Blue clay, &c. | |
| Lincolnshire Limestone. | Rag | 10 |
| | Freestone | 20 |
| | Rag | 2 |
| | Freestone | 2 |
| | Pale limestones with scattered oolitic grains: false-bedded in lower part | 50 |
| | Grey earthy limestones, with scattered oolitic grains; Shelly oolite with ochreous galls | 10 |
| | Calcareous sandstone and irregular clay band | 2 |
| Lower Estuarine Series. | Sands and laminated clays | 6 |
| Northampton Sand. | Ironstone, ferruginous and sandy rock | 14 |
| Upper Lias - Blue clay. | | |

A well at Pits Hills Farm proved 99 feet of stone, the bottom-bed being oolitic. In order to examine the strata I was let down the well, but could not make many observations, and was plunged into a foot or two of water at the bottom. About half-way down the stone contained scattered oolitic grains. At Haydor Lane 96 feet of rock was penetrated; and at Silk Willoughby 104 feet of the Lincolnshire Limestone was proved in a boring.

The beds beneath the freestone have been exposed in the railway-cutting and adjoining quarry west of Ancaster station. The beds yield some material employed

* See also Brodie, Proc. Cottesw. Club, vol. i. p. 54; Jukes-Browne, Geol. S.W. Lincolnshire, pp. 51, 58, &c.

for road-metal and rough building-purposes, but the greater portion of the stone is more appropriately used for lime-burning: the lime being found suitable for mortar and agricultural purposes. As a building-stone the lower beds furnish but an inferior material, that does not stand the weather. These beds come to the surface over much of the ground west of the Ermine Street. (See Fig. 58, and Fig. 62, p. 220.)

The following is the section at the Ancaster Stone Quarries, the overlying Upper Estuarine Beds varying in amount at different places :—

| | | Ft. In. | Ft. In. |
|---|---|---|---|
| Upper Estuarine Series. | Grey, brown and white clay - <br> Band of greenish-coloured clay <br> Dark blue clay, with thin bands of indurated grey earthy limestone near top - - <br> Grey and purple ochreous clay <br> Rusty bed, 2 or 3 feet - - | 15 0 to | 20 0 |
| Lincolnshire Limestone. | Coarse and fine grained false-bedded oolite (Rag), the top bed fairly even: the upper beds stained irregularly of a red or crimson-red colour, the lower beds blue or blue-hearted - | 8 0 to | 12 0 |
| | Fine yellow freestone: fine-grained oolite, showing in the quarry-face no marked lines of division or open jointing, but separating into irregular masses when quarried: the master-joints do not extend to the base of the freestone - - | about | 15 0 |

The division between the rag and freestone is marked in some places, but in others the beds appear to merge; and there are indications of local thickening of the rag in an easterly direction.

The rusty bed on top of the rag appears to be to some extent the decomposed surface of the oolite commingled with clay, and ochreous material.

The Rag beds are employed for road-mending, and also for building-purposes: they are sometimes spoken of as the Weather Bed.

Where the capping of clay is but 4 or 5 feet thick, as towards the southern side of the quarries, the Rag-beds are much broken up, and even the freestone appears crumbly and friable at the top.

The valuable freestone, known as the Ancaster Stone, belongs to the upper part of the Lincolnshire Limestone, and occurs below the outcrop of the Upper Estuarine Series. It is largely worked at the Ancaster Stone quarries on Wilsford Heath (Mr. Lindley's and Mr. Kirk's). There the beds are obtained beneath a capping of clay 15 to 25 feet thick, and the greater the thickness the better preserved are the stone-beds beneath. Thus the freestone, in particular, occurs in a tolerably massive form, although the blocks obtained are of limited dimensions. The stone is parted by joints, but not by open fissures, except at considerable intervals.

The Freestone is a fine but variable oolite, some beds being coarser, and containing comminuted shells. Where much exposed some of the beds scale off on the vertical faces. As a rule the beds are not very thick, nor are they very regular, the mass of the stone being more or less false-bedded. Blocks from 1 to 2 feet thick and 4 or 5 feet across are obtained.

Mr. Jukes-Browne mentions that beneath the main freestone, another bed of ragstone (1 ft. 6 in. to 2 feet) and below it a fine-gained freestone (of similar thickness) have been worked. Palatal teeth of *Strophodus* and a Saurian vertebra have been obtained below this lower bed of freestone.*

In old times stone was extensively quarried at Pits Hills Plantation, south of Ancaster. At this locality there was no protecting cap of clay, but building-stone of excellent quality was obtained, though I am informed not in blocks of large size. No doubt a considerable amount of walling-material was procured, while if the good stone was in small blocks, it had to a great extent proved its character by having withstood the effects of long weathering. An open quarry showing the character of the beds was to be seen to the north of Copper Hill. (Fig. 59.)

FIG. 59.

*Quarry north of Copper Hill Farm, near Ancaster.*


The stone remains to some degree moist in its natural position at some depth from the surface, drying and hardening after it is quarried. Here as in other cases, the stone should be dressed for use while the quarry-water still remains. For I am informed by Mr. Lindley that old and seasoned stone from ancient buildings, which has long withstood the action of the weather, is not durable if dressed again, and then used in other edifices. (See p. 473.)

The Old quarry, north of Copper Hill Farm, showed the following section (Fig. 59):—

| | | Ft. In. | | Ft. In. |
|---|---|---|---|---|
| Lincolnshire Limestone. | 3. Rubble of oolite - - | 4 0 | to | 5 0 |
| | 2. False-bedded oolite (Rag), in thin layers resting evenly on - - - - | 7 0 | to | 10 0 |
| | 1. Bedded oolite (Freestone), the layers themselves showing current-bedding, and the top-bed, in places, consisting of a compact limestone with scattered oolitic grains - - - | 7 0 | to | 8 0 |

The beds of freestone are much jointed; here and there a more massive bed appears, but this becomes disintegrated in places where long subjected to atmospheric influences.

The railway-cutting east of Wilsford showed the following beds, much tumbled:—

* Geol. S.W. Lincolnshire, p. 58.

| | |
|---|---|
| Lincolnshire Limestone. | Flaggy oolite, stained red in places.<br>Massive beds of oolite, coarse-grained in places and shelly.<br>Tough grey shelly and oolitic limestone splitting irregularly.<br>White oolite. |

Ancaster Hall was built from stone obtained at the Castle Quarries (Wilsford stone) now disused.

The Greylees pits, west of Sleaford, show about 15 feet of remarkably false-bedded shelly oolite, with *Ostrea* and shell-fragments; beds that recall the shelly beds at Ponton. At Bully Wells there is a large quarry and lime-kiln; the upper beds comprise fissile false-bedded oolites, and these rest on hard blue-hearted oolitic and shelly limestone, like beds seen at Washingborough, near Lincoln. They contain *Galeolaria* (*Serpula*) *socialis*, as at Glendon and other localities.

### *Sleaford to Lincoln.*

At South Rauceby, south of the village and east of the road, a quarry showed about 16 feet of oolite. There is no clay covering, and the top-beds which are false-bedded, split into thin slabs; these pass down irregularly into false-bedded freestone, with more solid beds at the base. Building-blocks are obtained.

In the Fenland area, the evidence of a well-section at Parson Drove, Pinchbeck North Fen, to the north-west of Spalding, indicated the presence of 82 feet of rock, which may be assigned to the Inferior Oolite, beneath the Great Oolite Series, &c.*

Northwards, in the deep boring at Woodhall Spa, Mr. Jukes-Browne has estimated the thickness of Lincolnshire Limestone and Northampton Sand at 140 feet.†

The lower beds of the Inferior Oolite have been quarried in various places along the escarpment east of Caythorpe, Fulbeck, and Leadenham. They consist of oolitic limestones, coarse and shelly in places, and sometimes pisolitic, together with compact limestone and sandy limestone.

The Basement Beds comprising representatives of Northampton Sand and Lower Estuarine Series, are not well-exposed along this escarpment; but northwards, at Coleby, they consist of ferruginous sandy beds, with ironstone-nodules and clay-partings, having a thickness of 10 feet. Coprolites are said to occur at the base. In this neighbourhood and also to the north of Waddington, the ironstone has been worked. At Coleby the richer bands contain as much as much as 40 per cent. of iron.‡

At Waddington, Mr. W. H. Penning noticed an interrupted band of ironstone, or ferruginous septaria, near the top of the blue clay (Upper Lias) that underlies the mass of concretionary ironstone (Northampton Sand).§ This feature may be compared with

* Jukes-Browne, Geol. S.W. Lincolnshire, p. 152.
† Geol. Lincoln, p. 208.
‡ Capt. Macdakin, Geol. Mag., 1877, p. 406; Geol. Lincoln, p. 37.
§ Ussher, Geol. Lincoln, p. 38, 39.

that exhibited in some of the sections near Towcester and Blisworth (pp. 178, 184). Ironstone was formerly worked at Canwick, where 9 feet of it was noted. Indeed, according to Mr. Dalton, the ironstone facies of the Northampton Beds, extends locally from Navenby to Burton-by-Lincoln.

FIG. 60.

*Diagram-section of the Oolite plain south of Lincoln.* (W. H. Dalton.)


C. Great Oolite Series.
B. Inferior Oolite.
A. Lias.
D D D. Line of perennial saturation, with springs at points of intersection with surface.

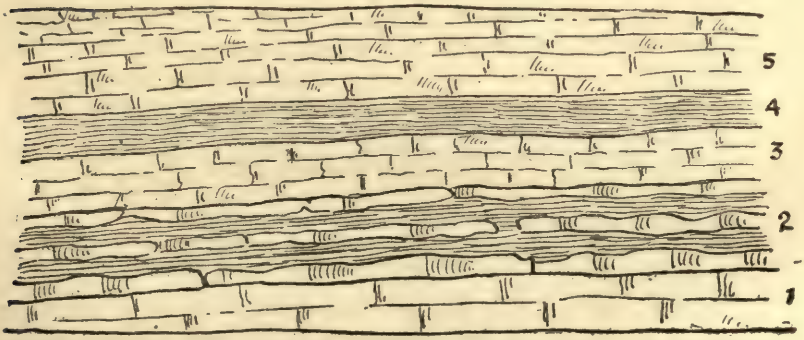
Further north near Navenby, Harmston, and Waddington the lower beds of Inferior Oolite comprise layers of oolite and marly, slightly oolitic, limestone, with thin bands of clay. These beds have been noted by Mr. Penning, in various exposures, to a thickness of about 20 feet. The higher beds have been well shown in cuttings of the railway between Dunston and Washingborough, and they have been opened up in quarries near Scopwick and Metheringham.* At Washingborough a thickness of 65 feet of stone-beds has been proved.

The railway-cutting north of Nocton showed the following series of beds, some of which may fairly be correlated with certain divisions noted by Mr. Ussher to the north of Lincoln.

A similar sequence of beds was shown in the cutting south of Heighington Station, and these beds were faulted to the north against the Great Oolite Series.

FIG. 61.

*Section in Railway-cutting north of Nocton, Lincolnshire.*




* See Ussher, Geol. Lincoln, pp. 45, &c.

| | | | Ft. | In. |
|---|---|---|---|---|
| Lincolnshire Limestone. | Hibaldstow Beds. | 5. Thin beds of pale-buff oolite - | 7 | 0 |
| | | Blue-hearted earthy oolitic limestone - - - | 1 | 6 |
| | | 4. Marly bed - - - | 4 | 0 |
| | Kirton Beds. | 3. Shelly limestones, with *Ostrea* and other Lamellibranchs - | 5 | 0 |
| | | 2. Grey and yellow limestones, and dark shales, resembling beds of Lower Lias: the bottom layer containing clusters of dark oolitic and other grains | 7 0 to 8 | 0 |
| | | 1. Compact buff limestone with scattered oolite grains; bed with *Pinna* at the top, other beds shelly in places, some coarse grained: on the whole resembling the Silver-bed of Lincoln. | | |
| | | Fine freestone with coarser oolitic grains (as at the Dean and Chapter pit, Lincoln), seen in deep road-cutting to north. | | |

A quarry east of Washingborough showed the following section:—

| | | Ft. | In. |
|---|---|---|---|
| Upper Estuarine Series. | Sandy and clayey beds; showing lenticular changes: with ochreous beds at base - - - 12 0 to | 15 | 0 |
| Lincolnshire Limestone. | Buff oolite, showing reddish tinges in places. Good wall-stone - - | 11 | 0 |
| | Blue-hearted oolite, like some beds at Ketton: used for road-stone, and called "Blue Stone," it breaks with a cleaner fracture than good freestone | | |

There are slight evidences of unconformity between the Estuarine beds and Lincolnshire limestone. Clay was proved below the "Blue Stone," to a depth of 5 feet. This would correspond with the clay separating the Hibaldstow and Kirton Beds. West of Washingborough church a thickness of 42 feet of stone-beds was proved (down to water).

The general section of the Lincolnshire Limestone south of Lincoln may be summarized as follows:—

| | Ft. | In. | Ft. | In. |
|---|---|---|---|---|
| 3. Buff and blue-hearted oolite more or less false-bedded, and earthy oolitic limestone - - | 12 | 0 to | 20 | 0 |
| 2. Grey marly and shaly bed - - - - | 3 | 0 to | 5 | 0 |
| 1. Compact and shelly limestone, grey limestones and shales - - - - - - | 12 | 0 to | 15 | 0 |
| Sandy and oolitic limestones, and chalky and creamy limestones (with scattered oolitic grains), with bands of marl and shale - | about | | 30 | 0 |

The lower beds (1) include the representatives of the stone worked at the Dean and Chapter Pit, Lincoln. From them I obtained specimens of *Ammonites polyacanthus*, *Natica cincta*, and

*Astarte elegans.* The higher portion resembles the Kirton Beds. Bed 2, which is well shown in the railway-cutting north of Nocton, may be on the horizon of the marly bed that overlies the Kirton Beds. At Nocton it rests on beds of grey limestone, of a "Liassic" aspect, and thus it would seem to be stratigraphically connected. Bed 3 may be compared with the Hibaldstow Beds.

### *Lincoln to Kirton Lindsey and Winteringham.*

The lower beds of the Inferior Oolite Series (the Northampton Sand and the lower portion of the Lincolnshire Limestone) have been well exposed at the Greetwell road quarry, east of Lincoln Gaol where the section was as follows*:—

| | | | Ft. | In. |
|---|---|---|---|---|
| Lincolnshire Limestone. | 7. | Marl and rubble - - - | 1 | 0 |
| | | White marly limestones, with scattered oolite grains: beds known as Top and Bottom Nerlys (freestone) - - - - | 5 | 0 |
| | 6. | Fine oolitic and fissile limestone with scattered oolite grains: Upper Silver Bed - - | 2 | 0 |
| | | Limestone with scattered oolite grains: Sink Stone - - | 1 | 0 |
| | | Compact limestone with scattered oolite grains; *Ammonites polyacanthus*, *Natica cincta*, and *Astarte elegans.* Bottom Silver Bed - - - 1 6 to | 2 | 0 |
| | 5. | Marl and limestone with scattered oolite grains: used for road-metal and concrete - - - | 1 | 6 |
| | 4. | Variable beds of limestone with scattered oolite grains, and bands of coarse oolite: a bored-bed in upper part. The lower layers form the Walling Bed, and the more compact beds are regarded as good Weather Stone - - - | 4 | 6 |
| | 3. | Oolitic limestone (of no use), with at base 6 inches of very tough oolitic rock with pebbles - - - | 2 | 2 |
| Northampton Sand (Dogger). | 2. | Ironstones worked to depth of 8 or 9 feet, when water is reached: total from - - - 6 0 to | 10 | 0 |
| | 1. | "Coprolite Bed" - - - | 2 | 0 |
| Upper Lias - | | Blue Clay. | | |

At the above quarry the beds are worked for building-stone, lime and concrete, and road-metal. The Walling Bed, which is blue-hearted, contains a few casts of Gasteropods. This bed is said to stand better as a weather stone if got up "green" (or when damp), and afterwards seasoned. The Silver bed, it is said, should be quarried in summer time and well dried.

The variable thickness of the Ironstone (Basement Beds), the occurrence of a pebbly layer at the base of the Lincolnshire

* Numbers are affixed to the records of strata for the purpose of comparison with other sections described in the immediate neighbourhood.

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Limestone, and the absence here and there of beds that can be classed with the Lower Estuarine strata, indicate some local unconformity.*

Sixteen feet of ironstone has in places been exposed in the workings of the Mid-Lincolnshire Iron Company. Mr. W. H. Dalton remarks that the rock is partly blue or green-hearted, and the lower portion of it is so crowded with phosphatic nodules as to be worthless for smelting. At the same time its hardness has deterred the makers of phosphatic manures from attempting to utilize it as a source of phosphoric acid.†

The ironstone is extensively worked to a depth of 10 feet in pits on the west side of Greetwell: here, as elsewhere, the rock is mainly brown, and the greenish cores are rejected. On the eastern side of the valley the ore is obtained by means of tunnels driven into the hill-side beneath the Lincolnshire Limestone. I observed no indications there of the pebbly layer in the limestone above the ironstone.

The details of the limestone-series differ a little from those in the pit just described. A thin layer of clay (3 or 4 inches) (5) separates the Walling Bed (4) from the Silver Beds (6) above, and the Silver Beds contain small pea-like pebbles of oolite. The beds on top comprise marly limestone and marls (7), and occasional layers of compact limestone (8) with scattered oolite grains and numerous small Gasteropods, as in the top beds of the Dean and Chapter pit, north of Lincoln. I obtained *Natica cincta*, *Ceromya concentrica*, and *Acrosalenia* from the Lincolnshire Limestone at this quarry.

Inferior Oolite was proved to a depth of 65 feet on the hill north of the railway-cutting at Greetwell.‡

The Dean and Chapter pit is situated on the east side of the main road, about one mile north of the North Gate, Lincoln. Here the stone is quarried for building-purposes and to be burnt for lime. The section was as follows §:—

| | | | Ft. | In. |
|---|---|---|---|---|
| Lincolnshire Limestone. | 8. | Hard grey limestones, slightly oolitic, and much shattered - | 2 | 0 |
| | | Marly layer with *Pholadomya* - | 1 | 0 |
| | | Irregular beds of shelly oolitic limestone (blue towards base), with oolitic marly and ferruginous layers; small Gasteropods - | 5 | 0 |
| | 7. | Blue shelly clay - - - - | 0 | 6 |
| | | Buff, grey, and blue, compact and argillaceous limestones, with occasional oolitic and iron-shot grains; bed with *Pinna* near the middle. These beds to a certain extent resemble the Kirton Beds: they yield no good building-stone - - - - | 6 | 0 |

* See also Ussher, Geology of Lincoln, p. 55.

† Ussher, Geol. Lincoln, p. 39.

‡ Geology of Lincoln, p. 55.

§ This pit is also described in the Geology of Lincoln, pp. 53, 57.

| | | Ft. | In. |
|---|---|---|---|
| | 6. Fine-grained, buff and shelly, limestones, more or less oolitic, with *Nerinæa*: some of these layers resemble Stamford Marble: they include the Silver Bed, which is regarded as the best local building-stone: it was used in Lincoln Cathedral - - - - | 6 | 0 |

The numbers are given for comparison of the strata with those noted at the Greetwell road quarry (p. 217). The Silver Bed has been used for chimney-pieces and floors of passages.

A band of ironstone, 4 ft. 6 in. thick, occurs above the Upper Lias north-east of Lincoln, where it has been exposed in the brickyard of Messrs. Swan Bros. and Bourne.

Further north exposures are not common, but at Glentworth and Hemswell the Basement Beds seem to be considerably thicker. The Lower Estuarine Series is represented by grey and brown loam, sand, and clay with ironstone nodules in the upper part; and it has been exposed to a depth of 10 or 15 feet. The lower beds of brown sandy rock, that represent the Northampton Sand, were estimated by Mr. Ussher to be from 10 to 15 feet thick.

Along the escarpment north of Lincoln, the lower beds of the Lincolnshire Limestone have been quarried in many places. They comprise creamy and oolitic limestones with thin bands of clay;* but they afford no sections of particular interest. Nor have we much evidence for tracing on the clay-band that further north overlies the Kirton Beds. (See Fig. 62.)

Mr. Dalton states that "In the Nettleham Road, rather more than half a mile from the Cathedral, a small quarry now abandoned shows, under 5 feet of rubble, a band of fossiliferous shaly marl nearly 3 feet thick overlying 6 feet of limestone." No such bed appears in the railway-cutting west of Greetwell, which exposes about 30 feet of the beds, but this "thick marl band" overlaid a similar thickness of stone-beds where seen on the Nettleham road.

The exposures north of this area, by Ancholme Head, are neither very numerous nor very clear in exhibiting the succession of the beds. The lower beds comprise hard grey limestones, which Mr. Ussher has grouped with the so-called "Hydraulic Limestone" that occurs in parts of Yorkshire in the Lower Estuarine Series. These are overlaid by "Semi-oolitic beds," forming the main mass of the Lincolnshire Limestone, and on top there are "Grey limestones."†

In North Lincolnshire Mr. Ussher has found it convenient to divide the Lincolnshire Limestone as follows:—

| | | Ft. In. | Ft. In. |
|---|---|---|---|
| Lincolnshire Limestone. | Hibaldstow Beds - - - | 20 0 | to 30 0 |
| | Kirton Beds - - - | 30 0 | to 40 0 |
| Basement Beds. | Lower Estuarine Beds - ; Northampton Sand (Dogger) | 15 0 | to 26 0 |

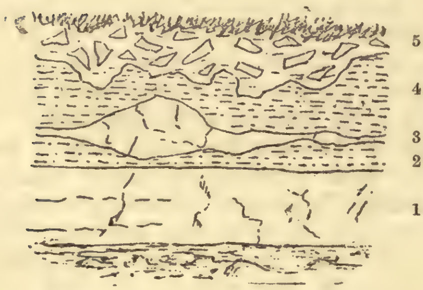
* Ussher, Geology of Lincoln, p. 54.

† Geol. Lincoln, pp. 44, 55.

The Yorkshire term of "Dogger,"* has been applied to the representative of the Northampton Sand; it is a ferruginous sandstone, about 5 feet thick. It has yielded a number of Lamellibranchs, including *Cardium, Corbis rotunda, Cypricardia, Isocardia, Modiola sowerbyana, Myopsis, Pholadomya Heraulti,* and *Thracia;* also the Echinoderm, *Galeropygus agariciformis.* Most of these fossils occur in the Yorkshire Dogger, but they are not species that characterize a distinct horizon.

FIG. 62.

*Quarry west of Ermine Street, near the 10th milestone, north of Lincoln.* (W. A. E. Ussher.)




| | | Ft. | In. |
|---|---|---|---|
| | 5. Brown soil with fragments of grey limestone. | | |
| Lincolnshire Limestone. | 4. Light drab loam - | 3 | 0 |
| | 3. Tough irregular and impure limestone 0 1 to | 0 | 4 |
| | 2. Drab loam - | 0 | 10 |
| | 1. Hard grey limestone - | 3 | 0 |

The Lower Estuarine Beds consist of bluish clay or shale, with sand irregularly associated.

Mr. Ussher states that the divisions of the Basement Beds cannot be separated by geological boundaries, as the series forms a narrow band on the upper slope of the Oolitic escarpment, and its total thickness is insignificant, probably nowhere exceeding 26 feet. The Lincolnshire Limestone, on the contrary, affords a marked contrast in its upper and lower beds, so that a geological boundary-line can be drawn from the Humber southwards, to separate the Hilbaldstow and Kirton beds. This boundary could not, however, be traced very far to the south, owing to the merging of these distinctive characteristics, and to the impossibility of restricting the variations in the Lincolnshire Limestone to definite stratigraphical horizons.†

The Lower Estuarine Series in the Howardian Hills of Yorkshire contains, in places, towards the middle part, one or two well-marked beds of cement-stone or "Hydraulic Limestone." They are described by Mr. Fox-Strangways as consisting of hard grey argillaceous limestone, never more than a few feet in thickness and separating in places into two beds divided by shale. The rock can hardly be regarded as an hydraulic limestone, for it is said to make "a very good lime for agricultural purposes." South of

* A name also locally applied to nodular or globular masses of stone.
† Ussher, Geol. N. Lincolnshire, p. 59.

Ellerker, the limestone could not be traced as a separate bed, and there was no evidence of it in a boring at Brantingham Grange.

The introduction by Mr. Ussher of the term "Hydraulic Limestone" for the beds at the base of the Lincolnshire Limestone in Lincolnshire is to be regretted, as the layers supposed to represent it are not worked for *hydraulic* lime, and beds on a slightly higher horizon (Kirton Beds) are. Nor have we any evidence from fossils, for comparing the so-called "Hydraulic Limestone" of Lincolnshire with that of South Yorkshire. The latter stratum is regarded as equivalent to the Eller Beck Bed, a layer containing marine fossils (including *Astarte minima*), discovered by Mr. G. Barrow in the Lower Estuarine Series of the north-eastern part of Yorkshire. Moreover, Mr. Ussher grouped the beds termed by him "Hydraulic Limestone," with the Basement Beds beneath the Lincolnshire Limestone; but it must be borne in mind that the Lower Estuarine Beds of Yorkshire form a more comprehensive stratigraphical division than the Lower Estuarine Beds of the midland counties.*

The HIBALDSTOW BEDS have been so named by Mr. Ussher (1890), because they are well exposed at the village of that name, situated between Kirton Lindsey and Brigg. In the Geological Survey map (sheet 86), published in 1887, and in the Memoir on the Geology of the country around Lincoln (1888 p. 44) these beds were spoken of as the "Ponton Beds," after Great Ponton. But as the characteristic *fossiliferous* Ponton Oolite cannot be definitely correlated with these beds, and portions of the Ponton Beds may be equivalent to the Kirton Beds, it has been considered best to adopt purely local names for the divisions.

As remarked by Mr. Ussher, they form the uppermost division of the Lincolnshire Limestone from Waddingham northwards to the Humber. They consist of buff or cream-coloured oolites, the oolitic structure varying from fine spherical to coarse, irregular granules, sometimes of large size. These beds do not appear to be ever intercalated with clay or loam. Their thickness is probably not much more than 20 feet.

The KIRTON BEDS are so called from the town of Kirton Lindsey, in the vicinity of which they present their most marked lithological characteristics, and are of the greatest economic importance. They consist of grey limestones, interstratified with beds of loam and clay; near Kirton they contain fine-grained irregular limestone-bands, which are ground up for hydraulic lime. In their lower portion the Kirton limestones, which are partially oolitic, frequently resemble the Hibaldstow Beds, weathering yellow and exhibiting oolitic structure throughout.

The Basement Beds form the upper part of the face of the Oolite escarpment, the Kirton Beds occupying its crest and the upper part of its dip-slope; these pass under the Hibaldstow Beds, which usually make a slight junction-feature at their very sinuous

* See Fox-Strangways, Geol. Ool. and Liassic Rocks, Malton, p. 6; Geol. country between York and Hull, p. 20; and Jurassic Rocks of Yorkshire, vol. i. pp. 194, 203.

boundary-line, and occupy the lower part of the dip-slope, terminated by the Alluvium between the Barnetby and Doncaster railway and Hibaldstow, and by the gravel-flats south of Hibaldstow.

Between Waddingham and Grayingham Warren Farm, there are limestones, referred by Mr. Ussher to the Hibaldstow Beds, which are similar in colour and texture to those commonly found in the Kirton Beds, yet they pass directly under the Great Oolite series. The Hibaldstow Beds, which are distinctly traceable south of a line between Grayingham Warren Farm and Waddingham, seem to preserve their very oolitic aspect only in their lower beds, and cannot be traced southwards as a distinct lithological division. The Kirton Beds lose their distinctive characters south of Grayingham Warren. By these changes we find as we proceed southward, a more and more homogeneous series of beds composing the Lincolnshire Limestone.* Nevertheless, in certain areas, as before mentioned, divisions that appear to correspond with the Hibaldstow and Kirton Beds, may be traced further south. (See p. 216.)

The following fossils have been recorded from these local divisions of the Lincolnshire Limestone :—

| —— | Kirton Beds. | Hibaldstow Beds. |
|---|---|---|
| Ammonites (allied to A. humphriesianus) - - | | × |
| „ (allied to A. Truellei) - - | × | |
| Belemnites - - - - - - | × | |
| Natica cincta - - - - - - | | × |
| Astarte elegans (Fig. 12) - - - - | × | |
| —— minima - - - - - - | × | |
| —— rhomboidalis - - - - - | | × |
| Ceromya bajociana (Fig. 21) - - - - | × | |
| Corbis Lajoyei, var. cingenda - - - - | × | |
| Gervillia acuta - - - - - | × | × |
| Gresslya Lycetti ? - - - - - | × | |
| Hinnites abjectus - - - - - | × | × |
| Homomya gibbosa - - - - - | × | × |
| Lima pectiniformis - - - - - | × | × |
| —— Lycetti ? - - - - - - | × | |
| —— strigillata - - - - - | × | × |
| Lithodomus - - - - - - | × | × |
| Lucina bellona - - - - - | × | × |
| Myacites jurassi - - - - | × | |
| Ostrea - - - - - - | × | |
| Pecten aratus - - - - - - | × | × |
| —— articulatus - - - - - | × | × |
| —— lens - - - - - - | × | × |
| Pholadomya fidicula - - - - - | × | × |
| —— Heraulti - - - - - - | × | × |
| Pinna lanceolata - - - - - | × | |
| Quenstedtia oblita - - - - | × | |
| Trichites nodosus - - - - - | × | |
| Trigonia hemisphærica - - - - | | × |
| Terebratula maxillata - - - - | × | |
| Galeolaria (Serpula) socialis - - - | × | |

Judging from the foregoing list, there appears to be no marked palæontological distinction between the beds. The Kirton Beds

* Ussher, Geol. N. Lincolnshire, pp. 63, 64.

however have yielded a number of Corals including *Isastræa Conybearei, I. Richardsoni, Latimæandra Flemingi, Thamnastræa defranciana,* and *Thecosmilia gregaria.*

The Rev. J. E. Cross has commented on the difference exhibited between the fossils from beds at the bottom of the Inferior Oolite at Santon and those obtained from the overlying beds. He calls the lower portion the Santon Oolites, and describes them as "a soft dark-coloured ferruginous bed, and an oolitic limestone bed above it." These beds are regarded by Mr. Ussher as above the "Hydraulic Limestone" in the section at Low Santon Lane; they belong to a type which can be best studied between Winterton and Roxby, and at Raventhorpe, west of Broughton, on the Oolitic escarpment. They may be grouped for the most part with the Kirton Beds.*

Mr. Ussher states that between Cleatham and Mount Pleasant a by-road, leading up the escarpment, affords a section of the Basement Beds of the Oolites, from the Dogger upwards. The beds are more continuously exposed than in any other part of the escarpment south of the Barnetby and Doncaster Line; in descending order they are as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Lincolnshire Limestone. | Cream-coloured, broken, shaly mudstones, similar to those below the "Hydraulic Limestone" - - | 5 | 0 |
| | Tough, pale grey limestone, in part siliceous and with oolitic grains, containing very small fossils; representing the "Hydraulic Limestone" 2 0 to | 3 | 6 |
| | Impure arenaceous shaly stone - - | 5 | 0 |
| Lower Estuarine Series. | Whitish sand-rock, exposed in the upper part of the road-cutting, apparently just above the "Dogger," and passing under, or dovetailing into, bluish-grey shales, for the most part concealed by grass; attaining a thickness of about - - - - | 12 | 0 |
| Northampton Sand. | Dogger, represented by tough, reddish-brown, fine-grained, ferruginous sandstone, very partially exposed, apparently about - - - | 5 | 0 |

By the Railway between Kirton and Scawby Stations, west of Gainsthorpe, the Kirton Beds are finely exposed, both in the cuttings and in a large quarry, which furnishes material for the manufacture of a valuable hydraulic lime, sold as "Blue Lias lime." † The section which I noted at Kirton Lindsey is as follows:—

* Quart. Journ. Geol. Soc., vol. xxxi. p. 121; Ussher, Geol. N. Lincolnshire, p. 60.
† See Ussher, Geology of North Lincolnshire, pp. 61, 69.

| | | | Ft. | In. |
|---|---|---|---|---|
| | | Rubble of Oolite (Hibaldstow Beds) and soil. | | |
| Lincolnshire Limestone. | | Marly clay (seen also in pit by road) - - 5 0 to | 6 | 0 |
| | | Top stone. Grey limestone, heavy and hard; used for building-stone, paving, road-metal, and building-lime | 1 | 0 |
| | Kirton Beds. | Cement-layer. Bed of limestone-shale forming natural cement - - - | | |
| | | Irregular beds of clay and limestone, like Lower Lias in appearance - - | about 15 | 0 |
| | | Thick beds of grey limestone with scattered oolitic grains - 3 0 to | 3 | 6 |
| | | Grey oolitic limestone - - | 1 | 2 |

Lower beds of gritty rock, marl, and oolitic limestone, may be traced in the railway-cutting east of the tunnel, but they were not very clearly exposed.

The only fossils obtained here by Mr. Ussher, were found in the upper beds below the marly clay. These were *Homomya gibbosa*, *Lima pectiniformis*, and *Pholadomya Heraulti*.* Mr. H. Parry showed me (in 1889) an Ammonite from the top stone-bed, and this was sent to Mr. G. Sharman. He says it is one of the group of Ammonites that includes *A. cymodoce*, *A. rotundus*, *A. gowerianus*, &c. These species, which approximate closely in character, belong to the Middle Oolites; hence considerable doubt is raised about the horizon of the specimen from Kirton, although I was assured that it did come from the stone *in situ*. Drift fossils however do get occasionally into crevices of the rocks.

Mr. Ussher states that by the road to Kirton, at about a quarter of a mile north of the tunnel, a quarry exposes 15 feet of pale bluish-grey shaly clay, rather loamy; it contains an even bed of tough limestone about a foot in thickness, and, near the base, nodular impersistent bands of limestone occur. These beds appear to rest upon the Kirton Beds; dark bluish-grey, impure, fossiliferous, shaly limestones. Oolitic *débris* (Hibaldstow Beds) overlies the shaly clay. The following fossils (identified by Messrs. Sharman and Newton) were obtained from the limestone and shales :—

Amberleya gemmata.
Cylindrites.
Natica canaliculata.
Gervillia acuta.
Lima.
Myacites.
Ostrea.
Pecten articulatus.
Pholadomya Heraulti.
Quenstedtia oblita.
Galeolaria socialis.
Montlivaltia.
Thecosmilia gregaria.

The clayey division that occurs between the Kirton and Hibaldstow Beds, was again seen near the Sturton Plantation N.E. of Manton. Here, according to Mr. Ussher, it is from 3 to 8 feet thick, and contains *Gervillia* and numerous specimens of *Trigonia hemisphærica*. Northwards the clay or loam becomes

* Geol. N. Lincolnshire, pp. 68, 69.

less distinct, being interstratified with even beds of bluish-grey limestone, as shown in sections near Wressle Houses, to the N.E. of Broughton.

The total thickness of the Lincolnshire Limestone passed through in the boring at Brigg, was estimated at 44 feet by Mr. Ussher: there no definite indication of the Lower Estuarine Beds was obtained.* (See p. 430.)

Mr. Ussher notes the following section in a quarry on the north side of the turning to Broughton:—

| | | | Ft. | In. |
|---|---|---|---|---|
| | | Dark brown sandy soil | 2 | 0 |
| Lincolnshire Limestone. | Rubbly oolitic limestone (base of the Hibaldstow Beds) | | 4 | 0 |
| | Kirton Beds. | Three even beds of grey limestone | 3 | 3 |
| | | Pale drab loam | 1 | 6 |
| | | Grey limestone - 1 3 to | 0 | 6 |
| | | Pale brownish, decomposed, shaly limestone | 1 | 0 |
| | | Hard, even-bedded, dark bluish-grey limestone, weathering light grey | 1 | 0 |
| | | Drab and dark grey loamy clay, passing into earthy limestone | 2 | 6 |
| | | Hard bluish-grey limestones, weathering to a pale drab colour | 4 | 0 |

At Scawby an irregular outlier of Hibaldstow Beds appears to rest directly on a clay stratum, forming the top of the Kirton Beds; as clay has been dug on the western margin of the outlier towards Moor Farm, to clay the fields, which are covered with Blown Sand. Near the Roman Road, on either side, west of Scawby Vicarage, there are shallow pits showing brown and grey clay, and loam.

The Hibaldstow Beds, which further south appear to be represented by grey limestones, were shown to a depth of five feet, near Grayingham Warren Farm. The beds (as described by Mr. Ussher) consist of fissile cream-coloured limestones with oolitic grains irregularly dispersed, resting upon cream-coloured and pale buff limestone. The underlying bed appears to be pale drab loam: hence the limestones are taken as the base of the Hibaldstow Beds. The following fossils were found by Mr. Ussher, but they are too poorly preserved for specific determination:—

Nerinæa.
Isocardia.
Lima.
Myacites.
Acrosalenia.

Near the Mill, south of Hibaldstow, the Hibaldstow Beds are exposed in a quarry to a depth of from 15 to 20 feet; they consist of pale buff and cream-coloured oolite, in rather thin broken beds.

At a mile and a quarter south of Redbourne, Hibaldstow Beds are to be seen in pits by the road to Waddingham, and in a quarry on the south side of the valley, west of the road; the beds in this quarry comprise partially oolitic, compact, grey limestones, in

* Geol. N. Lincolnshire, pp. 71, 72, 211.

which *Lucina bellona, Trigonia hemisphærica,* var. *gregaria,* and *Rhynchonella spinosa* ? were obtained. Oolite has been quarried near Hibaldstow on the north, and not far from Sturton on the south.*

North of the railway-tunnel at Kirton Lindsey there is an outlier of Hibaldstow Beds, and the following strata were shown in a quarry:—

| | | Ft. | In. |
|---|---|---|---|
| Lincolnshire Limestone. | Limestone with scattered oolitic grains | 2 | 3 |
| | Oolite - - - - - | 4 | 6 |
| | Irregular hard grey limestone, with scattered grains of oolite. | | |

From the beds at this locality Mr. Ussher obtained some Corals and a *Trigonia.*

Mr. Fox-Strangways remarks that further north the Hibaldstow Beds consist of white very oolitic limestone, which is much purer and softer than the Kirton Beds below. A peculiar feature in the structure of the rock is that the oolitic grains are often aggregated together into small lumps about the size of a bean, which give it, at first sight, almost the appearance of a conglomerate.

He states that in an old quarry by the road to Santon the lower part of this series is just exposed, forming a rubbly oolite, which is frequently decomposed into a kind of sand. The Hibaldstow Beds about here appear to be very thin, but perhaps the increased dip may in great measure account for the narrowness of the outcrop, or, what is more probable, the limestone may have been denuded before the deposition of the Great Oolite Clay above, as there appear to be indications of an unconformity between the two in this neighbourhood.†

Referring to the Kirton Beds of Appleby and Winterton, Mr. Strangways states that they comprise the greater part of the Lincolnshire Limestone, and about Appleby cover a larger surface than the rest of the Lower Oolite divisions put together; they consist for the most part of siliceous earthy limestones, which become purer as we ascend in the series. The lower part of these beds is seen in the cutting at Santon, the upper beds are exposed under the Hibaldstow Beds in a quarry close by; thence the outcrop extends in a westerly direction along the ridge formed by Santon and Risby Warrens. Between Winterton and Roxby the lower part of the Kirton Beds contains layers of rubbly or brashy limestone, including a representative of the so-called "Hydraulic Limestone." That they should be mapped rather as the base of the Kirton Beds, than as a part of the Basement Beds, seems evident from the section by the lane on either side of the Railway Bridge at Low Santon (a Farm three-quarters of a mile west of Appleby Station). There, as far as the tumbled character of the beds permits observation, the following section has been obtained by Mr. Ussher:—

* Ussher, Geol. N. Lincolnshire, pp. 73, 74, 77, 78.
† Geol. N. Lincolnshire, pp. 78, 79.

| | | Ft. | In. |
|---|---|---|---|
| Lincolnshire Limestone (Kirton Beds). | Rather compact grey limestones with small fossils. | | |
| | Drab and brown sandy or loamy shale, partly consolidated, with grey clayey shale; in the upper and lower parts, beds of the Raventhorpe type occur, becoming in places very oolitic, and containing numerous small fossils at the base - - - about | 9 | 0 |
| | Rubbly and broken, tough pale brown and grey, irregular oolitic limestones, stained by ferruginous infiltration in places - - - - 5 0 to | 6 | 0 |
| | Hydraulic Limestone. | | |
| | Impure broken limestone. | | |
| | Lower Estuarine clays. | | |

Rather more than half a mile west of Appleby Station, *Homomya Vezelayi* and *Gresslya abducta* were obtained.

Mr. Strangways further states that north of Winterton the boundaries of the Kirton Beds become more obscure, and it is a matter of some difficulty to decide how much should be included within them. A large part of the rock when met with beneath the surface in shafts, bore-holes, &c., has usually a dark shaly appearance, and this is probably the reason why, in the shafts and bore-holes at Appleby, and also on the north side of the Humber, a considerable part of the section which must include this rock, is called "bind." These beds when burnt make good agricultural lime. In places near Winterton the limestone is much hidden by Drift Sands, Boulder Clay, &c., but at a little distance to the north of the village, the beds rise to a higher level and are better seen; beyond this they are concealed by superficial deposits and are not again exposed on this side of the Humber.*

* Geol. N. Lincolnshire, pp. 75, 76, 79.

# CHAPTER VIII.

## GREAT OOLITE SERIES.

### (BATHONIAN.)

THE term Great Oolite was used in 1812 by William Smith, being applied to the Bath stone which locally is so much more important than the Inferior Oolite. At one time the term Superior Oolite was employed in contradistinction from Inferior Oolite, but the term was used in so comprehensive a sense that even the Portland Oolite was included.* The name Upper Oolite has also been applied to the Great Oolite, but was similarly liable to mislead; hence the term Great or Bath Oolite came into general use, while the more comprehensive name Bathonian was introduced by D'Omalius d'Halloy in 1843.†

As our knowledge of the strata increased, other local divisions came to be included; and probably owing to the difficulty of distinguishing the equivalents of Great and Inferior Oolite in Yorkshire, John Phillips in 1829 unfortunately used the term "Bath oolite formation" for all the strata from the Cornbrash to the Inferior Oolite, inclusive. Later on it became customary to restrict the term to the beds above the Inferior Oolite, sometimes including the Fuller's Earth, and usually including the Cornbrash. In this comprehensive sense it is best to adopt the term Great Oolite Series, and group the beds as follows:—

| | | | |
|---|---|---|---|
| Great Oolite Series. | Cornbrash. Zone of *Ammonites macrocephalus*. | | |
| | Forest Marble and Bradford Clay - Great Oolite and - | Great Oolite Clay. Great Oolite Limestone. | Zone of *Am. arbustigerus*. |
| | Stonesfield Slate - Fuller's Earth - | Upper Estuarine Series. | |

### GREAT OOLITE SERIES.

### 1. DORSETSHIRE TO OXFORDSHIRE.

### FULLONIAN OR FULLER'S EARTH CLAY AND ROCK.

### GENERAL ACCOUNT OF THE STRATA.

The term Fuller's Earth was applied in 1799, by William Smith, to certain marls and clays, near Bath, that yield an important bed of economic fuller's earth. These clays directly overlie the Inferior Oolite and underlie the Great Oolite.

From a geological point of view the term is an unfortunate one, for important beds of fuller's earth occur also in the Lower

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* See Townsend, Character of Moses, p. 105; and Sowerby, Mineral Conchology, vol. ii., 1818.

† Attale Riche, Étude Strat. Jurassique Inf. du Jura Méridional, 1893, p. 125. The name Bathian has been used by Mayer-Eymar.

Greensand at Nutfield in Surrey and Woburn in Bedfordshire, and beds or seams are found in places in the Ludlow Series, as well as in other strata. Hence it has been suggested that the term "Fuller's Earth Oolite," be used to distinguish the beds of Jurassic age.* This name however is not satisfactory, for although it was given to notify the age of the beds, it might be taken to indicate their lithological character, whereas they exhibit no oolitic structure. Again, the occurrence in the formation of beds of economic fuller's earth is local. For these reasons some modification of the name appears desirable, and it is suggested that the term Fullonian (from the Latin *Fullonius*) would meet all requirements. The beds are to some extent equivalent to the Vesulian formation of Marcou, named from the town of Vesoul, in Haute-Saône.

Where best developed, in Dorsetshire and Somersetshire, the Fuller's Earth or Fullonian formation has been divided as follows: —

Upper Fuller's Earth Clay.
Fuller's Earth Rock.
Lower Fuller's Earth Clay.

The clays are blue, grey, and yellowish in colour, and are usually more or less marly in character; only the upper bed has yielded the fuller's earth of commerce. Nodules of "race," occasional bands of earthy limestone and thin layers of sandstone occur in the clays.

The Fuller's Earth Rock which was recognized by William Smith (1815–16), consists of earthy limestone, hard enough in places to be used as material for mending roads, though it cannot be recommended for the purpose. A specimen from Oldford, Frome, examined under the microscope by Mr. Teall, showed organic fragments, and a few quartz grains, in a granular amorphous matrix. The bands of rock alternate with soft marls, and they are often nodular or impersistent in character. They have been traced northwards more or less persistently from Dorsetshire as far as Lansdown near Bath; beyond this the rock-beds are less constant, and have only been recognized in places. The Fuller's Earth Rock is thus a lithological rather than a stratigraphical division, for the stony bands merge gradually into the clays above and below, and cannot be regarded as having a fixed horizon. Fossils, as a rule, are more abundant in the stone-beds and associated marls, than in the more clayey divisions, but the latter are especially characterized by *Ostrea acuminata*, and the economic fuller's earth has yielded a large number of Ostracoda.*

On the whole, Lamellibranchiata and Brachiopoda are the most abundant fossils. The remains of Saurians and Fishes occur, but rarely. Cephalopoda are not uncommon in the Fuller's Earth Rock, and it is characterized by the presence of *Ammonites*

* T. R. Jones and C. D. Sherborn, Proc. Bath Nat. Hist. Club, vol. vi. p. 249.

*subcontractus.* This appears to be the form figured as "*A. modiolaris*" by William Smith, but it is not the same as the original *A. modiolaris* of Lhwyd. It should be mentioned that *A. subcontractus* has been recorded by E. Witchell* from the Clypeus Grit of Rodborough Hill, a fact of considerable interest as showing the incoming in the upper part of the Inferior Oolite of this Bathonian type of Ammonite; for the same species occurs in the Great Oolite. *Ammonites viator* (*A. Morrisi* of Oppel) and *A. arbustigerus* also occur in the Fullonian formation.

The following are the more abundant and characteristic fossils of the Fullonian or Fuller's Earth formation:—

| — | Lower Clay. | Rock. | Upper Clay. |
|---|---|---|---|
| Ammonites arbustigerus. (Fig. 63) | | × | |
| —— bullatus | | × | |
| —— subcontractus. (Fig. 64) | | × | |
| —— viator | | × | |
| Belemnites parallelus | × | × | × |
| Anatina plicatella | | × | |
| Avicula costata | × | × | × |
| —— echinata. (Fig. 124) | × | | × |
| Ceromya plicata | | × | |
| Cypricardia bathonica | | × | |
| Goniomya angulifera | | × | |
| —— literata | | × | |
| Gresslya peregrina. (Fig. 121) | × | × | |
| Homomya gibbosa | | × | |
| Isocardia minima | | × | |
| —— nitida | | × | |
| Modiola gibbosa | | × | × |
| —— Lonsdalei | × | | |
| Myacites calceiformis | × | × | |
| —— tenuistriatus | × | × | |
| Nucula variabilis | × | | × |
| Ostrea acuminata. (Fig. 65) | × | | × |
| —— Sowerbyi. (Fig. 95) | | | × |
| —— subrugulosa. (Fig. 110) | | × | |
| Pecten vagans. (Fig. 122) | × | × | × |
| Pholadomya deltoidea | | × | |
| Placunopsis socialis | | | × |
| Rhynchonella varians. (Fig. 67) | × | × | × |
| Terebratula globata. (Fig. 28) | × | × | × |
| Waldheimia ornithocephala. (Fig. 66) | × | × | × |

Prof. Tate in 1870 argued that the "Fuller's Earth" formation should on palæontological grounds be considered as the uppermost zone of the Inferior Oolite, because, of the species he had been able to catalogue, 69 in number or 83 per cent. occurred in the Inferior Oolite, and 49 only or 60 per cent. in the Great Oolite.† The results obtained from specimens collected during recent work on the Geological Survey, are at variance with those of Prof. Tate. Of 72 species collected by Mr. Rhodes and myself, 58 are known also in the Great Oolite, and 42 in the Inferior Oolite, a number being common to the two formations.

* Proc. Cotteswold Club, vol. vii. p. 125.

† Quart. Journ. Science, vol. vii., 1870, p. 68.

## FULLONIAN OR FULLER'S EARTH FOSSILS.

FIG. 63.

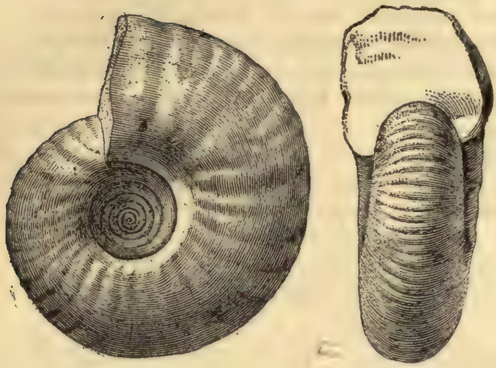


FIG. 65

FIG. 66.

FIG. 64.

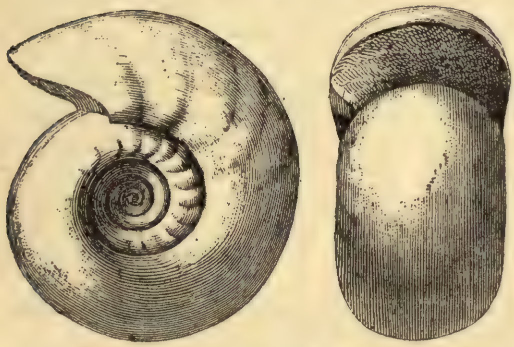


FIG. 67.

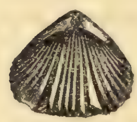


FIG. 63. Ammonites arbustigerus, d'Orb. ½.
,, 64. —— subcontractus, Mor. & Lyc. ½.
,, 65. Ostrea acuminata, Sow. Nat. size.
,, 66. Waldheimia ornithocephala, Sow. Nat. size.
,, 67. Rhynchonella varians, Schloth. 1½.

The Ammonites (*A. subcontractus* and *A. viator*) are decidedly Bathonian, and so generally do we find the former species in the Fuller's Earth Rock, it might be termed the zone of *A. subcontractus*. It is however more convenient to take *A. arbustigerus* as the zonal index for the Great Oolite Series, from the Fuller's Earth to the Forest Marble.

The Gasteropods, as a rule, are too poorly preserved to admit of specific identification, but the genera belong as much to the Inferior Oolite as to the Great Oolite.*

The Lamellibranchs include 43 species found also in the Great Oolite, and 30 in the Inferior Oolite, many of them passing upwards from the one formation into the other. *Avicula*

* The species are included with those from the Great Oolite in the Catalogue of British Jurassic Gasteropoda by Hudleston and Wilson; see also Hudleston, Gasteropoda of Inferior Oolite, p. 19.

*echinata*, *Gervillia acuta*, *Nucula Menkei*, *Ostrea acuminata*, *O. Sowerbyi*, and *O. subrugulosa*, represent the Bathonian side, while the species of *Homomya*, *Modiola*, *Myacites*, are more allied to the Bajocian.

The Brachiopoda are about equally divided. *Terebratula globata* passes upwards from the Inferior Oolite, while *Waldheimia ornithocephala*, and its ally *W. lagenalis*, are Great Oolite forms.

The Echinodermata, Corals, &c. are rare, and the Ostracoda, of which Prof. Jones and Mr. Sherborn have recognized 62 species, are with three exceptions new.

These observations after all serve to confirm those of Mr. Etheridge, who states that of 110 species from the Fuller's Earth, 65 were derived from the Inferior Oolite and 88 occur in the Great Oolite series.*

Although numerical estimates of species cannot be said to furnish the most reliable data for classifying strata, yet the palæontological evidence favours our grouping of the Fullonian Beds with the Great Oolite. Again in lithological characters and method of formation, the Fullonian clays, marls, and earthy limestones, closely resemble beds in the Great Oolite of the counties of Gloucester, Oxford, and Northampton. The Fullonian formation, as Mr. Etheridge admits, is of a transitional character, but it is a subordinate and local accumulation, and, for general purposes of classification and correlation, not important enough to stand alone. It has been suggested that a divisional-plane be taken on top of the Lower Fuller's Earth Clay†; but no such division is practicable, and to attempt it would be to violate the principles of stratigraphy.

When we enter the region of east Gloucestershire and north Oxfordshire, it is difficult in places to separate the uppermost strata of the Inferior Oolite from the Fullonian Beds, for there are limestone-beds that may in point of time represent the lower clays of the "Fuller's Earth" of other tracts. Reference has already been made to these passage-beds. (See p. 129.)

In the region south of Gloucestershire, however, the field-geologist has as a rule no difficulty in fixing the plane of division between "Fuller's Earth" and Inferior Oolite, for there is no marked alternation of limestones and clays at the junction; and although we may occasionally find a band of limestone near the base of the Fullonian, yet in places the surface of the Inferior Oolite is bored by Annelides and Lithodomi and the junction is well marked.

We may therefore regard the Fullonian formation as extending from the Dorsetshire coast through Somersetshire and Gloucestershire to the neighbourhood of Chipping Norton in Oxfordshire. In this northern area the upper Fullonian clays merge into the Stonesfield Slate Series; and further on, both are to a certain

* Stratigraphical Geology and Palæontology, p. 422.
† H. S. Solly and J. F. Walker, Proc. Dorset Nat. Hist. Club, vol. xi. p. 120.

extent represented by the Upper Estuarine Series of the Midland counties. Geologically, the most important development of the Fullonian Beds is in Dorsetshire, where its thickness is about 150 feet. North and north-east of Bath the thickness diminishes, and the "Fuller's Earth," excepting that it promotes landslips, occupies an insignificant part in the surface-features of the country. Its thickness near Stroud and Cheltenham is about 70 or 80 feet, and it dimininishes eastwards.

## Local Details.

### *Bridport and Weymouth to Crewkerne.*

The Fullonian Beds form the dull grey and somewhat treacherous cliffs between Bridport Harbour and Eype mouth; these are known as the "West Cliff," but have also been described under the names of Fourfoot Hill and Watton Hill. The formation (so far as exposed) consists of about 100 feet of pale bluish-grey marly clay, with many nodules and occasional bands of grey earthy limestone. Small concretions of carbonate of lime ("race") are also met with. About 9 feet from the top of the Fullonian formation, there is a prominent band of hard and fissile white marl (3 feet thick in places), and another impersistent band of the same rock occurs, a little higher up, in the bluish-yellow marl that here forms the uppermost portion of the strata. These beds are surmounted by the Forest Marble. (See p. 342.) At the western end of the cliffs the "Fuller's Earth" is faulted against the Middle and Upper Lias, and at the eastern end, it is faulted against the Midford Sand.* The latter fault cuts the cliff obliquely, and the "Fuller's Earth" in proximity to it, consists of grey marl with hard bands of earthy limestone and much fibrous carbonate of lime ("beef"), the beds being more or less disturbed. We are not here presented with the full thickness of the Fullonian formation, which may, as stated by Dr. Wright, attain a thickness of 150 feet. (See Fig. 99, p. 343.)

Fossils are by no means numerous. Towards the upper part of the formation I obtained *Ostrea acuminata*, and, near the foot of the clay-cliffs, there were to be found a number of tender bivalves of the genera *Lucina* and *Myacites*.

The lowest beds of the Fullonian, consisting of grey marly clay, are exposed in the cliffs between the mouth of the Bride or Bredy, and Burton Bradstock. There they rest evenly on the Inferior Oolite, and are faulted at one point with a downthrow of 10 or 15 feet on the east; but the beds are not accessible, except in the tumbled masses that may occasionally be found on the foreshore. (See Fig. 32, p. 55.)

East of Burton Bradstock, at Cliff End, we again find the upper beds of the Fullonian, overlaid by Forest Marble. Near the

* See section by Buckland and De la Beche, Trans. Geol. Soc., ser. 2, vol. iv., plate 2, and pp. 29 and 40; also Fig. 41, p. 52, in Memoir on the Lias of England and Wales.

junction, but belonging to the Fullonian, specimens of *Avicula costata?, Nucula Menkei, Eulima*, and *Spinigera* may be obtained.

Many specimens, obtained from the "Fuller's Earth," have been recorded from the Forest Marble, and *vice versâ*, for, as remarked by Lycett, fossils "were picked up from a bank on the sea shore."* *Trigonia Moretoni*, recorded from this locality, may belong to the Forest Marble.

The following fossils were collected by Mr. J. Rhodes and myself at Burton Bradstock and Eype:—

| | |
|---|---|
| Fish-remains. | Lucina despecta var cardioides. |
| Eulima. | Modiola gibbosa. |
| Spinigera. | Myacites. |
| Arca Pratti. | Nucula Menkei. |
| Avicula costata? | Ostrea acuminata. |
| Cardium. | Pecten. |
| Cucullæa concinna? | Posidonomya. |
| Leda lachryma. | Eryma? |
| Lima. | Lignite. |
| Lucina despecta. | |

Dr. Wright records in addition, *Ceromya concentrica, Pholadomya lyrata* (*carinata*), and *Waldheimia ornithocephala*; and the Rev. H. S. Solly and Mr. J. F. Walker, have found *Terebratula globata, Rhynchonella varians* var. *Smithi, R. spinosa* var. *powerstockensis*, and *Trigonia elongata* var.†

A few miles further east, the Fullonian Beds were again exposed by the coast-guard station on the borders of the West Fleet, south of Langton Herring. Attention was first directed to these beds by Robert Damon.‡ They form a bank about 30 feet high, made up chiefly of an elongated variety of *Ostrea acuminata*, with which *O. Sowerbyi* is also associated. *Serpula obliquestriata* occurs also in the blue clay, which may be traced above and below this remarkable Oyster-bed. The general section here is as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Forest Marble (Bradford clay) | *Rhynchonella*-bed | 2 | 0 |
| Fullonian | Bands of pale earthy and flaggy limestone and clay | 6 | 0 |
| | Clay, seen to depth of | 20 | 0 |
| | *Ostrea*-bed | 25 0 to 30 | 0 |
| | Clay. | | |

The *Ostrea*-bed again occurs in the low-cliff bordering the West Fleet on the opposite side of the little bay, south-west of Langton Herring.

The "Fuller's Earth Rock" is not shown on the Dorsetshire coast, if we except some hard bands at or near the top of the Fuller's Earth clay at Eype: but these bands do not present the usual fossiliferous character of the Rock. The sections however

* Supp. to Mollusca from the Great Oolite, p. 118.

† Wright, Quart. Journ. Geol. Soc., vol. xii. p. 310; Solly and Walker, Proc. Dorset Nat. Hist. Club, vol. xi. p. 120.

‡ Geology of Weymouth, 1860, p. 12.

are not continuous, so that while we have positive evidence of clayey beds above the Inferior Oolite and beneath the Forest Marble, we have no section to show the entire sequence. It is not right under these circumstances to deny the persistence of the Fuller's Earth Rock, although it is just possible it may have tapered away or have been overlapped by the Forest Marble. For some distance inland we find no distinct bed of Fuller's Earth Rock, for it has not been traced on the Geological Survey Map beyond a tract of ground between South Perrot and Mosterton: thence over the greater part of the country to the south and south-east, towards Bridport, the Cretaceous rocks overlap the Forest Marble and rest directly on the Fullonian Beds.

The "Fuller's Earth clay" was opened up in the railway-cutting near Smokeham, south of Powerstock station, and a number of fossils (now in the Dorchester Museum), were obtained from the beds: but the cutting is obscured. By Wicker Farm, nearer to Toller Porcorum, the beds have been exposed in the railway-cutting: here they consist of bluish-grey slightly calcareous clay, and this is burnt (with "slack" or small coal) for ballast, that is used on the railway. At an adjoining kiln, the clay is used for the manufacture of bricks and drain-pipes. The following fossils were collected by Mr. J. Rhodes and myself at this locality:—

Tooth of Saurian.
Ammonites.
Belemnites parallelus.
Avicula costata.
—— Münsteri.
Cardium?
Lima.
Modiola Lonsdalei.
Nucula variabilis.
Ostrea acuminata.
—— Sowerbyi?
Posidonomya.
Serpula tetragona.
Rhynchonella varians.
Waldheimia ornithocephala.

These beds most probably belong to the Lower Fuller's Earth clay, as the same group of fossils occurs in the lower beds that are exposed above the Inferior Oolite in the railway-cutting west of Crewkerne station. At that locality *Avicula echinata* and fragments of *Pecten* occur, in addition to a number of the species above noted. Sections are to be seen here and there in the brickyard west of Crewkerne station, and in that at High Cross Hill, between Haselbury and East Chinnock. Here we have grey clay with a good many nodules of "race," due probably to the decay of fossils; but Belemnites are preserved. (See Fig. 35, p. 69.)

### *Sherborne to East Cranmore.*

Passing eastwards from Crewkerne, we come to the best development of the Fullonian series in this country. From Thornford near Sherborne to the neighbourhood of Bruton, the Lower and Upper Fuller's Earth clays are separated by a mass of Fuller's Earth Rock, which forms a well-marked escarpment.

The Lower Fuller's Earth clay with an occasional band of earthy limestone, may be seen resting on the Inferior Oolite, and faulted against it, in the railway-cutting east of Bradford Abbas.

There it contains crushed specimens of *Waldheimia ornithocephala.* (See Fig. 36, p. 77.) The Lower beds were well exposed near New England, on the western slopes of Stout Hill, north-east of Milborne Port. Here nearly 50 feet of clay was to be seen in a lane-cutting; and the following fossils were obtained by Mr. J. Rhodes and myself:—

| | |
|---|---|
| Belemnites parallelus. | Ostrea acuminata (abundant). |
| Avicula costata. | —— gregaria. |
| —— Münsteri. | Pecten vagans. |
| Modiola Lonsdalei. | Rhynchonella varians. |

Small specimens of *Ostrea acuminata* were also abundant in the clays beneath the Fuller's Earth Rock, west of the Cock Inn, Holton. The Fuller's Earth Rock in this district consists of grey and buff earthy and sometimes shelly limestone, with bands of marly clay. Numerous quarries and lime-kilns occur along the outcrop, but the stone is now seldom burnt for lime, although employed for building walls and for mending some of the by-roads.

Shallow pits have been opened in the rock near Clifton Wood to the south and south-east of Stoford, also west of Thornford; and the beds are exposed in the road-cutting at Dancing Hill, south of Sherborne. They form a low ridge that extends through Sherborne Park, but the outcrop is displaced by faults in several places. Northwards from Henover Hill, by East Hill, and Stout Hill, they form a fine escarpment. The best sections are those exposed in the railway-cuttings north-east of Milborne Port station, and south-east of Shepton Montague.

The general appearance of the rock and its fossils is somewhat similar to that presented by many sections of the Great Oolite in the midland counties, where those beds consists of pale earthy limestones and marls with numerous Lamellibranchs.

The following is the section of beds exposed in the Railway-cutting at Laycock, north-east of Milborne Port station:—

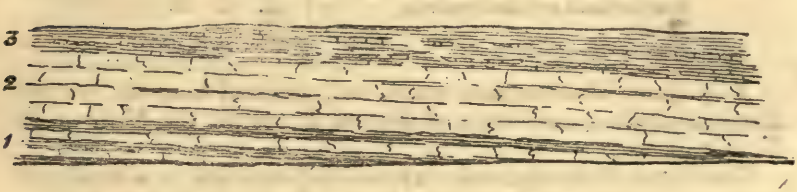
| | | Ft. | In. |
|---|---|---|---|
| Fuller's Earth Rock. | Grey and brown earthy limestones, rubbly on top, and very fossiliferous - 8 0 or | 9 | 0 |
| | Thicker beds of buff earthy limestone, shelly in places: the shells weathering out on joint surfaces - - - 9 0 or | 10 | 0 |
| | Dark bluish-grey marls, with indurated bands of light bluish-grey earthy limestone. Casts of *Myacites* in natural position; and *Pholadomya* (not so abundant as at Thornford) - - about | 15 | 0 |
| Lower Fuller's Earth Clay. | Clays, not well exposed. | | |

Further north, between Charleton Horethorne, and Stowel, and again west of the Cock Inn, Holton, the Fuller's Earth Rock has been quarried, and numerous fossils may be obtained.

The cutting near Shepton Montague showed the following beds:—

FIG. 68.

*Section in Railway-cutting, south-east of Shepton Montague, Somerset.*




| | | FT. | IN. |
|---|---|---|---|
| Fuller's Earth Rock. | 3. Clay with thin bands of earthy limestone, *Ostrea*, *Rhynchonella*, *Waldheimia*, and Lignite - - - - about | 5 | 0 |
| | 2. Hard grey earthy limestone, irregularly bedded and much jointed: blue-hearted in places. *Ammonites subcontractus*, and many other fossils - - - | 12 | 0 |
| | 1. Blue marly clay with thick bands of earthy limestone - - - - about | 12 | 0 |

List of Fossils collected by J. Rhodes and myself from the Fuller's Earth Rock of Thornford (T.), Milborne Port (M.), Charleton Horethorne (C.), and Shepton Montague (S.) :—

| | |
|---|---|
| Ammonites subcontractus - - | T. S. |
| —— viator - - - - | M. C. |
| Belemnites parallelus - - | T. M. S. |
| Amberleya? - - - | C. |
| Chemnitzia - - - - | M. |
| Pleurotomaria - - - | T. M. C. |
| Anatina plicatella - - - | M. C. |
| —— sp. - - - - | S. |
| Cardium cognatum - - - | M. |
| Ceromya plicata - - - | Holton. |
| Corbis Lajoyei - - - | M. |
| Gervillia acuta - - - | M. |
| Goniomya literata - - - | M. S. |
| Gresslya peregrina - - - | M. |
| Homomya gibbosa - - - | M. |
| Isocardia nitida - - - | S. |
| Lima duplicata - - - | M. |
| —— gibbosa - - - | M. S. |
| —— pectiniformis - - - | M. |
| Modiola gibbosa - - - | S. M. |
| Myacites tenuistriatus - - | T. S. |
| Nucula - - - - | S. |
| Ostrea subrugulosa - - - | C. S. |
| Pecten demissus - - - | T. M. S. |
| —— lens - - - - | T. |
| Pholadomya deltoidea - - | T. M. S. |
| —— oblita - - - - | S. |
| —— ovalis - - - - | M. |
| Pinna - - - - | T. |
| Placunopsis radians - - - | T. |
| Trigonia costata? - - - | T. |
| —— (cast) - - - - | M. |

| | |
|---|---|
| Unicardium - - - - | M. |
| Rhynchonella obsoleta - - | S. |
| —— varians - - - - | T. M. C. S. |
| Terebratula globata - - - | M. C. |
| —— maxillata - - - | M. |
| Waldheimia ornithocephala - | M. C. S. |
| Corals - - - - | M. |
| Serpula tricarinata - - - | M. C. |

A specimen of *Ammonites viator*, var., obtained from the Fuller's Earth at Godminster, south of Bruton, is now in the Museum at Jermyn Street.

The Upper Fuller's Earth clay was well exposed in a brickyard north-east of Maperton, and south-east of the Cock Inn, Holton. About 25 feet of grey marly clay was exposed, the beds, where dry, being pale and hard, and much resembling those exposed in the cliff near Eype. Some small iridescent Ammonites were found in the clay, and among the débris on the slopes of the banks, I picked up a fine slab containing remains of *Lepidotus*. The latter specimen was probably derived from the Forest Marble, traces of which occur on top of the clay.

A well at Cuddlesome to the east of Bratton, was sunk to a depth of 50 feet, through Upper Fuller's Earth Clay to the Fuller's Earth Rock.

Lamyat Beacon, north-west of Bruton, is a conspicuous outlier of Fuller's Earth Clay and Rock ; *Lima duplicata* and *Rhynchonella varians* were found here. At Scale Hill south-east of Batcombe the thickness of the beds was thus estimated by De la Beche* :—

| | Ft. |
|---|---|
| Upper Fuller's Earth - - - - - | 133 |
| Fuller's Earth Rock - - - - - | 25 |
| Lower Fuller's Earth - - - - - | 21 |
| | 179 feet. |

I was unable to verify this particular estimate, but the attenuation of the Lower Fuller's Earth clay is borne out by evidence obtained near Frome.

South of West Cranmore, the Fuller's Earth Rock forms a gentle escarpment, not far above the Inferior Oolite, and higher up comes the Upper Fuller's Earth clay. The Rock has been exposed in the park at East Cranmore, to the south of the Hall, and *Pholadomya*, *Modiola*, and other fossils have been obtained.

Wanstrow itself is situated on Fuller's Earth clay, not Great Oolite as represented on the Geological Survey map. Grey marly clay is shown in the lane on the east side of the village.

### *Frome to Bath.*

Approaching the Mendips we find the beds maintain their ordinary characters. East of Stoney-lane House, south-west of

* Mem. Geol. Survey, vol. i. p. 280.

Whatley, we find the Fuller's Earth Rock, yielding *Goniomya*, *Pholadomya*, *Pinna*, *Rhynchonella varians*, &c.; and the same rock, consisting of pale grey earthy and shelly limestone, interstratified with grey and brown "racy" clays, may be seen between Murdercombe and Egford Bridges, to the west of Frome.

As before mentioned, there does not appear to be any considerable thickness of clay between the Inferior Oolite and the Fuller's Earth Rock in the neighbourhood of Frome. At the same time the Fuller's Earth Rock itself may be developed at somewhat different horizons in the central portion of the series, and in this neighbourhood the stone-beds do not occur in so thick a form as at Shepton Montague and Sherborne.

The beds near Frome were well exposed in a cutting on the eastern side of the stream at Egford Bridges. Here they comprised about 10 feet of pale earthy and hard shelly limestones and marl, appearing in rubbly and irregular beds. Fossils were very abundant; and from this section, and others exposed at the Sewage-works north of Frome, I obtained the following species:—

Ammonites.
Pleurotomaria.
Anatina plicatella.
Astarte rotunda.
Cardium (cast).
Ceromya plicata.
Cypricardia bathonica (cast).
Cyprina (cast).
Gervillia.
Goniomya literata.
Gresslya peregrina.
Isocardia minima.
—— nitida.
Lima duplicata.
Lucina.
Modiola gibbosa.
—— sowerbyana.
Myacites tenuistriatus.
Nucula.
Ostrea subrugulosa.
Pholadomya deltoidea (abundant).
Trigonia (cast).
Rhynchonella varians (abundant).
Terebratula globata (abundant).
—— maxillata.
Waldheimia bullata.
—— ornithocephala (abundant).
Serpula tricarinata.

The following section was seen in a disused quarry, south-west of Bonnyleigh Hill, between Frome and Beckington:—

| | | |
|---|---|---|
| Fuller's Earth Rock. | Clay with bands of pale earthy limestone. Many fossils - - | 12 to 15 feet. |
| Lower Fuller's Earth Clay. | Pale clay with "race," and with nodules and bands of pale earthy limestone - - - - | |
| Inferior Oolite | Rubbly beds of oolite - - - | about 12 feet. |
| | Massive beds of pale oolite. (Many Ammonites formerly obtained, when stone was dug to build adjoining house) - - - - | |

The total thickness of the Fullonian series at this locality cannot be much more than 35 feet, as the shelly oolitic limestones of the Forest Marble appear in the scarp above this quarry: whereas at the boring for coal at Buckland Denham, about 3 miles to the west, the formation must be upwards of 100 feet thick. From this it seems possible that the Forest Marble overlaps some of the higher beds of Fuller's Earth, and such would also appear to be the case between Nunney and West Cranmore: but further evidence is needed on this point. (See Fig. 38, p. 91.)

The Fullonian series is exposed in places along the railway between Frome and Radstock. Near the 118 and 119 milestones, grey marly clay with occasional bands of marly limestone were to be seen. *Ostrea acuminata* is abundant in the clay, and *Rhynchonella varians* in the stone.

South of Green Parlour, Radstock, there was exposed a section of grey marly clay, with nodular beds of pale earthy limestone, yielding *Waldheimia ornithocephala*, *Rhynchonella varians*, *Avicula costata*, and *Ostrea acuminata*. There is a specimen of *Ammonites viator*, var., from the Fullonian Beds of Radstock, in the Museum of Practical Geology. The Lower Fuller's Earth appears to be very thin, but the Rock perhaps occurs at irregular horizons. It spreads over a flat area, and has been quarried immediately south of Green Parlour.

The Fuller's Earth Rock has not been traced (on the Geological Survey Map) further north than Stoney Littleton, in the main escarpment south of Bath. It has however been partially mapped in the Wellow outlier, but this tract of ground and that to the west of Combe Hay need revision. An examination of the ground near Upper and Lower Baggeridge, between Wellow and Norton St. Philip, shows that Fuller's Earth Rock occurs along the scarps in an attenuated condition. In the road-cutting leading from Wellow to Upper Baggeridge Farm, there may be seen (above the Inferior Oolite), grey clay with *Ostrea acuminata* and *Rhynchonella varians*, and this is overlaid by brown earthy and rubbly limestone with *R. varians*, *Waldheimia ornithocephala*, *Isocardia*, *Modiola sowerbyana*, *Ostrea Sowerbyi*, *Pecten demissus*, and *Pinna*. These beds may be traced around the hill to Hassage, and thence towards Norton St. Philip.

Fuller's Earth Clay with occasional bands of earthy limestone, was well exposed in the railway-cuttings between Wellow and Midford. In this neighbourhood we first come to the beds that have been worked for economic purposes: and the fuller's earth of commerce has been obtained at various points in the outliers of Wellow, South Stoke, and Combe Monkton. It has been worked at Wellow, Combe Hay, near Dunkerton, Duncorn Hill, near English Combe, South Stoke, Odd Down, Midford, Combe Monkton, Lyncombe, and Widcombe.

The total thickness of the Fullonian series in this neighbourhood was estimated at from 135 to 150 feet by Lonsdale.*

The lower beds were well exposed in the cutting south of Midford railway-station, as follows :—

| | | Ft. | In. |
|---|---|---|---|
| Lower Fuller's Earth Clay. | Grey marly clays with *Ostrea acuminata*, *Rhynchonella varians*, and *Terebratula globata*. | | |
| | Bands of pale earthy limestone with Lamellibranchs. | | |
| | Clays with *Modiola*, *Myacites tenuistriatus*, *Pholadomya* (abundant), *Terebratula globata* - - - - - - | 3 | 0 |
| | Earthy limestones (in places). | | |
| Inferior Oolite. | Indurated buff oolite. | | |

* Trans. Geol. Soc ser 2, vol. iii. p. 250.

Near Severcomb Farm the lower beds, with *Waldheimia ornithocephala*, were to be seen resting on a bored surface of the Inferior Oolite. (See p. 97.)

The Fuller's Earth Rock makes no conspicuous feature in this neighbourhood. It consists of marls and clays with irregular bands and nodular masses of pale grey earthy limestone, about 5 feet in thickness, having much the same character as the beds in Dorsetshire, and being likewise very fossiliferous. It has been exposed to the south-east of Highbarrow Hill (H.); in the road leading from Combe Monkton to the Paper Mill on the west; also above Perrymead, in the lane from Widcombe (W.) to Combe Down; and at Bath (B.), above the Royal Villas, west of Wesley College. From these beds I have obtained the following fossils:—

| | | | |
|---|---|---|---|
| Ammonites arbustigerus | B. | | |
| Nautilus | B. | | |
| Cypricardia bathonica | B. | H. | |
| —— caudata | B. | | |
| Goniomya | H. | | |
| Gresslya peregrina | B. | W. | |
| Homomya | B. | | |
| Isocardia | B. | W. | H. |
| Myacites securiformis | B. | | |
| —— tenuistriatus | H. | | |
| Ostrea subrugulosa | B. | | |
| Panopæa ? | B. | | |
| Pecten vagans | B. | | |
| Pholadomya Heraulti | B. | W. | H |
| Rhynchonella concinna | W. | H. | |
| —— varians | B. | W. | H |
| Terebratula globata | B. | H. | |
| Waldheimia lagenalis | B. | | |
| —— ornithocephala | B. | W. | |
| Serpula tricarinata | B. | | |
| Holectypus hemisphæricus ? | B. | | |

The Fuller's Earth at Wellow presents the same characters as the beds worked at Midford. At Combe Hay a shaft was sunk to a depth of 30 feet. The opening of the tunnel showed yellow fuller's earth 3 feet or more, that passes underground into blue earth, 4 or 5 feet. The earth is micaceous in places. The beds on top comprised yellow and grey marly clay, with *Ostrea acuminata*, *Ceromya*, &c.

The connection of the beds with the Great Oolite, is shown by the following section at "Combe Grove Pit," which was recorded by William Smith*:—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite (see p. 265). | Bastard freestone - - - | 10 | 3 |
| | Shelly limestone - - - | 7 | 0 |
| | Sand and burs - - - - | 6 | 0 |

* Memoirs of W. Smith, p. 60.

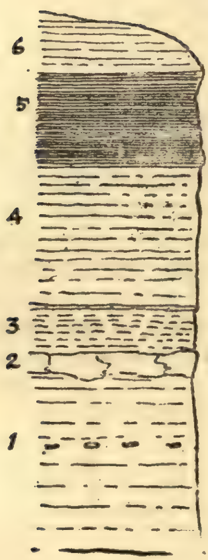
| | | Ft. | In. |
|---|---|---|---|
| Fuller's Earth Beds. | Dark marl | 1 | 9 |
| | Bastard fuller's earth | 6 | 0 |
| | Dull black [earth] and selenite | 2 | 0 |
| | Light blue [earth] | 1 | 2 |
| | Fuller's earth | 5 | 0 |
| | Hard grey stone | 2 | 0 |
| | Tender stuff | 1 | 4 |
| | Black marl | 4 | 6 |
| | | 47 | 0 |

The economic fuller's earth of the neighbourhood of Bath, is a bluish- or greenish-grey clay, that weathers to a brown or yellowish-brown colour. It is slightly calcareous and ferruginous, and contains small quantities of magnesia, soda, and potash. It is a soft dull earthy clay, having however a shining streak, and being somewhat greasy to the touch. Although apparently of an unctuous character, the clay possesses no plasticity, as when placed in water it forms no paste, but subsides as a pulpy impalpable powder. The analyses of the earth kindly made by Mr. J. Hort Player (see p. 490) afford no clue to its fulling properties, and these are therefore probably due to peculiar physical characters.

The section of the beds at the Midford Fuller's Earth pits, between Midford Castle and the Cross Keys Inn, is as follows:—

Fig. 69.

*Section at Midford near Bath.*




Great Oolite.

| | | Ft. | In. |
|---|---|---|---|
| Upper Fuller's Earth Clay. | 6. Soft marl and brown clay | 5 | 0 |
| | 5. Dark bluish-grey clay | 4 | 0 |
| | 4. Brown marly clay with indurated bands of earthy marl, and "beef" (fibrous carbonate of lime). Some lignite and many fossils | 6 | 6 |
| | 3. Bastard fuller's earth: blue and yellow | 1 | 6 |
| | 2. Soft marly stone | 0 | 6 |
| | 1. Yellow fuller's earth, with occasional indurated bands and small hard nodules of earthy limestone. This earth passes laterally into the Blue earth further in the hill | 5 | 0 |

I obtained the following fossils from the clay above the economic fuller's earth :—

| | |
|---|---|
| Belemnites aripistillum. | Ostrea subrugulosa ? |
| —— parallelus. | Pecten demissus. |
| Cardium. | —— vagans. |
| Ceromya. | Placunopsis socialis. |
| Cyprina. | Rhynchonella varians. |
| Isocardia. | Waldheimia ornithocephala. |
| Myacites jurassi ? | |

A number of Ostracoda and some Foraminifera have been obtained from the economic bed of fuller's earth, by Prof. T. R. Jones and Mr. C. D. Sherborn.*

A Pit at Odd Down showed the following section, which was recorded by H. W. Bristow :—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite | Limestone | 6 | 0 |
| Fuller's Earth | Yellow marl, very soft | 7 | 0 |
| | Blue clay | 2 | 6 |
| | Rubbly rock, blue in the inside, with yellow coating | 7 | 0 |
| | Bastard fuller's earth, blue | 5 | 0 |
| | Rubbly rock as before | 1 | 6 |
| | Blue fuller's earth, variable | 3 | 6 |
| | Rubbly rock as before. | | |

A well at Beckford's Tower, on Lansdown, noted by Bristow, proved the following strata :—

| | Ft. | In. |
|---|---|---|
| Great Oolite | 30 | 0 |
| Fuller's Earth. Light-grey clay with occasional layers of thin stone | 70 | 0 |
| Sand [? Inferior Oolite]. | | |

### *Bath and the Cotteswold Hills to Chipping Norton.*

At the Box tunnel the thickness of the Fullonian formation has been estimated to be 148 feet,† but as the wells at Bath do not prove more than 70 feet of the beds, I think that thickness must have been overestimated.

Highbarrow Hill and Kelston Round Hill near Bath, are capped by tiny outliers of Great Oolite, resting on Fuller's Earth clay with *Rhynchonella varians*, &c.

In a lane east of Slaughterford, north-west of Corsham, the thickness of the beds was estimated at 65 feet by Prof. Hull—and there the marls and clays contained a central division, about 10 feet thick, of Fuller's Earth Rock.‡ The Rock has not been recognized further north, although occasional layers of earthy and shelly limestone or calcareous sandstone, are met with in the blue and yellow shales and marly clays that represent the Fullonian formation.

Northwards along the Cotteswold Hills, the exposures are few and far between, for the beds are not worked for economic

* *See* Geol. Mag., 1886, p. 272, and Proc. Bath Nat. Hist. Club, vol. vi. p. 249.
† Lycett, Cotteswold Hills, p. 85.
‡ Geol. parts of Wilts and Gloucestershire, p. 12.

purposes other than "marling," and rarely on this account. Traces of clay and earthy limestone were exposed in the valley of the Broadmead Brook, north of Marshfield; and clays were exposed here and there to the south-east of Horton. The presence of the formation is indicated by springs and marshy ground.

A number of fossils have been collected from the formation near Cubberley, a few miles south of Cheltenham;* but as a rule not many fossils have been obtained from the formation in Gloucestershire. Near Stroud and Minchinhampton, *Ostrea acuminata* occurs in the clays and bands of earthy limestone. The beds were proved in the Sapperton railway-tunnel, and the thickness was estimated at 70 feet. Here *Ostrea subrugulosa, Homomya Vezelayi, Myacites calceiformis, Ceromya plicata, Avicula echinata, Pecten vagans, Sphæra Madridi, Arca lata,* and *Rhynchonella concinna* have been obtained.†

The following section was made by E. Witchell from a trial-shaft sunk on Stroud Hill:—

| | | Ft. | In. |
|---|---|---|---|
| Fullonian (Fuller's Earth). | Bands of sandstone alternating with clay, and beds formed of the valves of *Ostrea acuminata* - - - - - | 15 | 0 |
| | Yellowish-brown marl and shale, with several thin bands composed of *O. acuminata*; passing downwards into blue and buff laminated shale - - - | 30 | 0 |
| | Blue marly clay and shale, the lower portion partly consolidated, and, when dry from exposure, having a conchoidal fracture - | 25 | 0 |
| Inferior Oolite. | | | |

In the shaly beds, Witchell obtained specimens of *Lima duplicata, Posidonomya opalina, Trigonia Witchelli, T. imbricata,* and remains of Crustacea belonging to the genus *Magita;* as well as numerous specimens of *Glyphea pseudoscyllarus.* From the upper beds he procured, in addition to *Pecten vagans, Placunopsis socialis,* and *Ammonites gracilis,* forms that characterize the Stonesfield Slate of the neighbourhood: but (as he remarks) the upper beds pass into the Stonesfield Slate.‡

Witchell also noted the presence of Fuller's Earth at White Hill, near Stroud. It occurred as an isolated mass, in a depression of the Inferior Oolite; and a well had been sunk in it to the depth of 35 feet. The clay must originally have sunk or slipped from higher ground into a fissure, in the Inferior Oolite, of considerable width and depth.

With regard to the Fuller's Earth near Minchinhampton, Lycett observed that its thickness varies from 60 to 80 feet. Northwards in the parish of Bisley, "it rapidly thins out, and at Througham and Lypiatt, where the Stonesfield Slate in mass begins to occupy its position, the thickness is reduced to about 9 or 10 feet. It consists of stratified blue and

* Hull Geol. Cheltenham, p. 52.
† Lycett, Cotteswold Hills, p. 89.
‡ Geology of Stroud, p. 69; Proc. Cottesw. Club, vol. vi. p. 144, vol. vii. p. 117.

brown marls and clays, traversed by three or four bands of hard brown argillaceous rock called 'clay-rag.' The uppermost of these is a lamellar argillaceous slate having all the characters of the Stonesfield Slate, and judging from the number of places where it occurs, would appear to be continuous over the whole district."* At Miserden the thickness of the beds was estimated at 30 feet by Witchell.

The Fullonian formation was exposed south of Bagendon Church, where it consists of stiff grey clay with much "race," and bands of hard earthy and shelly limestone, yielding *Pholadomya.*

In a cutting of the railway south of Chedworth, the junction with the Great Oolite was well exposed, and the following beds were seen (see Fig. 42, p. 128):—

| | | Ft. In. |
|---|---|---|
| Great Oolite. | Rubble of white oolite and marl. | |
| | Fine hard false-bedded oolite (= Taynton Stone) - - - - | 4 0 to 5 0 |
| Stonesfield Slate and Fuller's Earth. | Blue and brown clay and marl with sandy layers and *Ostrea* - - - | 4 0 to 6 0 |
| | Impersistent bands of hard partially oolitic sandy limestone, fissile and false-bedded. | 4 0 |
| | Clay and impure fuller's earth - - | |

Here we find the blending of the Fuller's Earth and Stonesfield Slate, of which we have evidence from the neighbourhood of Lansdown near Bath, onwards to Stonesfield and Chipping Norton in Oxfordshire.

Through Chedworth village, a long cutting was made in blue Fuller's Earth clay with beds of impure fuller's earth. On the south side of the tunnel the junction with the Great Oolite was again exposed, though not very clearly at the time of my visit, owing to slips. Beneath flaggy beds of oolite, and layers of hard concretionary and flaggy sandy limestone (Stonesfield Slate), there occurred about 4 feet of clay with *Ostrea acuminata*, a hard band of white marl, and a considerable thickness of blue clay beneath. The entire thickness of the Fuller's Earth was shown further on, in a cutting west of the Barrow near the Roman Villa at Chedworth. For the most part it consists of blue and grey clay with "race," and occasional bands of earthy limestone towards the base; and near its junction with the Inferior Oolite it yielded *Ostrea acuminata, Avicula echinata, Homomya,* and *Pholadomya.* The thickness was about 50 feet.

In the railway-cuttings between Andoversford and Bourton-on-the-Water, fine sections of the Great Oolite and the passage through the Stonesfield Slate into the Fuller's Earth, have been exposed. The cutting north of Hampen showed the following section (see Fig. 43, p. 131):—

---

* Quart. Journ. Geol. Soc., vol. iv. p. 187; see also Lonsdale, Proc. Geol. Soc., vol. i. p. 414; Hull, Geol. Cheltenham, p. 51; and Brodie and Buckman, Quart. Journ. Geol. Soc., vol. i. p. 222.

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite | False-bedded oolite (= Taynton Stone) about | 30 | 0 |
| Stonesfield Slate and Fuller's Earth Series. | Yellowish marl (a few inches) passing into brown and blue shaly beds, with concretionary layers of micaceous and sandy limestone—irregular and impersistent, and associated with buff and grey sands. These beds are very changeable in character. The concretionary beds exhibit "pot-lid" features, they are slightly oolitic in structure, and pass into slaty beds (Stonesfield Slate) in the cutting N.W. of Salperton | 10 | 0 |
| | Bluish-marly shales with micaceous gritty layers, slaty at base | 9 | 0 |
| | Shaly beds | 2 | 0 |
| | Blue, obscurely oolitic and shelly limestone | 0 | 4 |
| | Bluish-grey marly shales, with bands of hard pale marl and impure fuller's earth, shown to depth of | 10 | 0 |

The total thickness of the Fullonian Beds is from 25 to 30 feet, and this was shown in the second cutting east of Notgrove Station. Here the mass of the formation consists of grey clay with "race," and yields *Ostrea acuminata.* Towards the upper part there was a layer of fissile calcareous sandstone, exhibiting sun-cracks and trails of animals. The clay rested on a thin band of earthy iron-stained limestone, below which was the coarse oolite of the Clypeus Grit.

Further eastward, in a cutting south-east of Roundhill Farm, a complete section of the Fullonian Beds is again shown, and there the Clypeus Grit is separated from the "Fuller's Earth" by about 8 feet of brown obscurely oolitic and rather sandy limestone, yielding *Ostrea acuminata, Homomya,* and *Trigonia.* The clays here are about 25 feet thick, and contain thin bands of fissile brown sandy and shelly limestone and white marl. It has been suggested that the beds of sandy limestone that overlie the Clypeus Grit, may correspond in age with the Chipping Norton Limestone. (See p. 133.)

On the Geological Survey Map the Fuller's Earth has not been traced further than Little Barrington to the west of Burford, in which neighbourhood it was considered to thin out by Lonsdale.* (See p. 510.)

Near Chipping Norton there has been much difficulty in correlating the beds. The observations of Mr. Hudleston, Mr. T. Beesley, and Mr. E. A. Walford, have it is true, smoothed the path for all subsequent inquirers, while the cuttings on the Chipping Norton and Banbury railway have afforded a capital view of the beds. Speaking with a little more confidence than they have done, I recognize the following strata:—

| | |
|---|---|
| Great Oolite Series. | White Limestones, &c. |
| | Stonesfield Slate Series. |
| | Fullonian Beds. (See p. 331.) |
| Chipping Norton Limestone. | |

* Proc. Geol. Soc., vol. i. p. 414.

The Chipping Norton Limestone has proved a source of much perplexity, because it overlies the Clypeus Grit, which has usually been regarded as the uppermost division of the Inferior Oolite of the Cotteswolds. It has yielded few fossils, and some of these have Bathonian affinities.* On the whole we cannot separate this Limestone on stratigraphical grounds from the Inferior Oolite; but it may be regarded as a passage-bed between that formation and the Fullonian. (See Fig. 92, p. 329.)

It seems hardly necessary in this northern area to separate the Fuller's Earth clay from the Stonesfield Slate; and both become incorporated with the Upper Estuarine Series, as we proceed from the neighbourhood of Chipping Norton eastwards and north-eastwards into Buckinghamshire and Northamptonshire. In fact, in the sections previously described (pp. 156, 159) at Sharpe's Hill and Swerford, we may note the incoming of beds that approximate in character to the Upper Estuarine Series.

As the Upper Estuarine Series constitutes a stratigraphical division that may include the Upper Fullonian, the Stonesfield Slate, and the lower part of the Great Oolite, it will be more convenient to describe the beds with the several subdivisions of the Great Oolite that occur in the midland counties and Lincolnshire.

* See E. A. Walford, Quart. Journ. Geol. Soc., vol. xxxix. p. 237.

# CHAPTER IX.

## GREAT OOLITE SERIES.

### Great Oolite and Stonesfield Slate.

### General Account of the Strata.

Reference has previously been made to the introduction of the term Great Oolite (p. 228). It is used by the Geological Survey to include the beds which in Wiltshire, Somersetshire, Gloucestershire, and Oxfordshire, occur between the Fuller's Earth and Forest Marble. The formation thus consists of a variable set of oolitic freestones, hard shelly limestones (rag), and earthy and compact white limestones and marls; together with occasional layers of calcareous sandstone, and the fissile sandy and oolitic limestones that constitute the so-called "Stonesfield Slate." Locally the following subdivisions may be made :—

| | | | |
|---|---|---|---|
| Upper Division. | Upper Rag-stones of Bath. | False-bedded oolites - | Kemble Beds. |
| | | Pale earthy white limestones, sometimes oolitic, or with scattered oolitic grains; and marls - - - | White Limestone. |
| Lower Division. | | False-bedded oolite — the main building-stone - - - | Bath Freestone. |
| | | Lower Ragstones; and fissile calcareous sandstone and oolitic limestone; and clays - - | Stonesfield Slate. |

It will be found that these divisions are by no means persistent, that the upper beds are in places partially overlapped by the Forest Marble, and the lower beds by higher stages of the Great Oolite. Pebbly oolite-beds, indicating local erosion, are occasionally met with. The thickness of the series ranges from 100 to 130 feet.

Lonsdale noted the chief changes undergone by the Great Oolite when traced north of Bath, and first pointed out the stratigraphical position of the Stonesfield Slate, which had previously been grouped with the Forest Marble and thus supposed to overlie the Great Oolite. The correct view was originally suggested to him by Greenough.* Messrs. Brodie and Buckman, from a study of the Stonesfield Slate of the Cotteswold District, concluded, in 1844, that "it is part of the Great Oolite, or at least not sufficiently distinguishable from it, to entitle it to rank as an independent formation."† This view is true enough from a stratigraphical point of view; while regarded from an economic

* Proc. Geol. Soc., vol. i. p. 415.
† Quart. Journ. Geol. Soc., vol. i. p. 224.

and also from a palæontological point of view, the Stonesfield Slate is of great importance.

The Stonesfield Slate is but locally developed, and appears to be intimately connected with the Fuller's Earth below and to merge upwards into the Great Oolite above. Thus it occupies a position analogous to that of the Collyweston Slate, which links together the Lower Estuarine Series and the Lincolnshire Limestone. Traced to the north-west beyond Stonesfield and Chipping Norton, both Fuller's Earth and Stonesfield Slate are represented by the Upper Estuarine Series.

In 1857 Prof. Hull divided the Great Oolite of Gloucestershire and Oxfordshire as follows* :—

| | |
|---|---|
| Upper Zone. | Marls and white limestones, usually devoid of oolitic structure, and evenly bedded. |
| Lower Zone. | False-bedded oolitic freestone, shelly limestones, clays, and sandy flags (Stonesfield Slate). |

In the Lower Zone Prof. Hull placed the building-stones of Minchinhampton, Taynton, &c., regarding them as on the same geological horizon as the Stonesfield Slate of Sevenhampton, Eyeford, &c. In the Lower Zone, also, were included portions of the Northampton Sand. (See p. 146.)

The lower beds evidently represent the shallower-water conditions. In the Upper Zone the fossils, though seldom fragmentary, occur often in casts, and appear to have been buried where they lived. The stratigraphical evidence has shown that the true Northampton Sand can be separated from the Great Oolite Series with which at one time it was confounded ; and the Stonesfield Slate, wherever it is developed, occurs at the base of the main freestones.

None of the subdivisions of the Great Oolite can be regarded as very constant : although broadly speaking we can recognize a lower division of sandy and oolitic flags and current-bedded oolite, and an upper division of soft earthy limestones and marls, over great part of the area. To the north-east of Oxfordshire other stratigraphical subdivisions become necessary.

The freestones of Bradford-on-Avon, Bath, Corsham, Minchinhampton, and Taynton degenerate, further north and are not distinguishable; and from the neighbourhood of Buckingham through Northamptonshire and Lincolnshire, the white limestones and associated marls (belonging to the Upper Division of the Great Oolite) form the chief portion of the formation to which the term of Great Oolite Limestone is applied. This division rests on the Upper Estuarine Series, and is overlaid by the Great Oolite Clay, with only occasional beds that present the characters of Forest Marble.

In the neighbourhood of Minchinhampton and for some distance northwards, it becomes a matter of difficulty to separate the Great Oolite and Forest Marble, for in this area there is a considerable development of false-bedded oolites above the white

* Geol. Cheltenham, p. 53. See also Geol. Parts of Wilts and Gloucestershire, p. 12; Quart. Journ. Geol. Soc., vol. xvi. p. 72.

limestones of the Great Oolite. These oolites are overlaid in places by the Bradford Clay, but on account of its inconstant character it is difficult to fix a definite plane of separation. These upper oolities will for convenience be referred to as the KEMBLE BEDS, as they are well shown near Kemble Station, the junction for Cirencester and Tetbury on the Great Western Railway. North-east of Cirencester they appear to be overlapped by the Forest Marble.

These difficulties in defining horizons are natural enough, and it is only needful to bear in mind that the subdivisions are made for local convenience.

### *Organic Remains.*

Including the Stonesfield Slate, the Great Oolite has yielded a rich and varied fauna and flora. Especially noteworthy are the Mammalian and Ornithosaurian remains of the Stonesfield Slate; but as a list of fossils from that deposit will be given further on, it will be sufficient here to notice the more generally distributed fossils of the Great Oolite.

Among Saurians, the remains of *Cetiosaurus, Megalosaurus, Steneosaurus,* and *Teleosaurus,* are more commonly met with; and of Fishes, those of *Mesodon* (*Pycnodus*), and *Strophodus.*

Of Cephalopoda, Belemnites are very rare, and Ammonites are only occasionally found; the species *A. subcontractus* occurs also in the Fuller's Earth Rock. Other forms of Mollusca are abundant, together with Brachiopods, Polyzoa, Echinoderms, Corals, &c. The Corals are frequently calcitic, and they occur at various horizons, more especially in the upper beds.*

Excepting in the Stonesfield Slate, the Lower Division contains few, if any, distinctive fossils. The false-bedded oolites naturally do not preserve many species, though layers made up of comminuted shells of *Ostrea*, &c., and fragments of Echini and Crinoids occur. There are layers, however, which yield Gasteropods, and they may be obtained on the weathered surfaces of the stone. Even at the celebrated quarries of Minchinhampton, few fossils are to be obtained during a casual visit; those which were procured by Dr. Lycett, representing the labours of many years. Again at Ashford Bridge near Stonesfield, certain fossiliferous beds have been assigned to the "lower zone" of the Great Oolite; but there seems no great reason for separating them from the "upper zone."

In the Upper Division, there occur rich fossil-beds, sometimes made up of fine examples of *Terebratula maxillata,* or *Ostrea Sowerbyi,* and containing in abundance *Lima cardiiformis, Pholadomya Heraulti, Pecten vagans, Rhynchonella concinna,* and Corals. Some of the rag-beds are largely made up of Polyzoa and minute Gasteropods.

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* See Tomes, Quart. Journ. Geol. Soc., vol. xli. p. 170.

## GREAT OOLITE FOSSILS.

FIG. 72.

FIG. 70.

FIG. 71.

FIG. 73.

FIG. 74.

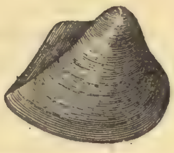


FIG. 76.

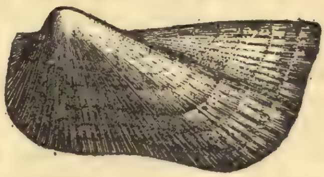


FIG. 75.

FIG. 78.

FIG. 77.

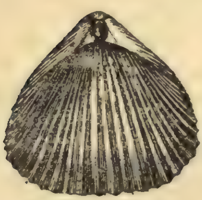


FIG. 79.

Fig. 70. Natica hulliana, *Lyc.*, Nat. size.
„ 71. Nerita costulata, *Desh.*, Small fig., Nat. size.
„ 72. Nerinæa Voltzi, *Desl.*, Nat. size.
„ 73. Purpuroidea Morrisea, *Buv.* ½.
„ 74. Cypricardia rostrata, *Sow.*, Nat. size.

Fig. 75. Lima cardiiformis, *Sow.*, Nat. size.
„ 76. Macrodon hirsonensis, *d'Arch.* ¾.
„ 77. Rhynchonella concinna, *Sow.* 1½.
„ 78. Terebratula maxillata, *Sow.* ⅔.
„ 79. Acrosalenia hemicidaroides, *Wright.*, Nat. size.

The following list is intended to show the more abundant and characteristic fossils of the Great Oolite, many of the species occurring throughout the formation:—

Ammonites arbustigerus (Fig. 63).
—— subcontractus (Fig. 64).
Nautilus Baberi.
—— dispansus.
Alaria armata.
—— hamulus.
Ceritella acuta.
Cerithium quadricinctum.
Cylindrites acutus.
Exelissa pulchra.
Natica hulliana (Fig. 70).
—— intermedia.
—— Michelini.
Nerinæa Eudesi.
—— funiculus.
—— Voltzi.
Nerita costulata (Fig. 71).
—— rugosa.
Patella cingulata.
—— rugosa.
Pseudomelania Lonsdalei.
Purpurina elaborata.
Purpuroidea Morrisea (Fig. 73).
Arca æmula.
—— Pratti.
Astarte angulata.
—— interlineata.
Avicula costata.
Cardium Stricklandi.
Ceromya concentrica.
—— excentrica.
Corbula involuta.
Cypricardia bathonica.
—— rostrata (Fig. 74).
Cyprina loweana.
Gervillia acuta.
—— bathonica.
—— Waltoni.
Homomya Vezelayi.
Isocardia minima.
Lima cardiiformis (Fig. 75).
—— duplicata.
—— impressa.
Lucina bellona.
Macrodon hirsonensis (Fig. 76).
Modiola imbricata.
—— Lonsdalei.
Ostrea acuminata (Fig. 65).
—— costata.
—— gregaria.
—— Sowerbyi (Fig. 95).
Pachyrisma grande.
Pecten lens (Fig. 123).
—— vagans (Fig. 122).
Pholadomya Heraulti.
—— socialis.
Placunopsis socialis.
Pteroperna costatula.
Tancredia brevis.
Thracia curtansata.
Trigonia Moretoni.
—— pullus.
Unicardium impressum.
—— varicosum.
Rhynchonella concinna (Fig. 77).
—— obsoleta.
Terebratula maxillata (Fig. 78).
Acrosalenia hemicidaroides (Fig. 79).
—— pustulata.
—— Wiltoni.
Clypeus Mülleri.
Echinobrissus Griesbachi.
—— Woodwardi.
Anabacia complanata.*
Calamophyllia radiata.
Convexastræa Waltoni.
Isastræa limitata.
Latimæandra lotharinga.
Thamnastræa Lyelli.

Crustacea are rare. The Isopod, *Cyclosphæroma,* from the Great Oolite of Northampton, was identified by Dr. H. Wood-

* Known to old writers as the "Button Stone," or "Shirt Button Madreporite" (*Porpites* of Plot).

ward;* and some Ostracoda have been found. Foraminifera also occur. The fossils on the Stonesfield Slate are noted on pp. 296, 314.

In some respects the fauna of the Inferior Oolite is repeated in the Great Oolite, excepting in a marked degree the Cephalopods. *Terebratula maxillata* (often termed *submaxillata*), so abundant in the Oolite Marl of Stroud, is one of the prevalent fossils of the Great Oolite: so also *Rhynchonella concinna* occurs in both Great and Inferior Oolite. Of the Lamellibranchs common to the two formations, there are similar species of *Arca, Astarte, Cardium, Ceromya, Corbula, Cypricardia, Gervillia, Hinnites, Lima, Lucina, Modiola, Myacites, Nucula, Ostrea, Pecten, Pholadomya, Trigonia, Unicardium,* &c.

Mr. Hudleston has remarked that the Gasteropod fauna of the Great Oolite at Minchinhampton, has far more resemblance to that of the Inferior Oolite which underlies it, than it has to the Gasteropod fauna of the Inferior Oolite in the Dorset district.† This may perhaps be accounted for by the thinness of the Fuller's Earth in this region—an attenuation which may imply a shorter duration of clayey conditions (see p. 151), so as to bring nearer together the conditions attending the Inferior and Great Oolites. Lithologically some beds of white oolite in the Inferior Oolite near Minchinhampton are precisely like beds in the Great Oolite at the same locality.

Again the shelly beds belonging to the Lincolnshire Limestone at Great Ponton and other places, have yielded a number of species that are found also in the Great Oolite. The following Gasteropods are common to the two formations:—

Actæon Sedgvici.
Bourguetia elegans.
Cerithium quadricinctum.
Cylindrites turriculatus.
Emarginula scalaris.
Exelissa pulchra.
Monodonta Lyelli.
Natica hulliana.
Nerinæa Eudesi.
Nerita costulata.
Patella rugosa.
Pseudomelania Lonsdalei.
Purpurina elaborata.
Rimula Bloti.
—— clathrata.
—— tricarinata.
Trochotoma extensa.
Trochus Ibbetsoni.
—— spiratus.

*Zones.*

The fossils of the Great Oolite and Stonesfield Slate do not lend themselves to particular zonal grouping. Strictly speaking the whole of the Great Oolite Series from the Fuller's Earth or Fullonian to the Forest Marble and Great Oolite Clay, belong to one zone. We have no constant horizons of Ammonites or Belemnites, nor could we expect them in the false-bedded oolites that were no doubt rapidly accumulated.

*Terebratula maxillata* is not sufficiently restricted in its vertical range to be of service; and in reference to Corals, Mr. Tomes

* Geol. Mag., 1890, p. 529.

† Gasteropoda of Inf. Ool., p. 70. See also Lycett, Quart. Journ. Geol. Soc., vol. iv. p. 181; Proc. Cotteswold Club, vol. i. p. 62; and Brodie, Quart. Journ. Geol. Soc., vol. vi. p. 245.

has remarked "that no satisfactory division of the Great Oolite could be made by means of the coral-fauna."*

Oppel took the Bradford Clay with the Great Oolite, and grouped them as the zone of "*Terebratula digona*": while he placed the Forest Marble and Cornbrash in the zone of "*Terebratula lagenalis*."† We cannot, however, separate Bradford Clay from Forest Marble.

*Ammonites arbustigerus* has been taken on the continent to indicate the horizon of the Great Oolite. It belongs to a group that includes *A. subcontractus, A. bullatus,* and *A. viator.* The *A. subbakeriæ,* of d'Orbigny, which occurs in the Bathonian of the Bas Boulonnais, may also (if it be not identical with one of the above-named forms) be considered to belong to the group. *A. arbustigerus* has been recorded from the Fuller's Earth of Somerset and from the Great Oolite of Minchinhampton. It occurs also in Normandy. We may therefore class the beds from the Fuller's Earth or Fullonian to the Forest Marble as the zone of *Ammonites arbustigerus.*

## LOCAL DETAILS.

### *Bradford-on-Avon to Bath.*

#### *Relations of Great Oolite to Fuller's Earth and Forest Marble.*

One of the problems in Jurassic geology is the disappearance of the Great Oolite south of Bath.‡ It forms the dominant features around the city, and stretches northwards and westwards to Minchinhampton, Cirencester, and Stonesfield. It is extensively mined at Box and at Bradford-on-Avon; but it tapers away between Wellow and Norton St. Philip, at a distance of about 6 miles south of Bath.

So few geologists have expressed any views on the subject that what has been said may be readily quoted.

The Rev. W. D. Conybeare remarked in 1822, that "The whole mass of this oolitic system in Dorsetshire (excepting the inferior oolite and its sand) presents the fissile character of the forest marble; but it seems more probable that the great oolite here passes into this structure (as it undoubtedly does occasionally in other places), than that the forest marble, generally a subordinate bed only, should here swell to such a disproportionate thickness, and the great oolite itself be wanting."§

Lonsdale seven years later, in his excellent account of the Oolitic District of Bath, after referring very briefly to the dying out of the Great Oolite, remarks "It might, however, be conceived, that the termination is only a lithological change, and

* Quart. Journ. Geol. Soc., vol. xxxix. p. 174.

† Juraformation, p. 443.

‡ H. B. W., Geol. Mag., 1888, p. 467; and Rep. Brit. Assoc. for 1888. p. 651. See also Proc. Geol. Assoc., vol. xiii., p. 133, and Fig. 1.

§ Outlines of the Geol. Eng. and Wales, p. 205.

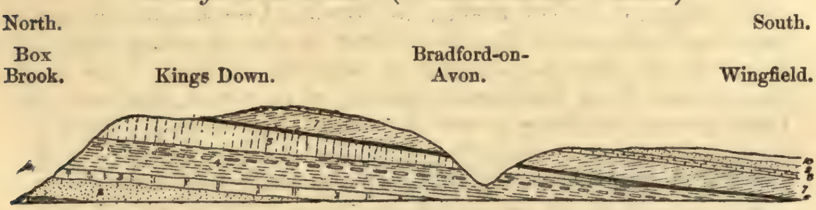
that here, as elsewhere, the great oolite merely assumes the characters of the forest marble."*

Subsequent writers have, as a rule, simply repeated these opinions, and it is only necessary to mention that in 1876, I ventured to say that "In the district south of Frome the Great Oolite thins away entirely, and is represented partly by the Forest Marble, and perhaps also by the Fuller's Earth."†

It might have been expected that the officers of the Geological Survey would long ago have settled the matter; but while the Oolitic area in question was surveyed geologically by John Phillips and H. W. Bristow, and the map shows the superficial distribution of the strata, yet the memoirs furnish but little help towards a solution of the problem. This, however, is not surprising when we come to examine the debatable ground. For, unfortunately, where the dying away of the Great Oolite takes place, there is a singular absence of sections; an absence no doubt due to the fact that there is little or no building-stone to be had, and that the clays would be too marly for brick-making. Moreover, Lonsdale's paper is such a model of careful and accurate work, that we may be sure he would have recorded any sections, open in his time, that threw a light upon the subject.

FIG. 80.

*Diagram-section to show the attenuation of the Great Oolite, near Bradford-on-Avon.* (Distance about 6 miles.)




10. Oxford Clay.
9. Kellaways Beds.
8. Cornbrash.
7. Forest Marble.
6. Bradford Clay.
5. Great Oolite.
4. Fuller's Earth Clay, with Fuller's Earth Rock.
3. Inferior Oolite.
2. Midford Sands.
1. Lias.

The problem, however, may be attacked from a more general point of view, and the questions that arise are these. Does the Great Oolite pass laterally into the Forest Marble, or into the Fullonian Beds (Fuller's Earth), or into both? Does it wedge out independently of either formation, there having been a pause in deposition further south? Or, was it deposited over much of the south of England and afterwards denuded in Oolitic times?

We may consider first, the relations of the Great Oolite and Forest Marble.

* Trans. Geol. Soc., ser. 2, vol. iii.p. 254.
† Geol. Eng. and Wales, ed. 1, p. 188.

Taking Bradford-on-Avon as a central point, we find the Great Oolite overlaid by the Bradford Clay, which all observers agree in regarding as a subordinate portion of the Forest Marble. There the rich beds of Crinoids which flourished on the surface of the Great Oolite, indicate some pause in the sedimentary conditions, and show that in this neighbourhood we have a marked divisional plane between the Great Oolite and overlying deposits, a boon indeed to those engaged in the process of Geological mapping.

We can trace this horizon of Bradford Clay northwards through Box and Corsham, but further on beyond West Keynton and Yatton Keynell, the fossiliferous Bradford Clay seems but locally developed, and near Cirencester and Kemble it becomes a matter of great difficulty to separate the Great Oolite from the Forest Marble. There is at any rate wanting in this northerly area, evidence of a pause between the Great Oolite and the Forest Marble, and Nature has consequently left no definite guide to enable us to draw a satisfactory boundary-line. Consequently Prof. Hull and Prof. Buckman, in the neighbourhood of Cirencester, and Phillips and Hull, in Oxfordshire, have differed considerably in their interpretation of the sections, differences with which I fully sympathize. While Lycett, in reference to the Sapperton area, near Stroud, remarks that "probably the terms Forest Marble and Bradford Clay might be omitted altogether without any detriment to science."*

Turning to the area south of Bradford-on-Avon, the most important evidence is the occurrence of the Bradford Clay in Dorsetshire. The characteristic "Bradford Encrinite" has long been known from the Forest Marble of that area, but even in 1884 Damon, referring to the Bradford Clay, observed that "its separate occurrence cannot be established in this district [Weymouth], though its prevailing fossil is sparingly distributed."†

In Dorsetshire the Forest Marble consists of three main subdivisions, as follows:—

Clay.
Shelly and oolitic limestone.
Clay.

At the base of the lower clay there is a rich fossiliferous bed which may be seen at Herbyleigh near Weymouth, at Burton Bradstock, and at Eype near Bridport. Attention was drawn to this bed when the Geologists' Association visited Dorsetshire in 1885, and I then remarked that it appears to represent the Bradford Clay.‡ We find the bed to yield numerous Brachiopods, large specimens of *Rhynchonella varians, R. Boueti, Waldheimia digona, Terebratula coarctata,* also *Mytilus pectinatus, Acrosalenia,* &c.

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* The Cotteswold Hills, 1857, p. 142.
† Geol. Weymouth, &c., 1884, p. 15.
‡ Proc. Geol. Assoc., vol. ix. p. 207.

Although the persistence of this fossil-bed had not before been dwelt upon, yet Davidson recorded several species from the "Bradford Clay" of Radipole near Weymouth, and from Burton Bradstock; these fossils were collected by Mr. J. F. Walker and Mr. Darell Stephens, to whom we thus owe our first acquaintance with the extent of this horizon.*

I have seen no evidence in this southern region of the Crinoid growth *in situ*, as we have it at Bradford-on-Avon, but the occurrence of this fossil-bed on top of the comparatively barren Fuller's Earth is significant, for it marks a considerable change in conditions. The Rev. O. Fisher, however, informed me (1889) that years ago he found evidence of Crinoid growth *in situ* north of Langton Herring.

The evidence before us is that the Bradford Clay is present in Wiltshire and in Dorsetshire, in the one area resting directly on the Great Oolite, and in the other on the Fullonian (Fuller's Earth); and the natural conclusion is that the Great Oolite of Bath and Bradford-on-Avon does not pass into the Forest Marble of Dorsetshire.

We have now to consider the relations between the Great Oolite and the Fullonian Beds. Junction-sections are unfortunately in most cases the exception rather than the rule; but in the area north of Bath, and extending to Stonesfield in Oxfordshire, there is abundant evidence to show the intimate connexion between the Fuller's Earth and the Great Oolite. This consists in the alternation of clays and stone-beds. I have noticed it on the slopes of Lansdown, N.W. of Charlcombe. In the Stroud area attention has been directed to the passage by E. Witchell, who observed that "the upper part of the [Fuller's Earth] formation consists of a sandy clay alternating with beds of sandstone, brown on the surface, blue internally, and closely resembling the Stonesfield slate, except that it is less laminated. The passage from the Fuller's Earth to the Stonesfield slate is shown in the disappearance of the clay and the greater development of the sandstone beds which assume a more persistent character."†

Similar indications of a transition have been shown on Sevenhampton Common, and in the cuttings of the railway betwee. Cheltenham and Hook Norton near Banbury; and they are observable at Stonesfield in the one open working I was able to examine, where there is an alternation of marls and stone-beds above the "slate." Moreover this feature at Stonesfield is confirmed by the careful record of the strata made in 1827 by Fitton,‡ when he sought to demonstrate the stratigraphical position of the first Mammals found at Stonesfield, although he did not at that time convince all the scientific sceptics. (See p. 312).

* Supp. to Brit. Jurassic Brachiopoda, pp. 151, 156, 173, &c.
† Geol. Stroud, pp. 70, 71.
‡ Zool. Journal, vol. iii. p. 402.

So far as I know there is no difference of opinion on this subject of the passage of Fullonian or Fuller's Earth into Great Oolite.

In Dorsetshire and South Somerset the Fuller's Earth is divisible into three stages, upper and lower divisions of clay, separated by the Fuller's Earth Rock, a marly limestone which forms a marked feature in the scenery between Sherborne and Wincanton. Northwards by Frome the Fuller's Earth Rock may be readily traced, but towards Bath it becomes much attenuated. Indeed, an examination of the Geological Survey Map (Sheet 19) suggests that the Fuller's Earth Rock might represent the Great Oolite, for curiously enough the mapping of the Rock ceases in one place near Stoney Littleton, where the Great Oolite comes on. Moreover the texture of the Fuller's Earth Rock is very similar to some of the soft beds of white earthy limestone that form the upper portion of the Great Oolite in East Gloucestershire and Oxfordshire.

The notion that the two might be portions of one formation possessed me for some time, but it was dispelled when I came to examine the ground at Bath. In several places where the Fuller's Earth Rock has become too attenuated to be shown on the map, it is nevertheless present; as I found to be the case between Wellow and Norton St. Philip; as the Rev. H. H. Winwood pointed out to me on the slopes of Lansdown, and as Prof. Hull has shown to be the case at Slaughterford, N.E. of Bath.

It is therefore clear that the Great Oolite overlies the Fuller's Earth Rock in the neighbourhood of Bath and Bradford-on-Avon. At the same time this Rock maintains a fairly uniform character of white marly limestone, and contains a similar assemblage of fossils, in its range from Dorsetshire to Somersetshire, while it merges upwards and downwards into the marly clays of the Fullonian formation, and is of varying thickness and importance.

The evidence before us, then, is that the Great Oolite, and more especially the Stonesfield Slate, pass downwards into the Fullonian. Bearing this in mind, it is worthy of note that the Fuller's Earth Rock does not extend far north of Bath (in the Cotteswold regions) where the Stonesfield Slate is developed at the base of the Great Oolite.

Here I may mention that in Normandy, the Fuller's Earth Marls appear to pass laterally into the Caen Stone, a rock yielding Saurian and other remains that serve to connect it with the Stonesfield Slate. The strata just mentioned are overlaid by the Great Oolite. The irregular and varying characters of the beds in that country have been pictured by M. Deslongchamps;* but as the authorities are not of one mind on the subject of the grouping and correlation of the strata, we shall perhaps do best to discuss the stratigraphical relations of our rocks on independent grounds.

* Études sur les Étages Jurassiques Inférieures de la Normandie, 1864.

We are now in a position to consider whether the Great Oolite is represented in any way by the Fullonian Beds of Dorsetshire. We have seen that where the two are developed, there no rigid line of division can be drawn, that where the Stonesfield Slate occurs the two are inseparable. Hence it is quite possible that south of Bradford on-Avon, the lower portion of the Great Oolite may be replaced to some extent by the Upper Fuller's Earth Clay. More than this I am not prepared to say, for it cannot be the case with the mass of the Great Oolite.

The Oolite has either wedged out abruptly, or it has been denuded over the whole or a portion of this southern area. The evidence of the quarries between Bath and Bradford-on-Avon, shows that the Rag-beds above the Freestones become thinner towards the south; but such evidence cannot be regarded as of much value when we remember how fickle are the majority of the oolites. Looking, however, at the subject from a broad point of view, I think we are justified in considering the case to be one of unconformable overlap or overstep; in other words, that the Great Oolite has suffered denudation locally, and to a certain extent contemporaneously, so far as the Great Oolite Series is concerned.

The Oolites as a whole are characterized by much false-bedding, by pauses in deposition marked by bored-surfaces, and occasionally by rolled masses of previously-formed Oolite. A minor amount of local erosion is evident, although in some instances scanty deposition of sediment accounts for the attenuation or local absence of beds.

The Forest Marble itself is remarkably false-bedded and current-bedded. In its changeful series we find clays and shales, sands and sandstone, shelly, and oolitic limestone. The curious track-marks and the ripple-marks show it was deposited under shallow-water conditions. The numerous ochreous clay-galls probably originated from rolled masses of clay. While the structure of the oolitic beds, the grains being irregularly mingled with comminuted shells, and lignite, or scattered in a sandy as well as in a calcareous matrix, suggest the notion that they may have been derived. This notion occurred independently of other considerations, and I find it was suggested in 1879 by Dr. Sorby,* from a microscopical examination of specimens of Forest Marble, from Wiltshire and Somersetshire. He observed that the facts clearly show that the oolitic grains were not formed *in situ*, but were drifted along with the shell-fragments. He noticed the occurrence of grains of previously consolidated limestone, which itself was oolitic; while in other instances the rock contained broken grains of oolite. Still more interesting is his statement that, "In a few cases, as at Frome, the greater part of the rock is composed of comminuted Corals and Polyzoa;" for it is not unreasonable to infer that these remains were derived from the Great Oolite.

* Address to Geol. Soc. 1879, Quart. Journ. Geol. Soc., vol. xxxv. (Proc.), p. 82.

The evidence is therefore in favour of the mass of the Great Oolite (over part at any rate of the Dorsetshire region) having been eroded, and there is consequently a local break between the Forest Marble and Fullonian formation, marked by the rich fossil-bed which has been identified with the Bradford Clay.

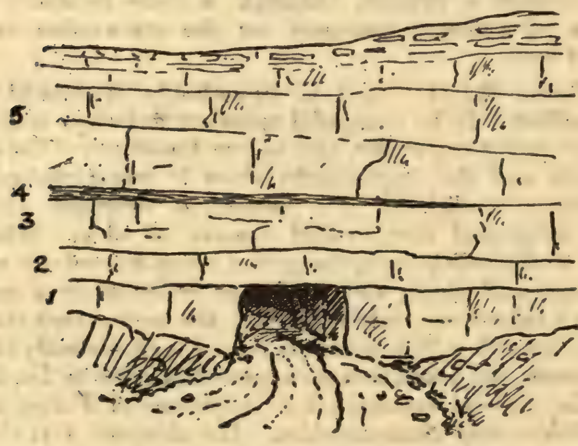
It is interesting to find that in the Geological View and Section through Dorsetshire and Somersetshire, published by William Smith in 1819, he noted the sequence of strata beneath the Cornbrash in the southern county as follows:—

| | |
|---|---|
| [Forest Marble.] | Clay.<br>Forest Marble.<br>Clay. |
| | Place of the Upper Oolite. |
| [Fullonian.] | Clay.<br>Fuller's Earth Rock.<br>Clay. |

Smith thus recognized the true position of the Great Oolite, as independent of Forest Marble and Fuller's Earth, and he showed it in his section as wedging out towards the outcrop. (See also Fig. 80).

FIG. 81.

*Section at Avoncliff, Bradford-on-Avon.*




| | |
|---|---|
| Great Oolite. | 5. Coarse wedge-bedded oolite.<br>4. Marl.<br>3. Shelly oolitic limestone.<br>2. Rag (Roof-bed).<br>1. Freestone. |

The first traces of Great Oolite appear in the scarp between Hassage and Norton St. Philip. To the north-east of Hassage we find exposures of oolite overlaid by clays and shelly limestone of the Forest Marble; and again east of Lower Baggeridge, an old quarry showed rubbly oolite resting on earthy limestone and clay, with *Rhynchonella varians*, &c., belonging to the Fuller's Earth.

There are, however, no clear and continuous sections, showing the sequence from Forest Marble through Great Oolite into Fuller's Earth. The Bradford Clay was not exposed, and it could only be inferred that the Great Oolite was represented by a few feet of oolite, that clearly occupied a higher horizon in the scarps than the Fuller's Earth Rock.

To the north-east of Farleigh, brown shelly and oolitic limestones are exposed on the western side of the road leading towards Westwood, but the absence of clear sections in this neighbourhood is unfortunate.

In the Bath district, the beds may generally be divided as follows* :—

| | | | Ft. | In. |
|---|---|---|---|---|
| Great Oolite. | Upper Division. | Upper Rags; oolites and shelly limestones - - | 12 0 to 50 | 0 |
| | Lower Division. | Freestones (oolites) - | 8 0 to 30 | 0 |
| | | Lower Rags; shelly and marly limestones, fissile oolite, &c. | 10 0 to 40 | 0 |

The Great Oolite has been extensively quarried or mined at Upper Westwood (Avoncliff or Ancliff), and to the south and east of Bradford-on-Avon. At Upper Westwood, the section is as follows (see Fig. 81):—

| | | | Ft. | In. |
|---|---|---|---|---|
| Great Oolite. | Upper Division. | [Rubble with Corals] - - | 5 | 0 |
| | | 5. Coarse oolite with shelly fragments; a thin-bedded stone, much broken up near the top [celebrated for the "Ancliff" fossils, described by Sowerby] | 15 | 0 |
| | | 4. Marly layer [with sponges and fragments of shells, &c.] - | 1 | 0 |
| | | 3. Coarse shelly oolitic and pasty limestone, of rubbly character; with shell-fragments, Polyzoa, &c. - - - - | 4 | 0 |
| | | 2. Rag; pale oolitic limestone, forming roof of mine - - | 2 | 6 |
| | Lower Division. | 1. Freestone; one or more beds of oolite, with ochreous galls in places, and more particularly in the lower part. On the whole a very uniform stone, and free from open joints; divided as follows:— | | |
| | | Good freestone 5 10 to | 6 | 6 |
| | | Freestone - - about | 10 | 0 |
| | | Rubbly stone - about | 3 | 0 |

A brief record of the above section was published by Lonsdale, with whose measurements my own agree; some additions are inserted in square brackets on his authority.† The "Ancliff Limestone" is noted for the tiny organisms it has yielded. *Ostrea costata* is noted as "one of the miniature productions." Many

* See also Lonsdale, Trans. Geol. Soc., ser. 2, vol. iii. p. 251.

† Trans. Geol. Soc., ser. 2, vol. iii. p. 252.

minute Gasteropods were obtained (from bed No. 5) by Lonsdale, and also by the Rev. George Cookson (who formerly resided at Westwood). These included species of *Cylindrites* (*Actæon*), *Neridomus*, *Nerita*, *Pileolus*, and *Rissoina* (*Rissoa*). In Mr. Hudleston's opinion, some of the forms described by Sowerby might be regarded as immature. The average length of the specimens is about 3 mm. Attention has recently been directed to the fossil-beds by Mr. W. H. Wickes.

To the south of Bradford-on-Avon we find sections showing the Bradford Clay, overlying the Great Oolite.

At the Lime-kiln on the east side of the Frome road,* and in another quarry on the slope of the hill to the north-east, the top bed of the Great Oolite, where it is protected by the covering of Bradford Clay, is a hard brown oolitic limestone. This, together with beds of coarser oolite beneath, are about 10 feet thick; below comes the Rag Bed which forms the roof of the mines, a hard band, about 2 or 3 feet thick, which overlies the Freestone. The Freestone is 6 or 7 feet thick, and is obliquely bedded at the Lime-kiln quarry, so that it does not afford so serviceable a building-stone as it does elsewhere.

Old quarries on the eastern side of Bradford-on-Avon, and to the south of the Melksham road, show also the connexion with the Bradford Clay, as follows:—

| | | | Ft. | In. |
|---|---|---|---|---|
| Bradford Clay | | Pale-grey marly clay with "race," *Avicula costata, Ostrea lingulata, Rhynchonella concinna, Waldheimia digona, Apiocrinus Parkinsoni,* &c. | | |
| Great Oolite. | Upper Division. | Shelly oolite with marly patches: minutely false-bedded | 1 | 0 |
| | | Marly layer | 0 | 4 |
| | | False-bedded shelly oolite, with *Ostrea, Pecten, Rhynchonella,* Polyzoa, Corals | 11 | 0 |
| | | Rag Beds | 3 | 0 |
| | Lower Division | Freestone: false-bedded buff oolite | 7 | 0 |

The thickness of the Great Oolite from the base of the Bradford Clay down to the top of the Freestone, varies in this neighbourhood from about 13 to over 27 feet. The beds are much thinner at the lime-kiln south of Bradford-on-Avon than at Upper Westwood.

Murrel (or Murhill) quarry near Winsley, about 1 mile west of Bradford, was described long ago by Lonsdale†: in the accompanying section, the details of the Lower Division are given on his authority; and those of the Upper Division on the authority of Mr. Wickes:—

* See also Lonsdale, Trans. Geol. Soc., ser. 2, vol. iii. p. 25.

† Abbreviated from Lonsdale, Trans. Geol. Soc., ser. 2, vol. iii. p. 253. See also J. C. Pearce, Proc. Geol. Soc., vol. i. p. 484.

| | | | Ft. | In. |
|---|---|---|---|---|
| Great Oolite. | Upper Division. | Coral band, with *Calamophyllia*, *Isastræa*, &c. - - - | 6 | 0 |
| | | Clay parting - - - | 0 | 4 |
| | | "Fossil Bed": with Polyzoa, *Entalophora* (*Spiropora*) *straminea*; Echinoderms, *Acrosalenia;* small Gasteropods, &c. - - - | 16 | 0 |
| | | Clay with Sponges, Crustaceans, small oysters, &c. - - | 1 | 6 |
| | | Rag - - - - - - | 7 | 0 |
| | Lower Division. | Freestone (the lower part soft) - | 10 | 0 |
| | | Rag beds, with layers of freestone and occasional partings of clay - | 43 | 0 |
| Fuller's Earth - | | (Fullonian). | | |

As pointed out by Mr. Wickes,* the Fossil-bed of Murrel is equivalent to bed No. 5 in the section at Ancliff. The Murrel quarry was worked some seventy years ago, but has long been abandoned. Tumbled masses of the fossil-beds now strew the floor of the quarry, which extends for several hundred yards along the scarp: hence a rich treat is afforded to the collector. Among the Gasteropods, Mr. Hudleston has identified *Cerithium costigerum*, *Exelissa formosa*, *Rissoina acuta*, *R. duplicata*, *Turbo burtonensis*, and *Solarium turbiniforme*.

The thickness of the lower Rag beds evidently increases in this direction, to the north of Upper Westwood.

The upper beds of the Great Oolite were exposed further north at Conkwell, as follows:—

| | | | Ft. | In. |
|---|---|---|---|---|
| Great Oolite. | Upper Division. (Upper Rags.) | Hard brown oolitic limestone, and pale oolite (white beds), with *Rhynchonella* - - - | 10 | 0 |
| | | Hard brown compact limestone, shelly and ochreous in places - | 5 | 0 |
| | | Calcareous sandy and oolitic marls, with Gasteropods; *Isocardia*, *Ostrea*, &c. - - - | 4 | 6 |
| | | Compact brown shelly limestone - | 0 | 10 |
| | | Marly and shelly oolite with *Pecten vagans* - - - - | 1 | 0 |
| | Lower Division. | Fine oolitic limestone, even bedded and with shelly layers; seen to depth of - - - - | 15 | 0 |

On Farley (at Farleigh) Down, and near Ashley Wood, north-west of Monkton Farley, there are several quarries and mines in the Great Oolite, where the following beds may be observed:—

| | | | Ft. | In. |
|---|---|---|---|---|
| Forest Marble. (Bradford Clay.) | Greenish marly clay. | | | |
| | Hard shelly oolitic limestone - - - | 15 | 0 to 20 | 0 |
| | Flaggy false-bedded white oolite (passing down into bed below) - - | | | |

* Proc. Geol. Assoc., vol. xiii, p. 135.

| | | | Ft. | In. |
|---|---|---|---|---|
| Great Oolite. | Upper Division. | Oolitic rag bed, very shelly, with *Pecten* and Polyzoa, &c. 3 6 to | 4 | 0 |
| | | Hard compact and oolitic limestone; with ochreous and sandy galls, that give rise to a honeycombed appearance on the weathered faces of the rock - - | 1 | 0 |
| | | Roof-bed; coarse oolite with many Mollusca, Polyzoa, Echini, and Corals. Large *Ostrea* on surface and Lithodomi - - - 1 2 to | 2 | 0 |
| | Lower Division. | Pale oolitic freestone; false-bedded in some places, and evenly bedded in others (about 24 feet). This has been divided as follows by the quarrymen*:— | | |
| | | Capping (fine-grained oolite used for carving) 1 6 to | 1 | 8 |
| | | Grey bed - - 1 8 to | 3 | 0 |
| | | White beds (used for carving) | 10 | 0 |
| | | Hard weather bed - 2 6 to | 3 | 0 |
| | | Red weather bed - 5 0 to | 9 | 0 |

The details vary from place to place, and in the escarpment below the monument on Farley Down, we find the Roof-bed to be very irregular, and to be surmounted in places by marly beds, with an impersistent Coral-bed, 2 to 10 feet thick. This Coral-bed was noticed by Lonsdale; and it has been observed by Mr. R. F. Tomes at this locality, and also on Combe Down. The Corals appear to have been drifted, and they include *Anabacia complanata*, *Calamophyllia* (*Eunomia*) *radiata*, *Convexastræa Waltoni*, *Isastræa limitata*, *Latimæandra*, *Microsolena excelsa*, *Montlivaltia caryophyllata*, *Oroseris Slatteri*, *Stylina Ploti*, and *Thamnastræa*.† Sponges also occur in the Coral-bed. Their occurrence was noted at "Ancliff" by Lonsdale, and on Bathampton Down, by Moore.‡ Lonsdale has also referred to the bed that "after long exposure to the weather often acquires a cavernous appearance, similar to that which is called 'rustic work' by architects." It may be on the horizon of the White Limestone of Cirencester. (See p. 286.)

Pale flaggy oolites, belonging to the upper part of the Great Oolite, were exposed to the south of King's Down; and here there is a comparatively sharp dip-slope towards Monkton Farley and South Wraxall. In fissures of the Oolites near Bath, Pleistocene mammalian-remains are occasionally found.§

Passing on to Bathampton Down,|| we find in the uppermost beds, traces of Bradford Clay fossils. Moore has stated that fragments of *Apiocrinus Parkinsoni*, species of Echini, *Ostrea*,

* See Lonsdale, Trans. Geol. Soc., ser. 2, vol. iii. pp. 251, 252; and account of Drewes quarry, Monkton Farley, in Report on Selection of Stone for building the New Houses of Parliament, 1839.

† Tomes, Quart. Journ. Geol. Soc., vol. xli. pp. 174, 189.

‡ Geologist, vol. iii. p. 440.

§ Moore, Proc. Bath Nat. Hist. Club, vol. ii. p. 37.

|| Hampton Down, Bath, is liable to be confused with Minchinhampton, as in both localities the stone has been termed "Hampton Stone."

and many Brachiopoda occur in the Coral-bed, which is separated from the freestone beds of the Great Oolite, by 5 feet of compact grey limestone yielding *Lima cardiiformis*, *Trichites*, Lithodomi, Polyzoa, and many Corals, and is overlaid by 4 or 5 feet of thin-bedded oolite.*

The beds of rubbly stone and marl, yielding Bradford Clay fossils, that here, and also at Combe Down occur on top of the Great Oolite, form an intimate link between that formation and the Forest Marble; and the upper beds of the Great Oolite above the freestone do not exceed 20 feet in thickness.

On Combe Down, near Lodge Hill (Prior Park), and St. George's Cross, there are several quarries where the following sequence was shown :—

| | | | Ft. | In. |
|---|---|---|---|---|
| Great Oolite. | Upper Division. | Rubble or Ridding; bands of rotten stone and marly beds with fossils; (some beds used for road-metal) - - - 10 0 to | 12 | 0 |
| | | Layer of large specimens of *Ostrea*. | | |
| | | Rag Beds; hard and rubbly limestones - - - - | 22 | 0 |
| | Lower Division. | Picking Beds (used for ashlar) - | | |
| | | Cockly Bed, with fossils - - | | |
| | | Freestone (in places divided into 3 weather-beds and a bottom-bed) 10 0 to | 14 | 0 |

The Rag, Picking, and Cockly beds are hard smooth-jointed beds, more or less oolitic.

In a section recorded by Lonsdale,† he notes that beneath the "Cockle Bed" there was from 25 to 30 feet of good freestone, and under that 10 feet of Lower Rags. The total thickness of freestone and Lower Rags does not exceed 35 feet. There is no doubt that in detail the beds vary very much indeed; what is called the Ridding or Riddingtop, is simply the weathered and rubbly stone or "Head" above the workable material, and it sometimes directly overlies the freestone beds; it is the material that has to be got *rid* of in the quarries, before the good stone can be obtained. The freestone which is minutely false-bedded in places, contains darker veins of shelly matter, with recognizable fragments of *Ostrea* and *Pecten*. The Cockle Bed (according to Lonsdale) contains Corals, and apparently from the same bed Mr. Tomes and Mr. T. J. Slatter have obtained a number of species.‡ This layer, which directly overlies the good freestone, also contains drusy cavities, lined with calc-spar; and there is a specimen from Box now in the Museum at Jermyn Street, showing one of these cavities, evidently due to the dissolution of a mass of Coral, portions of which are to be seen in the stone.

From a quarry near St. George's Cross I collected the following fossils from the upper rubbly beds of stone and marl,

* Moore, Geologist, vol. iii. p. 443; H. Jelly, Mag. Nat. Hist., 1839, p. 551.
† Trans. Geol. Soc., ser. 2, vol. iii. p. 252.
‡ Quart. Journ. Geol. Soc., vol. xli. p. 174.

which appear to be equivalent to the strata yielding Bradford Clay fossils on the summit of Farley Down, &c. :—

| | |
|---|---|
| Myacites. | Terebratula maxillata. |
| Ostea acuminata. | Serpula. |
| —— Sowerbyi. | Apiocrinus Parkinsoni. |
| Pecten vagans. | Echinobrissus. |
| Rhynchonella. | |

The basement-beds of the Great Oolite were exposed in the lane-cutting on the north side of Combe Down, and they consist of coarse oolite with clayey galls, and tiny fragments of shale; and also of flaggy beds. In the section at Combe Grove pit (noted p. 241), the strata down to the Fuller's Earth, are recorded on the authority of William Smith. The "Sand and burs" were grouped by him with the Fuller's Earth Beds, but they would now be classed as representing the Stonesfield Beds, at the base of the Great Oolite.

At Odd Down a quarry afforded the following section :—

| | | | Ft. | In. |
|---|---|---|---|---|
| Great Oolite. | Lower Division. | Rubble - - - | 2 0 to 3 | 0 |
| | | Freestone (Best stone) - | 10 0 to 15 | 0 |
| | | Bastard stone (Lower Rags) - - - | 15 0 to 20 | 0 |
| Fullonian (Fuller's Earth). | | Blue "Marl-bed" throwing out springs. | | |

The stone is very irregular and false-bedded; there are five or six layers of the good stone, which in places is worked underground.

The Blue Marl indicates the nearness of the Fuller's Earth, but it may represent a bed seen at Lansdown, that occupies a position above the lowest bed of flaggy oolite.

### *Bath, Corsham, and Marshfield to Nailsworth.*

On the south-eastern side of Lansdown we find only the Lower Rags exposed. They comprise thin-bedded and flaggy oolite, much of it shelly, and some beds containing lignite. The stone has been quarried for building walls, for roofing-purposes, and for road-metal.

The general section afforded by quarries and cuttings near the Hare and Hounds," and to the north-west of Charlcombe, is as follows :—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite and Stonesfield Beds. | Flaggy and shelly oolite - - ; Hard brown oolite with marly patches, becoming compact at base. *Ammonites subcontractus* - - - | 12 | 0 |
| | Clay, with nodules of pale-grey earthy limestone - - - | 2 0 to 3 | 0 |
| | Fissile brown shelly oolite - | 3 0 to 4 | 0 |
| Fullonian (Fuller's Earth). | Blue clay with *Ostrea acuminata, Rhynchonella varians,* &c., seen to depth of about | 20 | 0 |

The sections show the intimate connection between the Fuller's Earth and Great Oolite, and the incoming of the conditions represented by the Stonesfield Slate. From the clayey bed near the base of the Great Oolite, which was exposed on the high ground north-west of Charlcombe, I obtained *Trochus Bunburyi*, *Lucina bellona*, and *Echinobrissus*. Lansdown is the locality where the "Lansdown Encrinite," *Millericrinus Pratti*, was first obtained from the Great Oolite.*

A tiny outlier of Great Oolite occurs on the Round Hill at Kelston, as noted by Sir A. C. Ramsay.†

The Great Oolite is quarried in places on Charmy Down, north-east of Lansdown, where we find false-bedded shelly, oolitic, and sandy limestones. I saw no evidence there of beds higher than the freestone division. The rock has been quarried on Little Salisbury Hill to the south, and again on Bonner Down, north-east of Batheaston. Where the full thickness of the Great Oolite is represented it is probably from 100 to 110 feet.‡

There are a number of quarries to the east of Box, and south of the railway-tunnel, where the general sequence is as follows:—§

| | | | Ft. In. |
|---|---|---|---|
| Great Oolite. | Upper Division. | Rubble; Fine pale and fissile oolites, with softer marly beds, shelly in places, and much false-bedded. Harder beds of fine-grained oolite at or near the base are known as *Scallett* (in places 10 feet above Scallett Rag), and have been used for carving and ashlar: they do not furnish a weather-stone, and are seldom quarried now-a-days | 20 0 to 35 0 |
| | | Coarse shelly oolites; one bed known as the Scallett Rag or White Rag; in some places divided into Black, White, Malmy and Red Rags | 5 0 to 10 0 |
| | | False-bedded oolite, known as Corn Grit, and employed for dressings | 15 0 to 20 0 |
| | | Roof-bed, forming the ceiling or roof of the mines; a hard coarse shelly oolite: too hard to be of much service, but employed for road-stone, when worked | 3 0 to 5 0 |
| | Lower Division. | Oolitic freestone or Ground Bed, somewhat variable in character, but yielding good weather-stone, and employed for plinths, strings, cornices, &c. | 12 0 to 14 0 |
| | | Stone-beds (proved in well) | 30 0 to 40 0 |
| Fullonian (Fuller's Earth). | | Clay ("red marl") and dark blue marly clay with "beef." | |

* See P. H. Carpenter, Quart. Journ. Geol. Soc., vol. xxxviii. p. 29.
† Hor. Section, Sheet 14, No. 2.
‡ See Memoirs of W. Smith, by J. Phillips, p. 59.
§ See also Lonsdale, Trans. Geol. Soc., ser. 2, vol. iii. p. 253.

Here the upper beds, which include the Scallett, are probably on the horizon of the Kemble Beds.

In the railway-cutting west of Corsham railway-station, we find immediately beneath the grey and yellow marl that belongs to the Bradford Clay, a group of false-bedded buff oolites with *Pecten* and *Trigonia.* The eastern entrance of the Box tunnel is situated in these upper beds of Great Oolite, and the tunnel penetrates this formation, as well as the Fuller's Earth and Inferior Oolite, in its extension westwards.

The Great Oolite has been extensively mined on the southern side of the railway, south-west of Corsham. From 10 to 25 feet of freestone in several beds has been worked at various depths up to about 100 feet from the surface. The "Corsham stone" is said to underlie the Bath or Box "Ground stone," and judging by the maximum thickness of the freestone-beds here obtained, we may infer that beds lower than those mined at Box are obtained near Corsham. The mines are reached by inclined tunnels which are driven through the superincumbent Forest Marble.

Prof. Hull notes that freestone was worked by means of a shaft 70 feet deep at Lower Pickwick.* A boring made in 1880 by Messrs. Le Grand and Sutcliff at Corsham (for Messrs. Randell, Saunders and Company), reached the Great Oolite at a depth of about 68 feet. (See p. 356.)

To the W.S.W. of Yatton Keynell there is an old quarry where the Great Oolite has been extensively worked. The following section was noted in 1886 in company with the Rev. H. H. Winwood:—

| | | | Ft. | In. |
|---|---|---|---|---|
| Forest Marble. (Bradford Clay.) | | Flaggy oolitic limestone - - ; Clay - - - - - | 4 | 0 |
| Great Oolite. | Upper Division. | Shelly oolite - - - | 3 | 0 |
| | | Marly layer - - 0 4 to | 0 | 6 |
| | | Marly and shelly oolites - - | 2 | 3 |
| | | Marl - - - - - | 0 | 6 |
| | | Irregular band of shelly oolite - | 0 | 4 |
| | | Shelly layer, with *Terebratula* - | 0 | 2 |
| | Lower Division. | Fine false-bedded oolitic freestone | 6 | 0 |
| | | Irregular rubbly and ferruginous bed, with Echini and Sponges - ; False-bedded oolite - - - | 10 | 0 |

I picked up one specimen of *Terebratula coarctata* which probably came from the clay at base of the flaggy limestone at the top of the quarry. The section was described by Prof. Hull as exhibiting the junction of the Upper and Lower "Zones" of the Great Oolite.† The upper beds of the Great Oolite here contain many of the characteristic Bradfordian fossils, and show the intimate connection between the Great Oolite and Forest Marble.

* Geol. parts of Wilts and Gloucestershire, p. 13.
† Geol. parts of Wilts and Gloucestershire, pp. 13, 14.

FIG. 82.

*Quarry at Yatton Keynell, north-west of Chippenham.*
(Prof. E. Hull.)

*a*. Forest Marble. Fissile shelly oolite, resting obliquely on the Great Oolite, 4 feet.
*b*. Great Oolite (Upper Division). Regularly bedded, massive, shelly, limestone, 7 feet.
*c*. Great Oolite (Lower Division). Shelly oolite full of false-bedding; the upper part coarse, the lower affording fine building-stone, which has been followed underground: 16 feet.

I obtained the following fossils from the Great Oolite Series of Corsham (C) and Yatton Keynell (Y):—

| —— | Lower Beds. | Upper Beds. |
|---|---|---|
| Cerithium | | C Y |
| Natica | | Y |
| Onustus burtonensis | | Y |
| Rimula clathrata | | Y |
| Trochus | | Y |
| Arca | | C |
| Astarte interlineata | | Y |
| Avicula costata | | C |
| Cardium Stricklandi | | C Y |
| Corbis Lajoyei | | Y |
| Corbula | | Y |
| Cyprina | | Y |
| Lima cardiiformis | | C Y |
| —— duplicata | | C |
| —— impressa | | C |
| Lithodomus | | C Y |
| Modiola | | C |
| Mytilus asper | | Y |
| Ostrea gregaria | Y | Y |
| —— wiltonensis ? | | C |
| Pecten hemicostatus | | C |
| —— vagans | | C Y |
| Tancredia curtansata ? | | C Y |
| Trichites | Y | |
| Trigonia pullus | | Y |
| Rhynchonella concinna | Y | C Y |
| —— obsoleta | | Y |
| Terebratula maxillata | | C Y |
| Waldheimia cardium | | C |
| —— digona | | C Y |
| Diastopora | | C Y |

| —— | Lower Beds. | Upper Beds. |
|---|---|---|
| Heteropora | Y | Y |
| Terebellaria | Y | C Y |
| Serpula | Y | Y |
| Apiocrinus | | C |
| Cidaris bradfordensis | | C Y |
| Echinobrissus | | Y |
| Hemicidaris | | Y |
| Calamophyllia radiata | | Y |
| Cyathophora | | C |
| Isastræa | | C Y |
| Montlivaltia | | C |
| Stylina Ploti | | C |

The lower beds of Great Oolite (belonging to the freestone division), consisting of false-bedded oolite, and resting on flaggy oolite, were exposed on Doncombe Hill, south-east of Marshfield; and a mile west of Marshfield the oolite was exposed to a depth of 5 feet. The upper beds were seen beneath the Bradford Clay in a lane below West Keynton Church, where they consist of buff false-bedded oolites, with marly layers, and beds of compact marly limestone. It is however noticeable that pale false-bedded and fissile oolites, resembling beds of Great Oolite, occur above the fossiliferous Bradford Clay at this locality. Stratigraphically there is no real break in the series.

At Luckington and Great Sherston, and again from Tormarton northwards to Hawkesbury Upton and Symonds Hall Hill, the Great Oolite has been worked in places, but I have no records of any sections showing the main subdivisions of the formation. (See Fig. 67, p. 214 of the Memoir on the Lias.)

A section at Tiltups End, between Kingscote and Avening, south of Nailsworth, was described by E. Witchell. It showed fissile sandy and shelly limestones, resting on thick beds of white limestone, exposed to a depth of 4 feet. The white limestones were taken by Witchell, as the top of the Great Oolite (following the Geological Survey); and below them come the weather-stones of Minchinhampton. From the upper beds he obtained several species of *Nerinæa* and other Gasteropods, including fragments of *Purpuroidea*, also *Cyprina loweana*, *Isocardia minima*, *Lima*, *Lucina bellona*, *Ostrea costata*, *Pecten vagans*, *Terebratula maxillata*, &c.* I should prefer to group all the beds above noted, with the Great Oolite, as the higher strata probably represent the Kemble Beds.

* Proc. Cotteswold Club, vol. viii. pp. 267, 268, 271.

# CHAPTER X.

## GREAT OOLITE SERIES.

### GREAT OOLITE AND STONESFIELD SLATE —

### (LOCAL DETAILS *continued*).

*Minchinhampton, Tetbury, and Cirencester.*

WE now come to the country around Minchinhampton, Tetbury, and Cirencester, where the Forest Marble and Great Oolite cover an extensive tract of country, where there are many quarries and railway-cuttings, and where it has been found exceedingly difficult to fix a recognizable plane of division between the two groups.

The fact is that false-bedded oolites occur at different horizons throughout the series; beds of compact white more or less oolitic limestone, with the irregular cavities that characterize the Dagham Stone, form a division in which these cavernous beds occur, at two if not at more horizons; fossil-beds yielding *Terebratula maxillata, Lima cardiiformis,* &c. are clearly impersistent for they appear as irregular beds or seams at different horizons; and clays with *Ostrea Sowerbyi* occur in both Great Oolite and Forest Marble.

There is indeed no band that can be relied upon as a constant horizon in the series. Even the Bradford Clay, as a fossiliferous bed, is to be found only here and there; and as several marly layers occur in the upper part of the Great Oolite, it is quite likely that each one may locally be fossiliferous, and even yield a similar assemblage of organic remains.

Prof. Buckman has remarked that he could by no means agree with Prof. Hull in his grouping of the upper beds of the Great Oolite. According to the former geologist, the upper portion of the Great Oolite comprises about 45 feet of "Yellowish oolite, with more or less of oblique lamination, sometimes separated into two or more stages with thin partings of sand or marl, [and it is] occasionally a hard compact freestone throughout." This division was generally grouped with the Forest Marble by Prof. Hull, who took the top of the White Limestone group as the upper limit of the Great Oolite. Prof. Buckman however maintained that the "yellowish oolite" is always found to occupy a position below the Bradford Clay, where that clay is present.*

* Quart. Journ. Geol. Soc., vol. xiv. p. 113; Hull, Geol. Cheltenham, pp. 65, 66; Lycett, Quart. Journ. Geol. Soc., vol. iv. pp. 183, 185; and Morris and Lycett, Gt. Ool. Mollusca, p. 2.

The general section by Prof. Buckman is as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite and Stonesfield Slate. | Yellowish oolite, &c. [= Kemble Beds] | 45 | 0 |
| | Marl, &c. with *Lima cardiiformis* and *Terebratula maxillata* - - | 4 | 0 |
| | Hard limestone with *Purpuroidea, Pachyrisma*, &c. - - - | 6 | 0 |
| | White limestone - - - - | 30 | 0 |
| | Rough freestone or Ragstone ("black rock" of quarrymen) - - | 25 | 0 |
| | Stonesfield Slate - - - | 15 | 0 |
| | | 125 | 0 |

With this general section my own observations agree. Consequently over much of the ground between Kemble, Tetbury and Minchinhampton, a larger area of Forest Marble is shown on the Geological Survey Map than would be mapped according to the grouping adopted.

The following are the principal divisions that may be found in the Great Oolite near Minchinhampton and Cirencester, further particulars of which will be subsequently given:—

| | | | Ft. | |
|---|---|---|---|---|
| Upper Division. | Kemble Beds. | Even beds of oolite with bands of marl. False-bedded oolites (becoming freestones in places): with marly and sandy layers, and impersistent fossil-beds yielding *Terebratula maxillata, Lima cardiiformis*, &c. | 30 | Kemble, Cuttings Tetbury road to Sapperton tunnel (G.W.R.). |
| | White Limestones. | White oolite and oolitic limestones, false-bedded in places; with beds having perforations or cavities like Dagham Stone. | 10 to 24 | Tetbury, Jackments Bottom, Minchinhampton. |
| Lower Division. | Bath Freestone and Stonesfield Slate. | False-bedded oolite (freestone). Grey limestones with white grains of oolite. Sandy beds (passing in places into Stonesfield Slate). | 40 | Tetbury, Minchinhampton. |

The following are among the abundant fossils in these subdivisions* :—

In the *Kemble Beds*:—Nerita rugosa, Purpuroidea Morrisea, Ceromya concentrica, Cyprina loweana, Lima cardiiformis, Lucina bellona, Pecten vagans, Pholadomya socialis, Rhynchonella obsoleta, Terebratula maxillata, &c.

In the *White Limestones*:—Cerithium, Natica intermedia, N. Michelini, Nerinæa Eudesi, N. funiculus, N. Voltzi, Purpuroidea Morrisea, Gervillia

* See Lycett, Cotteswold Hills, pp. 90, &c.; Witchell, Geol. Stroud, pp. 72, &c.

socialis, Isocardia minima, Lima cardiiformis, Lucina bellona, Macrodon hirsonensis, Ostrea costata, Pachyrisma grande, Pecten vagans, Pteroperna costatula, Terebratula maxillata, Anabacia, Isastræa, &c.

In the *Lower Division*:—Nerita rugosa, Arca Pratti, Gervillia acuta, Lima cardiiformis, Pecten lens, P. vagans, Placunopsis socialis, Trigonia impressa, Rhynchonella concinna, Clypeus Mülleri, &c.

In the cuttings and quarries near Kemble railway-station, and bordering the Cirencester Branch railway, the following sequence may be traced :—

| | | Ft. | In. |
|---|---|---|---|
| Kemble Beds. | Shattered oolitic limestone - - | 4 | 0 |
| | Marly clay with palatal teeth of Fishes | 5 | 0 |
| | Brown oolite in tolerably even layers - | 4 | 0 |
| | False-bedded shelly oolite, with palatal teeth of Fishes, *Ostrea*, &c., and beds of somewhat sandy limestone yielding remains of *Thuytes divaricatus* - | 7 | 0 |
| | Hard fissile sandy limestone and marls | 3 | 0 |
| | Pale false-bedded sandy and oolitic limestone - - - - | 1 | 4 |
| | Hard shelly and oolitic limestone - | 2 | 2 |
| | Marly oolitic clay with irregular layers of limestone, with *Rhynchonella obsoleta*, *Terebratula maxillata*, and spines of Echini. | 1 0 to 1 | 3 |
| | Impersistent white marly and slightly oolitic limestone. Fossil Bed, with *Terebratula maxillata*, *Rhynchonella obsoleta*, *Lima cardiiformis*, &c. - | 1 | 6 |
| White Limestone. | Pale buff and white oolites and sparsely oolitic limestone - | 4 6 to 6 | 0 |

Here the Kemble Beds are well shown, though we do not see their connection with the Forest Marble, which must (with its basement Bradford Clay) be near at hand.

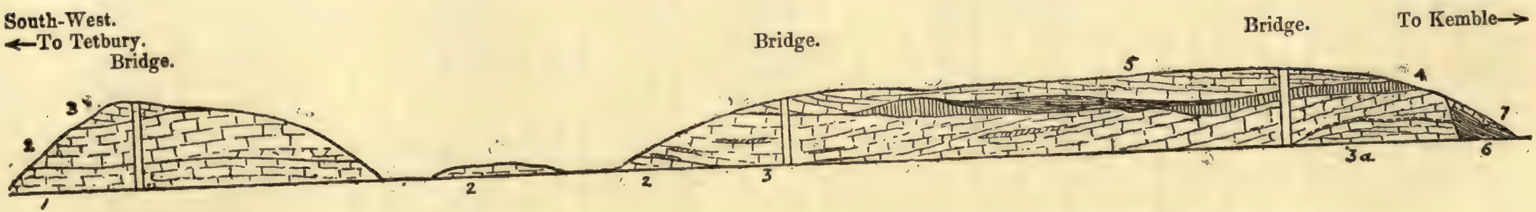
Leaving Kemble Station, and passing along the Kemble and Tetbury Railway, we come to two shallow cuttings in Great Oolite, before we reach the principal section. At the commencement of that section we find an exposure of grey clay, with a rubble on top of shelly and marly limestone, suggestive of Cornbrash. The clay is evidently Forest Marble, and faulted against the Great Oolite. A long and interesting section of Great Oolite is then seen as follows (see Fig. 83):—

| | Ft. | In. |
|---|---|---|
| 5. Pale false-bedded and fissile oolite (like the beds worked at Kemble Station); with marly layers - - - | 6 | 0 |
| 4. Brown and white marly clay, with occasional fissile beds of pale shelly oolite: *Ostrea* abundant - 0 2 to | 1 | 6 |
| Hard irregular marly stone, weathering to a rubbly marl at surface (impersistent). Fossil Bed; with *Terebratula maxillata*, *Lima cardiiformis*, &c. - - - - 2 0 to | 4 | 0 |

FIG. 83.

*Section on the Tetbury Branch of the Great Western Railway, between Kemble Junction and Jackment's Bottom.*

(Distance, $\frac{3}{4}$ mile. Vertical scale, 40 feet to 1 inch.)




7. Rubble of Cornbrash.
6. Forest Marble clay.
5. Pale false-bedded and fissile oolite. } Great Oolite.
4. { Marly clay with interrupted stone-bed. Rubbly marl and limestone (Fossil Bed). } Great Oolite.

3. False-bedded oolites with occasional Fossil-beds: separated at 3*a* by an irregular marly parting. } Great Oolite.
2. Even layers of white oolite. } Great Oolite.
1. Compact limestones with scattered oolite-grains, and tubiform perforations. } Great Oolite.

| | | | Ft. | In. |
|---|---|---|---|---|
| Great Oolite (Upper Division). | Kemble Beds. | 3. Obliquely bedded oolite, very shelly in places: *Lima*, &c. These beds become more massive, where capped by brown clay - - - | 5 | 6 |
| | | Irregular marly parting (impersistent). | | |
| | | False-bedded oolite and thick beds of pale limestone, more or less false-bedded and shelly. The distinction between these two masses of false-bedded oolite is not apparent west of the bridge, for the clay-parting dies away. Moreover fossil-beds with *T. maxillata*, *Ostrea*, &c. occur irregularly at different horizons down to the base of the series - - - | 8 | 0 |
| | White Limestone. | 2. White marly oolite with scattered oolitic grains: perforated in places - | 3 | 0 |
| | | Even beds of white oolite, and marly beds - - - - - | 7 | 0 |
| | | 1. Dagham stone: bluish limestone the top compact and the bottom oolitic, with irregular perforations to a depth of 2 feet - - - 0 9 to | 3 | 6 |
| | | White, more or less oolitic stone, with tubiform markings - - - | 1 | 0 |

The White Limestone is well seen at Jackment's or Jacuman's Bottom; an appellation said to be derived from its position on the Roman way known as Akeman Street.

At Tetbury Station and in adjoining quarries to the south-east, we have evidence of the following series of beds:—

| | | | | Ft. | In. |
|---|---|---|---|---|---|
| Great Oolite. | Upper Division. | Kemble Beds. | Brown thin-bedded and false-bedded shelly oolites, with thin clay-seam - - - - | 3 | 0 |
| | | White Limestone. | Paler false-bedded oolite with shelly bands: sandy in places, and with an occasional marly layer - - | 15 | 0 |
| | | | Hard white compact oolitic limestone (like Dagham stone): burnt for lime - - - - | 4 | 0 |
| | | | Soft limestone and marl, with fossils | 1 | 6 |
| | | | Hard bed, as above (like Dagham stone) - - - - | 4 | C |
| | Lower Division. | | Fine buff oolitic freestone (six or seven beds) seen to depth of - | 11 | 6 |

I obtained *Ceromya concentrica*, *C. Symondsi*, and *Pholadomya* (cast), from the fossil-bed in one of the quarries.

The full thickness and sequence of the Lower Beds cannot be very clearly made out. There are shallow cuttings on the railway, and in adjoining roads, to the south-east of Haresdown Barn, and near Rodmarton Cottage; and these show a variable set of beds beneath the white limestones, &c. These lower beds include grey limestone with white oolite grains, about 15 feet thick; and lower down, 6 feet of sandy beds that approach Stonesfield Beds in character. In one cutting, however, west of the road near Rodmarton Cottage, there were shown a pisolitic bed 3 feet thick, resting on a brecciated and nodular limestone 16 inches thick, with tubiform markings; and these beds resemble certain layers which are shown in the cutting by Hayley Farm, and which I have grouped with the Upper Division of the Great Oolite. (See p. 277.)

The upper beds of the Great Oolite and the junction with the Forest Marble, were shown at Vaze's Quarry, in the valley north-west of Tetbury. The section was as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Forest Marble (Bradfordian). | Fissile and more or less sandy oolite, much false-bedded: the lower beds used for planking - - - | 15 | 0 |
| | Grey clay - - - 1 0 to | 3 | 0 |
| Great Oolite (Kemble Beds). | Oolite in thick beds, shelly in places; the bottom layer current-bedded, and resting on a fairly level surface of markedly false-bedded oolite beneath. Beds used for walling - 10 0 to | 12 | 0 |
| | Buff and white, false-bedded oolitic free-stone: hard and soft beds - 10 0 to | 12 | 0 |
| | (White Limestone series, below; but not exposed.) | | |

Proceeding along the railway-cuttings north of the old Tetbury road station (G.W.R.), we find shallow sections of fissile and false-bedded shelly oolite, divided by a band of marly clay 6 to 8 inches thick. These represent the upper (Kemble) beds of the Great Oolite, and cannot be far below the Bradford Clay. Further on by the 92nd milestone, lower beds are seen, as follows:—

| | | | Ft. | In. |
|---|---|---|---|---|
| Great Oolite. | Kemble Beds. | Rubbly and fissile oolite, with *Ostrea* (abundant), large specimens of *Terebratula maxillata, Lima cardiiformis*, and Corals - - - - | 10 | 0 |
| | | Seam of clay. | | |
| | White Limestone. | False-bedded white oolite, with Corals (stone quarried) - - about | 12 | 0 |

At this locality, a little south of the Thames and Severn Canal, a fault is marked on the Geological Survey Map. North of the canal we find, on the east side of the railway, a quarry in fissile shelly oolite.

In the south-eastern part of Hayley Wood there is a fine cutting on the Great Western Railway, which shows the following sequence:—

| | | | Ft. | In. |
|---|---|---|---|---|
| | | Marly bed (base of Forest Marble?) 1 0 to | 2 | 0 |
| Great Oolite (Upper Division). | Kemble Beds. | Soft oolite, rubbly, and with marly layers; and one or two bands of compact limestone, with irregular cavities like Dagham stone - - | 4 | 6 |
| | | Hard creamy limestone; pale matrix with brown oolitic grains - - | 3 | 0 |
| | | Oolitic marly layer with Lamellibranchs | 1 | 0 |
| | | Pale fine-grained and hard oolite with cavities in top part: *Nerinæa* - - | 4 | 0 |
| | | Pale and brown oolite - - - | 6 | 0 |
| | | Hard pale oolite, prominent layer - | 1 | 3 |
| | | Fissile and shelly oolite; false-bedded shivery freestone - - 10 0 to | 12 | 0 |
| | White Limestone. | "White Lias" (I was informed) had been proved about 4 feet beneath the level of the railway. | | |

The beds, which exhibit a gentle anticline, dip at about 2° towards the north-west and south-east. The higher beds (above the shivery freestone) are tolerably even layers, though wedge-shaped in places.

South-east of the railway-bridge there is a fault that brings on higher fissile beds of gritty limestone and shales, that belong to the Forest Marble.

In the cutting by Hayley Farm, south of the small tunnel, and in that between the two tunnels, we have the following succession of beds:—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite (Upper Division).—Kemble Beds. | Rubbly and coarse-grained oolites, with marly layer near base; beds becoming flaggy near the top | 10 | 0 |
| | Hard white pisolitic and oolitic limestone, with hard nodules near the top. Bone of *Megalosaurus* (?) on surface of stone - - 1 6 to | 2 | 0 |
| | Ochreous marly and sandy parting (impersistent), with tooth and bones of *Megalosaurus*, and Plant-remains. | | |
| | Pisolitic and brecciated oolite | 1 | 9 |
| | Clayey seam. | | |
| | Compact oolite, with large grains* | 1 | 2 |
| | Brown and white fossiliferous oolite | 1 | 6 |
| | Pale and buff oolites (freestones) | 11 | 6 |
| | Fine oolitic and pale earthy limestone, and rubbly marl, passing into brown oolite at base. Fossil Bed: with *Natica*, *Nerinæa pseudopunctata?* *Pleurotomaria*, *Cypricardia caudata*, *Homomya Vezelayi*, *Lima impressa*, *Lucina bellona*, *Myacites*, *Ostrea costata?*, *Rhynchonella obsoleta*, *Terebratula maxillata*, *Echinobrissus Woodwardi*, &c. | 5 | 0 |

Remains of *Mesodon* and *Strophodus* were also obtained from the beds in this cutting: and the fossils agree generally with those obtained from the Upper beds of Great Oolite by College Farm, Cirencester. The beds dip at an angle of 2° towards the south-east.

The short cutting between the two tunnels, although it showed beds perhaps on a lower horizon than those in the cutting to the south, yet it did not exhibit any marked fossil-bed. This, however, is not surprising when we know that the fossil-beds (as seen near Kemble) end off abruptly.

Beneath the beds thus recorded in the open sections, adjoining the Sapperton railway-tunnels, we have the following account of the strata noted by the Engineer, R. P. Brereton, and published by J. H. Taunton† :—

| | | | Ft. | In. |
|---|---|---|---|---|
| Great Oolite. | White Limestone - | White Limestone Bed | 10 | 0 |
| | Lower Division - | Lower Beds of Great Oolite | 40 | 0 |
| | | Fuller's Earth - - 80 0 to | 90 | 0 |
| | | Inferior Oolite (seen at northern end of great tunnel). | | |

* See Hull, Geol. Cheltenham, p. 65.

† Proc. Cotteswold Club, vol. v. p. 255.

That the "White Limestone" comes beneath the mass of oolites shown in the cuttings south of the railway-tunnels, is to some extent confirmed by a quarry east of the White Horse, on the main road to the west. There we find white oolites exposed to a depth of 7 or 8 feet as follows :—

| | |
|---|---|
| Great Oolite (Upper Division). | White Oolite. |
| | Rubbly layer with *Isocardia* and *Terebratula maxillata*. |
| | White limestone (like Dagham stone) with burrows or cavities passing down irregularly, 2 feet or more. |
| | White oolite. |

The Great Oolite has for a long period been extensively worked on Minchinhampton Common,* near Stroud ; for the beds yield good weatherstone. The district has been rendered famous to geologists from the long continued labours of Dr. Lycett, who obtained over 320 species of organic remains from the strata.†

It is difficult now to recognize the particular beds described by him, but as he observes : "The shelly weatherstones which contain the well known Minchinhampton fossils, appear to extend over very limited areas in large useful blocks, and with testacea entire ; thus it has happened that nearly the whole series of beds in one quarry are shelly, and produce large blocks of stone, and in another neighbouring quarry a large portion of the whole mass wanting these features is useless for economic purposes. . . . Even in the larger of the two quarries now used upon Minchinhampton Common, the uppermost or planking bed changes its condition very materially between the two extreme ends of the section, losing all its testacea towards its southern extension."

It is not surprising then, that the section recorded by Lycett differs materially from that open at the time of my visit, about 30 years afterwards. This no doubt arises in great measure from the fact that beds split up differently according as they are subject to atmospheric influences, thus forming freestone at the base, wall-stone nearer the surface, and rubble on top.

The following is an account of the principal quarry at Minchinhampton, from my notes of 1886 :—

| | | | Ft. | In. |
|---|---|---|---|---|
| Upper Division. | 8. Rubble - - - | 5 0 to | 6 | 0 |
| | 7. Thin-bedded compact limestone and sandy beds. [=Dry Wall Stone] - - | | | |
| | 6. Hard pale and smooth limestone with scattered oolitic grains, and with hollows due to decomposed Corals - - | | 1 | 0 |
| | 5. Wedge-bedded oolite, pale buff or white, and shelly ; exhibiting honeycombed weathering | | | |

* Amberley Heath, a second name for Minchinhampton Common, gives name to the genus *Amberleya*, described by Morris and Lycett, Supp. to Gt. Ool. Mollusca, p. 19.

† J. Lycett, The Cotteswold Hills, 1857, p. 93, and Quart. Journ. Geol. Soc., vol. iv. pp. 185, 186.

| | | | Ft. | In. |
|---|---|---|---|---|
| Great Oolite. | | in places. *Purpuroidea* near base in bottom layer. [=Planking] - - - - | 8 | 0 |
| | | 4. Parting with *Lima cardiiformis.* | | |
| | | 3. False-bedded white shelly oolite [=Soft white stone] - 4 0 to | 6 | 0 |
| | Lower Division. | 2. Current-bedded stone with shelly layers and comminuted shells, *Lima*, &c. [=Weatherstone and Shelly Beds] 12 0 to | 15 | 0 |
| Fullonian - - | | 1. Clay (not seen). | | |

According to Morris and Lycett the stone-beds to which they apply the general terms of "Shelly Beds" and "Weatherstone series," here rest on the Fuller's Earth "without any appearance of Stonesfield Slate;" they add however, that "as a general rule, throughout the district, the Great Oolite, near to its base, has one or more beds, which possess all the essential characters of Stonesfield slate";* and this fact is noted by Prof. Hull, who observes that "At the base of the Great Oolite, along the margins of Stroud and Nailsworth valleys, a few inches or feet of brown sandy slates with partings of clay may frequently be observed."†

Bed 2 in the above section is now known to the quarrymen as the Weatherstone. It corresponds with beds C., D., and E. of Lycett's section, which he divides as follows:—

| | Ft. | In. |
|---|---|---|
| C. Soft yellowish oolite, much false-bedded; numerous holes bored by *Lithodomus*. Known to the workmen as Oven Stone. The softness enables it to be sawed into ridge-tiles and copings for walls. It is termed "Soft Shelly Sandstone" by Morris and Lycett - - - - - - - | 6 | 0 |
| D. Weatherstone, in two or three beds, full of shells, *Ostrea*, &c. - - - - - - | 6 | 0 |
| E. Basement-bed, with *Ostrea* - - - - 0 4 to | 0 | 9 |

Bed 3 is the soft pale calcareous oolite with occasional sandy partings (Bed B. of Lycett), described, I know not why, as "Thin-bedded yellowish sandstones" by Morris and Lycett. *Astarte angulata* occurs here; and *Ostrea*, *Tancredia*, and other shells are abundant towards the base. The thickness noted by Lycett is 10 to 14 feet.

Bed 5 corresponds with the main mass of Planking (Bed A. of Lycett), in which he obtained a large number of organic remains. Among these are *Ceritella*, *Cerithium*, *Cylindrites*, *Natica*, *Nerinæa*, *Nerita*, *Patella*, *Pileolus*, *Purpuroidea*, *Trochotoma*, *Trochus*, *Turbo*, *Arca*, *Gervillia*, *Lima*, *Limopsis*, *Ostrea*, *Pecten*, *Sphæra*, *Tancredia*, &c. together with fragments of Echinoderms, Corals, Crustacea, Fish-remains, and Lignite.

Cephalopoda, Brachiopoda, and Mollusca of the Mya-group are stated to be rare. Specimens from Minchinhampton of *Ammonites subcontractus*, *A. arbustigerus*, *A. Waterhousei*, and *A. biflexuosus*, are preserved in the Woodwardian Museum at Cambridge. The occurrence of *Pholas oolitica* has been noted at Minchinhampton and Bisley Commons.‡

Speaking of the Weatherstones, Morris and Lycett state that "The shelly relics often constitute a considerable proportion of the whole mass; they are converted into crystalline carbonate of lime, which frequently fills the interior of the univalves; and it is to the abundance of this mineral, disseminated everywhere, that the weatherstones owe their superior durability upon exposure to the atmosphere. As a general rule, therefore, the beds which contain the greatest abundance of shells are those which are most fitted to resist the action of frost; water percolates

* Gt. Oolite Mollusca (Palæontogr. Soc.), p. 4.
† Geol. parts of Wilts and Gloucestershire, p. 12.
‡ Lycett, Cotteswold Hills, pp. 93, 94; and Proc. Cotteswold Club, vol. i. p. 17 Morris and Lycett, Mollusca of the Great Oolite, pp. 3, &c.

their structure in much smaller quantity, and more slowly, and, on escaping, carries away but little lime in solution."*

Lycett mentions that "In one curious instance a large Nautilus was severed by a joint, and the divided portions remained a yard apart on opposite sides of the chasm."†

The lower beds of Great Oolite are evidently thinner at Minchinhampton than they are further east near Sapperton. Prof. Hull notes their thickness as varying from 20 to 40 feet. The total thickness of the Great Oolite was estimated to be 120 feet by Morris and Lycett. This would include the Kemble Beds, which are probably not exposed in the Minchinhampton quarries, the upper beds (there seen) belonging to the White Limestone subdivision.

West of the Folly at Minchinhampton, the following section was opened in beds mapped by the Geological Survey as Forest Marble, but which I should include with the Great Oolite:—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite (Kemble Beds ?). | Thin pale, false-bedded and shelly oolites, with sandy layers and small hard calcareous and sandy nodules - | 5 | 6 |
| | Pale oolite. | | |

This nodular bed occurs in the Upper Beds of the Great Oolite, and may be compared with that noticed in the railway-cutting south of Sapperton tunnel. It is probably not far above the beds shown in the Minchinhampton quarries. The stone is quarried for building walls, for road-metal, &c.

The following section of the beds at Bussage, west of Chalford, was noted by E. Witchell‡:—

| | | | Ft. | In. |
|---|---|---|---|---|
| Great Oolite. | [Kemble Beds.] | Rubbly oolite - - - - | 7 | 0 |
| | White Limestone. | Buff limestone, with casts of *Natica*, *Purpuroidea*, &c. - - | 3 | 0 |
| | | White limestone - - - | 6 | 0 |
| | | *Pachyrisma*-bed, consisting principally of shells of *Pachyrisma grande* - - - - | 1 | 0 |
| | | White limestone, with casts of *Natica* - - - - | 2 | 6 |
| | | White freestone. | | |

The only other locality where the *Pachyrisma* has been found is at Cowcomb Hill, south of Chalford. Among other fossils that have been obtained from Bussage, are the following: *Astarte flexicostata, Gervillia ornata, Pecten Woodwardi*, and *Sowerbya Woodwardi.*

Reference has been made (p. 279) to the incoming of beds of the character of Stonesfield Slate in the vicinity of Stroud and Minchinhampton. Witchell observed that "In a well sunk on Stroud Hill, in connection with the Water Works, the lower part

* Mollusca of Gt. Oolite (Pal. Soc.), p. 2.

† Quart. Journ. Geol. Soc., vol. iv. p. 184. Lycett remarks that the term "Lissens" is applied by the quarrymen to the open joints in the strata.

‡ Geol. Stroud, p. 77.

of the Stonesfield Slate was found to be laminated, and split up on exposure like the true roofing-tile."*

At Througham Field, north-east of Bisley, and south of Througham or Druffham, we find quarries opened for the working of Stonesfield or Bisley Slates. The Stonesfield Slate series is overlaid by 10 feet of current-bedded oolite, which is quarried for building-stone, for wall-stone, and for road-metal. The details of the underlying beds vary very much, but the following section noted in Mr. Freeman's quarry (in company with J. H. Taunton), affords a good example of the series: there the oolitic freestone is not seen:—

| | | Ft. | In. |
|---|---|---|---|
| | Soil. | | |
| Stonesfield Slate. | Oolitic sandy stone, yielding the best "slate," but now for the most part worked away - - - - | 2 | 6 |
| | Calcareous sandstone, used for wall-stone and road-metal - - - | | |
| | Soft calcareous sandstone with scattered oolitic grains - - - - | 4 | 6 |
| | Hard calcareous sandstone: building-stone - - - - - | | |
| | Fissile sandy beds - - - | 2 | 6 |
| | Hard irregular earthy sandstone, obscurely oolitic; with fossils 1 2 to | 2 | 0 |
| | Fissile micaceous sandstone with *Trigonia impressa.* Slate Bed. The top 4 in. will never split; the next 9 in. forms good slate; the lower part is not so good - - - - | 2 | 0 |
| | Fissile sandy beds - - - | 1 | 6 |
| Fullonian - | Clay. | | |

The "slate" does not exhibit planes of division in the quarry. It is never more than 18 inches thick, and this occurs at slightly different horizons.

Stone tiles or "Slates" have also been obtained from Miserden (Miserdine), Rendcomb, and Nettlecomb near Birdlip; and Prof. Hull states that they have been worked on the north-east side of Oakridge Common and at Battlescomb, east of Bisley.†

In quarries north-west of Queen Anne's Monument in Oakley Park, Cirencester, and by the four-mile Lodge near Sapperton, there were exposed about 12 feet of false-bedded oolite and shelly rag with an occasional marly layer, containing *Ostrea*, &c. The beds probably belong to the upper division (Kemble Beds) of the Great Oolite. Lower beds were to be seen at Dean's Quarry on the Stroud or Minchinhampton road, 3 miles from Cirencester, where the following section was exposed:—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite (Upper Division). | Pale oolites - - - - - | 3 | 0 |
| | Rubbly and sandy marl and tough oolite [Echinobrissus] - - | 1 | 6 |
| | Compact limestone, oolitic, with irregular cavities like Dagham Stone - | 2 | 4 |
| | White oolite and coral-limestones, false-bedded - - - - | 6 | 0 |

* Proc. Cotteswold Club, vol. vii. p. 117.

† Geol. parts Wilts and Gloucestershire, p. 13; Geol. Cheltenham, p. 60; Lycett, Cotteswold Hills, p. 100.

The late Joshua Brown of Cirencester, collected many Corals from this quarry, including *Convexastræa Waltoni, Isastræa gibbosa, I. limitata, Thamnastræa Lyelli*, &c. Mr. Tomes compares the Coral-bed with that on Farley Down near Bath.*

On the north side of the Tetbury road, a little more than 2 miles from Cirencester, beyond the old pit known as Jarvis' Quarry, we find the following section :—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite. (Upper Division)— Kemble Beds. | Rubble and false-bedded shelly oolite, with *Ostrea* - - - - | 7 | 6 |
| | Marly and shelly clay with *Ostrea* (abundant), and *Terebratula* - - | 0 | 6 |
| | Shelly and oolitic limestones with Fish-remains, *Ostrea, Pecten vagans*, &c. (stone worked for building-purposes and road-metal) - - - | 7 | 0 |
| | Clay-band - - - - | 0 | 6 |
| | Marly and shelly oolitic limestone. Fossil Bed; with *Terebratula maxillata, Lima cardiiformis*, &c - - | 2 | 0 |
| | Shelly oolitic limestones, "Soft Cockly Beds" - - - about | 4 | 0 |

The top beds are evidently the same as those that occur at the base of the Bradford Clay at Jarvis' old quarry, where they attain a thickness of 12 feet. The above beds compare well with those seen near Kemble. I obtained the following fossils from them :—

Crocodilian tooth.
Hybodus.
Mesodon (Pycnodus).
Strophodus.
Corbula?
Lima cardiiformis (abundant).
—— duplicata.
—— impressa.
—— strigillata.
Opis?
Ostrea.
Pecten annulatus.
—— lens.
—— peregrinus?
—— vagans (abundant).
Unicardium varicosum.
Terebratula maxillata.
Echinobrissus Griesbachi.
Isastræa limitata.

By the College Farm at Cirencester the following beds were exposed at the Lime-kiln :—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite (Upper Division)— Kemble Beds and White Limestone. | Rubbly oolite. | | |
| | Rubbly marl and pale limestone with *Natica intermedia, N. Stricklandi? Trochotoma obtusa, Mytilus sublœvis, Homomya Vezelayi, Lima cardiiformis, Terebratula maxillata*, and *Pygurus*. | | |
| | False-bedded oolitic limestone, irregular. | | |
| | Thin-bedded oolite and sandy layers - | 3 | 0 |
| | Oolitic limestone - - - | 4 | 0 |
| | Rubbly and marly beds - 1 0 to | 1 | 6 |
| | Compact oolitic coral-limestone, with in the upper part (for about 1 foot) irregular ferruginous and earthy veins, causing cavities as in the Dagham stone. *Convexastræa Waltoni?* and *Stylina* - - - - | 4 | 6 |
| | Oolites with sandy partings in places - | 4 | 6 |

* Quart. Journ. Geol. Soc., vol. xli. p. 172.

A well sunk at the Farm was carried to a depth of 140 feet, into the Fuller's Earth. The full thickness of the Great Oolite probably does not exceed 120 feet.

The task of fixing a precise division between Great Oolite and Forest Marble, is difficult enough in the neighbourhood of Cirencester. From a general point of view there is indeed a marked difference between the white limestones, the marls and more or less shelly oolites that belong to the Great Oolite; and the hard oolitic shelly and sandy flags and planking of the Forest Marble, separated as these are by beds of clay, and accompanied as they sometimes are by sands and concretionary masses of calcareous sandstone. Nevertheless the junction-beds not unfrequently comprise alternations of marls and clays with shelly and oolitic limestones, there being clayey bands, sometimes crowded with *Ostrea Sowerbyi,* at several distinct horizons. The fauna of the Bradford Clay is only preserved here and there; and to the north and north-east of Cirencester, as remarked by Prof. J. Buckman,* we have but rare indications of it. On the whole the flaggy beds of Great Oolite are not so hard nor so thinly divided, as are those of the Forest Marble; nor when obliquely bedded, are they separated by the even bands of blue and shaly clays that mark the Forest Marble. Again, the Forest Marble limestones are usually characterized by ochreous clay-galls, and they are more often blue in colour, owing to the protecting layers of clay associated with them.

Great Oolite has been quarried in several places bordering the Great Western (branch) railway south of Cirencester station. The junction-beds with the Forest Marble are shown in some of the openings, and it is evident that the clays and marl-beds are of varied thickness in different places, and it is impossible to correlate the layers, bed for bed, in the several exposures.

The following section was shown in one of the quarries :—

| | | FT. | IN. |
|---|---|---|---|
| Forest Marble. | Clay, with band of blue flaggy oolitic and shelly limestone - - - | 2 | 6 |
| | Brown and bluish clay, with band of marly oolitic limestone - - | 3 | 6 |
| *Passage-beds.* | Hard blue and brown oolitic and shelly limestone - - - - | 3 | 0 |
| | Oolitic marly clay, with "race," and *Ostrea* - - - - - | 1 | 2 |
| Great Oolite | Pale oolite, (with *Ostrea*) - - | 4 | 6 |
| | Marly clay, with *Ostrea* - - | 0 | 6 |
| | Pale false-bedded oolites - - - | 17 | 0 |

*Echinobrissus Griesbachi* was obtained from the Great Oolite at this locality. Other Echinoderms also occur sometimes abundantly in this neighbourhood. A large number of specimens (many hundreds indeed) of *Acrosalenia pustulata,* were obtained at Cirencester, by Fred. Bravender and T. C. Brown, in the winter 1858–59.† The following section was given by Bravender:—

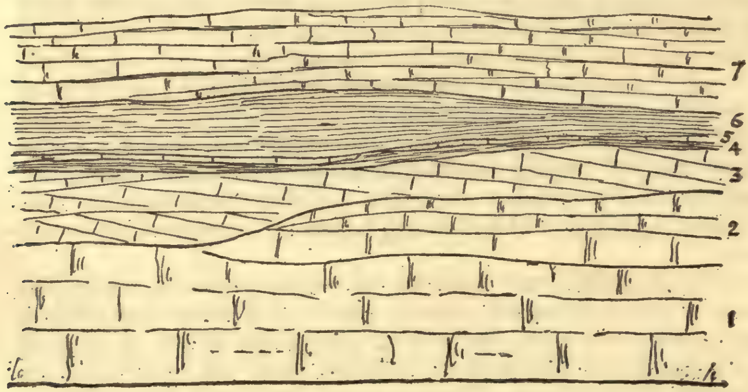
* Quart. Journ. Geol. Soc., vol. xiv. p. 117.
† Wright, Ool. Echin. Pal. Soc., pp. 460, 461.

| | | Ft. | In. |
|---|---|---|---|
| Forest Marble - | Bradford Clay with *Waldheimia digona* | 6 | 0 |
| Great Oolite (Kemble Beds). | Oolite - - - - - | 6 | 0 |
| | Marly vein with *Acrosalenia* - - | 0 | 2 |
| | Band of stone - - - - | 0 | 4 |
| | Clay bed - - - - | 2 | 0 |
| | Oolite. | | |

The only other species found was *Holectypus depressus;* but I was informed by Mr. W. A. Baily of Cirencester, that the specimens of *Acrosalenia* occurred in a cluster, and that he conveyed away a barrow-load of them. Few, if any, examples can now be found in the quarry.

Fig. 84.

*Section at Hare Bushes Quarry, north-east of Cirencester.*




An interesting section (Fig. 84) has been opened to the north-east of Cirencester, at the Hare Bushes quarry, a little south-west of the Foss Way. It was as follows:—

| | | | Ft. | In. |
|---|---|---|---|---|
| | Forest Marble (passage-beds.) | 7. Thin bedded marly and shelly oolitic limestone - - - - - | 4 | 0 |
| | | 6. Pale and dark brown clay with "race" and *Ostrea* - 0 6 to | 3 | 0 |
| Great Oolite. | Kemble Beds. - | 5. Shelly oolite - - - - | 0 | 3 |
| | | 4. Oolitic marl with *Ostrea Sowerbyi* (abundant) - - - - | 0 | 5 |
| | | 3. False-bedded buff oolite, shelly and fissile - - - - 2 0 to | 3 | 0 |
| | White Limestone. | 2. Buff and white, compact, and slightly oolitic limestones, with fibrous markings on surface - 3 0 to | 4 | 0 |
| | | 1. Brown oolitic and somewhat sandy limestones: seen to depth of - | 4 | 0 |

The false-bedded oolite rests on a very uneven surface of the compact white limestones, which appear in greater thickness at the southern end of the quarry. The appearances point to some contemporaneous erosion of the strata. About 10 feet more of oolite was at one time exposed at this quarry, as mentioned by

Prof. Buckman.* The details of the beds are however subject to much variation. From this locality he obtained the Reptilian eggs named *Oolithes bathonicæ*, in a bed of white freestone; and these he considered to have belonged to *Teleosaurus*.† (See pp. 17, 313.)

These rocks are overlaid to the north-east by beds of undoubted Forest Marble, well shown in a quarry and in the adjoining railway-cuttings that extend by the Norcott plantation.

The upper strata may be grouped as passage-beds between the Great Oolite and Forest Marble; and the top bed appears to correspond with the thick layer of blue and brown oolitic and shelly limestone, marked in the section south of Cirencester. The top layer of white and compact limestone belongs to the White Limestone series, and corresponds with one of the beds of Dagham stone.

The general section of the Great Oolite at Cirencester appears to be as follows:—

| | | | Ft. | In. |
|---|---|---|---|---|
| Upper Division. | Kemble Beds. | Oolites (false-bedded chiefly at base) and marly beds with occasional fossil-beds - - from 30 0 to | 10 | 0 |
| | White Limestone. | White and oolitic limestones with tubiform markings (Dagham Stone) 8 0 to | 10 | 0 |
| | Lower Division. | False-bedded and fissile oolite and calcareous sandstones - 25 0 to | 35 | 0 |

The Kemble Beds evidently become thinner when traced from Kemble to Cirencester; while onwards in a north-easterly direction they become overlapped, near Baunton Downs, by the Forest Marble, which then rests directly on the White Limestone.

*Cirencester to Sevenhampton, Salperton, Naunton, and Stow-on-the-Wold.*

A quarry on the Cheltenham road, east of Stratton, showed the following section:—

| | | | Ft. | In. |
|---|---|---|---|---|
| | Forest Marble (*passage-beds*). | Rubbly beds of marl and marly limestone, with band crowded with *Ostrea* - - - - - | 3 | 0 |
| Great Oolite. | Kemble Beds. | False-bedded shelly oolites, fissile in places, and with thin partings of marl - - - - - | 4 | 0 |
| | | Fissile marly bed - - - | 0 | 3 |
| | | Hard rubbly oolite - - - | 3 | 0 |
| | | False-bedded oolite - - - | 2 | 3 |
| | White Limestone. | Hard and compact white limestone, with scattered grains of oolite - | 2 | 3 |
| | | Marly band - - - - | 1 | 0 |
| | | Fine-grained brown oolite - - | } 4 | 0 |
| | | Hard white oolite - - - | | |
| | | Fine-grained brown oolite - - | | |

* Quart. Journ. Geol. Soc., vol. xiv. p. 117. See also Journ. Bath and W. of Eng. Soc., vol. xiii. p. 220.

† *Ibid.*, vol. xvi. p. 107. See also figure in Prestwich's Geology, vol. ii. p. 206.

The beds here are very changeable in character within short distances. The Gas House Quarry, half a mile north of Cirencester, described by Prof. Buckman, showed beds that probably correspond with those noted in the above section. It was carried to a greater depth, so that he describes 35 feet of stone-beds beneath the top rubbly layers. He moreover records *Waldheimia digona* from "Bradford Clay," evidently a portion of the 3 feet of rubbly beds above mentioned.*

North of Stratton there is considerable difficulty in tracing out the sequence of the beds, but there are several quarries along the main road. In one of these we find a section showing about 10 feet of false-bedded oolite, shelly in places, and yielding *Strophodus* and *Ostrea*, representing the Upper (Kemble) Beds.

East of Daglingworth the connection of these with the underlying beds, was shown in a quarry north of the 15th milestone as follows:—

| | | | Ft. | In. |
|---|---|---|---|---|
| Great Oolite. | Kemble Beds. | Brown oolitic and shelly limestone 2 0 to | 3 | 0 |
| | | Rubbly oolitic bed with *Ceromya excentrica, Homomya Vezelayi, Lima cardiiformis, Lucina bellona, Modiola, Pholadomya, Terebratula maxillata,* &c. - - - - - - | 2 | 6 |
| | White Limestone. | Hard bed of limestone, the surface covered with large *Ostrea Sowerbyi.* 1 0 to | 1 | 6 |
| | | Dagham Stone; the cavities filled with irregular ochreous marl. Compact oolitic limestone passing down into White Oolite, with a shelly bed (3 ft. down) yielding *Nautilus, Purpuroidea glabra, Pecten,* &c. - | 9 | 0 |

## Dagham Stone.

In the neighbourhood of Cirencester there are found layers and blocks of Great Oolite characterized by irregular and ramifying tubiform cavities. Where the stone is *in situ* and protected from the direct influence of the weather, the cavities are usually filled with ochreous material; where exposed to the action of the weather, the cavities in the stone have been emptied and enlarged. Irregular blocks have been obtained for rustic work or rockeries, on Dagham or Daglingworth Downs to the north of Cirencester. Attention has previously been called to stone of this character, under the name of "Dagham Stone." Referring to this rock, my father, S. P. Woodward, has stated that "In Gloucestershire there is a bed of the Great Oolite, called 'Dagham Down Stone, because it forms the substratum of a large extent of (formerly) down-land. This must have originally enveloped a continuous bed of sponges, or something of the kind, for now the rain eats into it irregularly, leaving holes such as one could make with the fingers in dough."†

* Quart. Journ. Geol. Soc., vol. xiv. p. 114.
† Geol. Mag., 1867, p. 405.

Lycett attributed these irregular holes "to the forcible escape of gases from beneath while the stratum was of a soft or pasty consistence";* and Prof. Allen Harker considers them to be due to the action of humic acid.† Witchell, again, remarked that these beds full of holes, have been called "holy-stones," and that "the probable explanation of this peculiarity is that the calcareous matter was deposited round soft substances which have been dissolved or otherwise removed, and through the labours of boring animals when the surface of the limestone was the floor of the sea."‡

The rock itself is a pale slightly oolitic limestone, that occurs in the White Limestone division of the Great Oolite. It is not, however, confined to one particular horizon, as two or more layers exhibiting these cavities may sometimes be observed, separated by some thickness of other beds. Where seen at some depth beneath the surface the cavities are filled, or partially filled, with ochreous marl containing oolitic grains; and although occasionally small cavities may be due to the decomposition of branching Corals, as I take to be the case at Minchinhampton, or of clusters of oolite grains that occur in the compact limestones, yet in the majority of instances no definite structure can be found associated with them.

Stone showing these curious hollows has been found in many places near Cirencester; but in most cases the stone has not been subjected to surface weathering, as on Dagham Downs. Lycett mentions the old monumental stone, the Longstone, near Minchinhampton, as being formed of rock full of irregular holes.

In a quarry in white and slightly oolitic limestone at Eastcombs near Bisley, the stone contained these ramifying ochreous perforations, which appeared like ferruginous stainings, to a depth of 3 or 4 feet, or more. Again near Ledgemore Bottom, north of Tetbury the rock is found in a weathered condition.

The appearances are not confined to the Great Oolite, as I have noticed them, on a smaller scale, in the Inferior Oolite between Stroud and Painswick. From their position they cannot have originated from modern surface-agencies, although these have modified and enlarged the hollows, especially at or near the surface. In all cases the original structure of the rock must have led to the formation of the features; but even underground the ochreous nature of the branching materials, and the sharp and irregular outlines of the walls of rock, show that the influence of permeating waters has been at work.

The most reasonable explanation seems to be that the soft calcareous mud was penetrated by burrowing organisms, which have left no other traces of their former presence in the now indurated deposit, than the irregular lines of weakness caused by their burrows. These have been subsequently acted upon both superficially and underground, by acidulated waters.

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* Quart. Journ. Geol. Soc., vol. iv. p. 185.

† Proc. Cotteswold Club, vol. ix. p. 316. See also Phillips, Geol. Oxford, &c., p. 243.

‡ Geology of Stroud, p. 78.

The Lower Beds of the Great Oolite have been exposed near Smith's Cross, south-west of Elkston, and again at Briary Hill, east of Nettlecomb, near Birdlip, where we find in sequence the following beds:—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite (Lower Division). | False-bedded shelly oolite - - | 4 | 0 |
| | Fissile shelly, sandy and marly oolite, passing down into thin false-bedded layers of calcareous sandstone and oolite (of Stonesfield type) - about | 10 | 0 |

*Ostrea* and *Rhynchonella concinna* occur here. Similar beds, comprising fissile shelly and oolitic limestone, with a clayey band, were exposed in a quarry west of Perrot's Brook, and south-east of Bagendon.

A quarry west of Baunton, and a little south of Trinity Mill, exposed a series of flaggy and sandy oolites and limestones, with an intermediate marly oolitic band (4 feet thick). From this band of marl, I obtained the following fossils:—

| | |
|---|---|
| Astarte (cast). | Pholadomya deltoidea? |
| Lima duplicata. | —— Heraulti. |
| Lucina bellona. | Trigonia. |
| Modiola imbricata. | Terebratula maxillata. |
| Ostrea Sowerbyi. | |

These beds come above the White Limestone, and the fossil-bed may be compared with that found east of Daglingworth (See p. 286.)

North-east of Baunton there is a quarry showing nearly 15 feet of thin bedded oolite, resting on false-bedded buff shelly and sandy oolite. These beds, mapped by the Geological Survey as Forest Marble, belong to the Upper Division of the Great Oolite (Kemble Beds).

South-east of Calmsden, a quarry between the railway and the high-road, showed the following sequence:—

| | | Ft. | In. |
|---|---|---|---|
| Forest Marble. | Shelly oolitic limestone - - - | 0 | 10 |
| | Brown sandy marl with *Ostrea* - - | 0 | 5 |
| | *Ostrea*-limestone, with *Lima cardiiformis* | 1 | 0 |
| | Irregular rubbly limestone, and brown sandy and "racy" marls; with *Ostrea Sowerbyi* (abundant) - - - | 2 | 6 |
| Great Oolite (Upper Division). | Hard brown oolitic and shelly limestone - | 1 | 6 |
| | Yellow rubbly marl - - - | 0 | 8 |
| | Brown shelly oolite with marly patches - | 2 | 0 |

The top beds here (in part at any rate) are equivalent to the beds seen in the quarry on the Cheltenham road, east of Stratton. (See p. 285). A quarry about ¾ mile S.S.W. of Calmsden, showed about 7 feet of false-bedded and current-bedded oolite and buff sandy oolite, worked for wall-building, &c. These beds are on a lower horizon, equivalent to the strata in the quarry west of Baunton.

Beds belonging to the White Limestone division of the Great Oolite, were well shown in a quarry by the cross-roads south-west of Baunton Downs, as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite (White Limestone). | Rubble of limestone - - - | 3 | 0 |
| | Hard false-bedded white oolite, with bed like the Dagham stone, in places, at the top - - - - 2 0 to | 3 | 0 |
| | Hard white limestone with scattered oolitic grains; brown in places - | 3 | 6 |
| | Brown limestone with abundant oolitic grains - - - - - | 1 | 0 |

North-east of Rendcomb, and north of Holly bush, a Lime-kiln on the west side of the road showed the following beds :—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite (White Limestone). | Smooth white limestone, slightly oolitic - | 2 | 6 |
| | Rubbly beds with *Lucina bellona* and *Cypricardia nuculiformis* - - ; Compact limestone - - - ; Hard Coral-limestone - - - | 2 | 6 |
| | Hard slightly oolitic stone - - ; Fine oolitic stone - - - - | 3 | 0 |
| | Coral-limestone - - - - | 1 | 0 |
| | Hard oolitic marly bed. | | |

The railway-cuttings between Cirencester and Chedworth have opened up some good sections of the Great Oolite. This rock is exposed near Wiggold (Wigwold) Copse, both in the cutting and in a quarry by the adjoining plantation. At the quarry we see about 6 feet of rubbly oolites and marls, resting on 3 feet of oolitic freestone. In the cutting we find lower beds, comprising about 6 feet of pale shelly and oolitic limestones, false-bedded, and presenting resemblances to the White Limestone. The same beds are exposed to a depth of 10 feet, further on to the south-east of Baunton Downs Farm, and clay-bands a few inches thick appear among the stone-beds.

The strata are best shown in a long cutting to the north-east of Baunton Downs, and there we appear to have evidence of the overlap of the Forest Marble on to the White Limestone division of the Great Oolite. (See Fig. 85.)

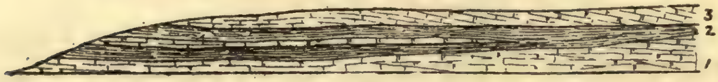
At the southern end of the cutting the upper beds of the Great Oolite showed an alternation of marls and oolites having a banded appearance. These are the beds exposed in the Wiggold Copse quarry. They are overlaid by obliquely bedded oolitic limestones with ochreous clay-galls, belonging to the Forest Marble. About midway in the cutting the section was as follows :—

| | | | Ft. | In. |
|---|---|---|---|---|
| Forest Marble - | | Hard current-bedded oolitic limestone with clay-galls - - 4 0 to | 6 | 0 |
| Great Oolite. | Kemble Beds. | Marly clay - - - 1 0 to | 1 | 9 |
| | | Oolite - - - - 1 1 to | 2 | 6 |
| | | Clay with thin bands of limestone in places - - - - - | 1 | 0 |
| | White Limestone. | Shelly, and pale earthy limestone with scattered oolitic grains - 3 0 to | 12 | 0 |

FIG. 85.

*Section north-east of Baunton Downs, between Cirencester and Chedworth, on the Midland and South-Western Junction Railway*

S. N.




| | | |
|---|---|---|
| 3. Hard flaggy and current-bedded oolitic limestone with clay-galls 4 to 6 feet. | | Forest Marble. |
| 2. Marly clay with impersistent band of oolite | 1 to 6 feet. | Great Oolite. |
| 1. White limestones, oolites, and marls | 3 to 6 feet. | |

The band of oolite in the Kemble Beds, tapers away towards the north; the marly clays also become attenuated, so that the Forest Marble is separated from the White Limestone by a band of clay 1 foot or 18 inches thick. The top bed of White Limestone is here a hard pale oolitic and shelly limestone, with cavities like the Dagham stone, and the beds beneath comprise alternations of more or less oolitic limestone and thin marls.

The Cutting, north of the Foss Way, showed hard white and shelly limestone, covered by greenish marl and dark shelly oolite in rough irregular beds. These upper beds probably belong to the Forest Marble. Further north there are several deep cuttings, one near the Barn, showing 6 feet of marls and limestones in alternate bands, overlying a hard pale limestone with scattered oolitic grains, and with cavities like the Dagham stone.

Northwards of the Barn, from 15 to 18 feet of more or less oolitic limestone was exposed, with occasional marl bands—the stone being employed for railway-works. At the time of my visit these cuttings were not completed, but they have since been described by Prof. Allen Harker.* In the cutting east of Allgrove (Aldgrove) Barn he notes two beds of limestone perforated by irregular cavities, and separated by a bed of "grey compact freestone" 4 feet thick. From another and lower bed of grey compact freestone, he obtained a number of spheroidal masses about the size of a cricket ball, made up of alternate concentric bands of pink and yellowish white limestone. In these masses he has found traces of *Solenopora* (or a closely allied Hydroid Zoophyte), a genus hitherto found only in Lower Silurian or Ordovician strata. This fossil was recognized by Prof. H. A. Nicholson. The mass of these beds I take to belong to the White Limestone division, although the rubbly oolites and marls, seen in places on top of the more compact and partially oolitic limestones, may belong to the Kemble Beds.

A cutting, which I noted, north-west of Long Furlong, and south-east of Chedworth, showed the following section:—

* Proc. Cotteswold Club, vol. x. p. 82.

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite (Upper Division). | Rubbly bands of shelly oolite - - | 4 | 0 |
| | Marly layer (impersistent) - - | 1 | 0 |
| | Even beds of more or less oolitic limestone—the top layer a hard white and pinkish limestone with scattered grains of oolite - - - - - | 6 | 6 |
| | Pale limestones, as above, with ferruginous cavities like Dagham stone in top layer - - - - - | 4 | 6 |

The pink limestone here is of the nature of that discovered by Prof. Harker, for I had brought away a specimen of it, which closely resembles the rock he kindly sent to me.

Further on to the south of Chedworth, the lower beds of Great Oolite were exposed as follows :—

| | | | Ft. | In. |
|---|---|---|---|---|
| Great Oolite. | Upper Division. | Rubble of white oolite and marl. | | |
| | Lower Division (with Stonesfield Beds). | Hard fine-grained and false-bedded oolite (freestone) - - - 4 0 to | 5 | 0 |
| | | Blue and brown clay with sandy layers and *Ostrea*. | | |
| | | Impersistent bands of hard partially oolitic sandy limestone, fissile and false-bedded in places; and impure fuller's earth. | | |
| Fullonian - | | Clays. | | |

On the south side of the Chedworth tunnel, the flaggy beds appear somewhat concretionary, and the Fullonian clays immediately below, yielded *Ostrea acuminata*. (See Fig. 42, p. 128.)

The Great Oolite and Forest Marble were shown in a quarry by the high-road, west of Coln St. Denis, where the section was as follows :—

| | | Ft. | In. |
|---|---|---|---|
| Forest Marble. | Oolitic and shelly limestone with ochreous galls and fine oolite - | 2 | 0 |
| | Thin-bedded oolite and laminated marly clay - - - - - | 1 | 0 |
| Great Oolite (Upper Division). | Compact brown limestone with occasional oolitic grains and dendritic markings - - - - | 2 | 0 |
| | Hard brown limestones - - - | 1 | 6 |

Prof. Hull reckoned the thickness of the upper division of the Great Oolite at Coln St. Denis to be as much as 145 feet, and that of the lower 45 feet;* but the evidence since afforded by the boring at Burford, and by railway-cuttings in Gloucestershire, would lead to the conclusion that the total thickness of the formation does not exceed 120 feet.

The cuttings on the Banbury and Cheltenham railway, between Andoversford and Bourton-on-the-Water have thrown much light on the nature of the Great Oolite in that region. (See Fig. 43, p. 131.) The beds become much more argillaceous, especially in the lower division, than they are near Cirencester and Tetbury on

* Explan. Hor. Soc., Sheet 59, p. 3.

the western side of the Cotteswold Hills: indeed in places we find that the formation comprises in bulk about one-third of marl and clay to two-thirds of limestone.

At the western end of the railway-cutting north of Hampen, the Fullonian beds (Fuller's Earth) are exposed, while the overlying strata of Great Oolite are much obscured. East of the bridge also we find beds of Great Oolite limestone much tumbled and obscured, but further on there is a clear sequence of beds from the Fuller's Earth, through the Stonesfield Slate Series and Great Oolite. The general section which I measured in detail is as follows:--

| | | | Ft. | In. | |
|---|---|---|---|---|---|
| Great Oolite. | Upper Division. | White limestones - - | 35 | 10 | 115 5 |
| | | Marly beds - - - | 28 | 3 | |
| | Lower Division. | Freestone (=Taynton stone) about | 30 | 0 | |
| | | Stonesfield Slate Series - | 21 | 4 | |
| Fullonian - - - | | Fuller's Earth (25 to 30 feet thick | 10 | 0 seen. | |

Immediately above the slaty beds in a cutting near Notgrove, Mr. E. A. Walford noted a Crinoid-bed with *Millericrinus Pratti* This bed is a brown shelly marl, with *Ostrea*, Cyprides, and Foraminifera, and with rolled and bored stones. In the overlying freestones he obtained *Ceritella, Cerithium, Cylindrites, Nerinæa, Corbula, Tancredia*, &c.*

Mr. R. F. Tomes has noted the occurrence of a thin Coral-bed, with *Isastræa, Thamnastræa,* and *Microsolena,* at Aylworth, on the railway between Bourton-on-the-Water and Cheltenham.† This layer occurs immediately above the Stonesfield Slate.

The details shown in the section of the Great Oolite north of Hampen (C.) were as follows: the numbers attached to the subdivisions are those given in the section Fig. 43, p. 131:—

| | | Ft. | In. |
|---|---|---|---|
| White Limestone (15). | White limestones; rubbly beds, with Gasteropods, *Ostrea, Terebratula maxillata* (smooth forms), and Corals | 6 | 0 |
| | Harder beds of white or creamy limestone, with scattered oolitic grains: *Lima cardiiformis* - - - | 5 | 0 |
| | Alternations of pale grey marly limestones, and somewhat fissile marls - | 5 | 0 |
| | Pale earthy and finely oolitic limestone: bored - - - - - | 1 | 2 |
| | Fissile, rubbly, and marly limestones - | 9 | 6 |
| | Hard fine-grained white oolitic limestone: *Lucina* - - - | 2 | 2 |
| | Fissile brown oolite - - - | 1 | 0 |
| | Hard and compact white oolitic limestone - - - - - | 6 | 0 |
| | Bluish-grey and yellow oolitic marls, with *Ostrea;* and with two bands of grey shelly oolitic limestone: with lignite in the lower band - - | 8 | 0 |

* Proc. Warwicksh. Nat. Club, March 14, 1882; and P. H. Carpenter, Quart. Journ. Geol. Soc., vol. xxxviii. p. 29.

† Quart. Journ. Geol. Soc., vol. xxxix. p. 170.

| | | Ft. | In. |
|---|---|---|---|
| Marly Beds (14). | Grey shaly and marly oolitic beds: *Ostrea Sowerbyi* - - - - | 3 | 0 |
| | Grey earthy and oolitic limestone: Gasteropod-bed, with Gasteropods and Lamellibranchs - - - | 1 | 0 |
| | Grey earthy limestones more or less oolitic: many Lamellibranchs - | 3 | 0 |
| | Yellow and grey rubbly oolitic bed, with *Trigonia costata ?*, &c. - - | 1 | 3 |
| | Bluish-grey oolitic marl, indurated in places: *Ostrea Sowerbyi* abundant, and forms like *O. acuminata* - | 2 | 0 |
| | Fissile and rubbly bluish-grey and yellow oolite, with marly and shaly bands; and curious tracks of animals, like those of the Forest Marble: *Modiola imbricata*, *Trigonia*, &c. These beds merge into those below - | 10 | 0 |
| Freestone (13). | Pale fine-grained oolite, false-bedded, with shelly and marly layers here and there, coarser oolite in places, and occasionally fissile beds (=Taynton stone) - - - about | 30 | 0 |
| Stonesfield Beds (12). | Yellowish marl, passing down into brown and blue shaly beds; with indurated and more or less concretionary layers of calcareous and micaceous sandstone (slaty beds): of which there are two prominent though impersistent bands. Buff and grey sands occur irregularly, and tracks of animals may be observed on some of the thin flaggy layers. The slaty beds are more pronounced further east - - | 10 | 0 |
| | Bluish marly shales, with micaceous gritty layers: slaty at base - - | 9 | 0 |
| | Shaly beds - - - - | 2 | 0 |
| | Band of bluish-grey obscurely oolitic and shelly limestone - - - | 0 | 4 |
| Fullonian (Fuller's Earth) (11). | Bluish-grey marly shales, with bands of hard pale marl, seen to depth of - | 10 | 0 |

A better section (D.) of the lower beds of the Great Oolite was shown, west of the railway-bridge, in the cutting north-west of Salperton. The Stonesfield Beds comprise layers of a very inconstant and variable character, the details being different on the eastern side of the bridge. The section was as follows (see Fig. 43, p. 131):—

| | | Ft. | In. |
|---|---|---|---|
| Freestone (13). | Irregular flaggy, false-bedded, and coarse-grained white and brown shelly oolites; with marly layers here and there (becoming thicker in places towards the base) - - | 12 | 0 |
| | Shaly and marly beds, with indurated sandy and calcareous bands - - | 3 | 0 |
| | Fissile grey and yellow calcareous sandstone, more or less concretionary, | | |

| | | Ft. | In. |
|---|---|---|---|
| Stonesfield Beds (12). | with pot-lid structure, slightly oolitic in places, and with here and there lenticular masses of soft sand 2 0 to | 3 | 0 |
| | Irregular bed of grey sand - - - | 3 | 0 |
| | Yellow and white micaceous sandy shales, and fissile sandy beds - | 3 | 0 |
| | Shelly and oolitic limestone, with *Ostrea acuminata;* passing down into fissile micaceous and calcareous sandstone with *Gervillia, Ostrea acuminata, O. Sowerbyi, Placunopsis socialis, Pleuromya, Trigonia impressa* (= Slaty beds of Sevenhampton, &c.) - - | 3 | 6 |
| Fullonian (Fuller's Earth) (11). | Yellowish-grey marl and micaceous shales, with ferruginous sandy and ochreous layers near top. | | |

Again towards Aylworth, in the second cutting (H.) east of Notgrove Station, and in the eastern end of the first cutting (G.), there were sections showing the lower beds of Great Oolite and Stonesfield Beds, and at one point the whole of the Fuller's Earth (about 25 or 30 feet) down to the Inferior Oolite. Still further east other sections were to be seen, the most important being that south-east of Roundhill Farm (N.), where the whole of the Fuller's Earth was again shown.

Stonesfield Slate has been extensively worked on Sevenhampton Common, north-west of Sevenhampton, principally to the east of Puckham Woods. The beds exposed in 1887, were as follows:—

| | | | Ft. | In. |
|---|---|---|---|---|
| | | Rubble and soil - - - - - | 1 | 0 |
| Great Oolite. | Upper Division. | Brown clay - - - - - | 1 | 3 |
| | | Rubbly oolitic marl, the surface of which is piped: *Ostrea acuminata* - - | 3 | 6 |
| | | Compact pinkish concretionary lime-rock (see p. 290) - - - | 1 | 0 |
| | Lower Division. | Fissile and false-bedded shelly oolite; a variable series of stone-beds, more or less oolitic, much coated in places with carbonate of lime derived from the rubbly marl above. [Ragstone] about | 14 | 0 |

The "Slates" were formerly worked below these beds, and are not now exposed, the workings having been given up about 40 years ago on account of the thickness of overlying material—the "slates" readily obtained having been exhausted.

Some details of the old quarries were published by Murchison, J. Buckman, and Strickland. Their records agree generally with the above account, and further note the occurrence of the Stonesfield Slate (4 feet thick) immediately beneath the Ragstone; while at the bottom of all, yellow clay (Fuller's Earth) was proved.* *Lima cardiiformis, Pecten,* and *Ammonites* were noted in the Ragstone by these authorities: the last-named form (rare indeed in this series) was however obtained by myself at Bisley. Plant-remains have also been recorded.†

* Murchison, Geol. Cheltenham, ed. 2, 1845, p. 18; see also Lonsdale, Proc. Geol. Soc. vol. i. p. 413; and Hull, Explan. Hor. Sec. Sheet 59, p. 4.

† See Brodie and Buckman, Quart. Journ. Geol. Soc., vol. i. p. 223; Hull, Geol. Cheltenham, p. 54; Phillips, Geol. Oxford, p. 168.

Slates were worked (in 1887) about one-third of a mile south-west of Whitall Farm, and the following section was exposed :—

| | | Ft. | In. |
|---|---|---|---|
| | Brown clay with weathered fragments of limestone - - - - | 1 | 6 |
| Stonesfield Beds. | Fissile blue limestone - - - | 0 | 4 |
| | Fissile sandy limestone or calcareous sandstone; 3 or 4 inches at base solid "Slate," the upper beds rotten - | 1 | 8 |
| | Greenish-yellow marl, with shaly bands | 1 | 0 |
| | Fetid greyish-brown sandy limestone, with *Ostrea* and Gasteropods. | | |

The "slates" here were greyish-brown and not distinctly oolitic. *Ostrea*, *Placunopsis socialis*, and *Trigonia impressa*, occur on the surfaces of the slaty beds.

The variable nature of the Stonesfield Slate Series, in this and other districts, is a characteristic feature—for the beds become of economic value at somewhat different horizons here and there, even in the same quarry.

At Kyneton Thorns between Condicote and Naunton, there were formerly many quarries, and it is recorded that at one of these, no less than 120,000 roofing slates were made in the course of a season. The stone was raised about December and spread over the surface of the ground, and when "weathered" (or frosted) the blocks were capable of being split into thin layers.* The following section was shown in one of the quarries† :—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite (Lower Division). | Rubble, &c. - - 3 0 or | 4 | 0 |
| | Ragstone - - - - | 13 | 0 |
| | Stonesfield Slate - - - | 5 | 0 |

Among the fossils, a new species of "*Asterias*" or *Astropecten cotteswoldiæ*,‡ Belemnites, Fish-remains, a tooth of *Megalosaurus*, and Plant-remains were obtained.

Slates have been quarried over a large area north and north-east of Naunton. The following section at Summer Hill, Eyeford, to the north-east of Naunton, was recorded by Prof. Hull :—

| | | Ft. | In. |
|---|---|---|---|
| Stonesfield Series. | Brown sandy slate - - - | 0 | 6 |
| | Thin-bedded limestone - - - | 1 | 4 |
| | Brown fissile sandstone - - - | 1 | 0 |
| | Thin-bedded limestone - - - | 1 | 4 |
| | Brown fine-grained sandstone, splitting into flags and slates - - - | 2 | 0 |
| | Thin irregular limestone - - | 0 | 6 |
| | Brown finely-grained sandstone, splitting into slates - - - | 1 | 0 |
| Fullonian. | Clay (probably Fuller's Earth). | | |

* See Murchison, Geol. Cheltenham, ed. 2, p. 22.

† Brodie and Buckman, Quart. Journ. Geol. Soc., vol. i. p. 223.

‡ Adopted for the "Great Seal" of the Cotteswold Club.

Many fossils from the beds in this neighbourhood were collected by the Rev. E. Witts, of Slaughter.*

Prof. Hull mentions that the lower beds near Aston Blank, have yielded good "slates" and flagstones, but the higher beds become oolitic; and such is also the case at Salperton and Hawling.† Slaty beds have also been obtained at Pewsdown, west of Hasleton, and to the north of Chedworth.

The following fossils have been recorded from the Stonesfield Slate of Sevenhampton (S.), Kyneton (K.), Salperton (Sp.), Naunton, and Eyeford (E.):—

| | |
|---|---|
| Rhamphocephalus Prestwichi‡ | K. |
| Megalosaurus | E. K. |
| Teleosaurus | E. |
| Hybodus | E. |
| Ischyodus emarginatus. | E. |
| Mesodon (Pycnodus) | E. |
| Belemnites bessinus | E. K. |
| Nerita | E. |
| Gervillia | Sp. |
| Ostrea acuminata | S. Sp. |
| —— Sowerbyi | E. Sp. |
| Placunopsis socialis | S. Sp. |
| Pleuromya | Sp. |
| Trigonia impressa | E. |
| Pachynereis corrugatus§ | E. |
| Astropecten cotteswoldiæ | K. |

At Wagboro Bush, near Stow-on-the-Wold, some Mollusca were obtained from the Great Oolite by Messrs. Brodie and Buckman; and the species were considered to indicate an horizon corresponding with the beds at Ancliff, near Bradford-on-Avon.‖ (See p. 261.) They include *Cylindrites* (*Actæon*) *cuspidatus*, *Neridomus* (*Nerita*) *minutus*, *Corbula*, and *Leda* (*Nucula*) *mucronata*.

Prof. Hull notes that at Oddington, Icombe, and Stow, the Great Oolite consists of compact oolite, showing much false-bedding, and splitting up into coarse slates and flags. He further remarks that "On the east side of Stow a bed of conglomerate may be observed in a quarry. The pebbles, which are well rounded, and not larger than a pigeon's egg, consist of white limestone, unfossiliferous and slightly oolitic."¶ This bed is probably the same as that noted further east, marking the base of the Great Oolite, where it rests on the Chipping Norton Limestone.

*Fairford, Northleach, Burford, and Wychwood Forest.*

An interesting fossil-bed in the Great Oolite is the Fairford Coral-Bed. The occurrence of this bed was noticed by John Woodward in 1728, for he then recorded "Branched coralloid

* See also Proc. Cotteswold Club, vol. x. p. 5.
† Hull, Geol. Cheltenham, p. 55, 60.
‡ Seeley, Quart. Journ. Geol. Soc., vol. xxxvi. p. 27.
§ Etheridge, Proc. Cotteswold Club, vol. ix. p. 2.
‖ Brodie and Buckman, Quart. Journ. Geol. Soc., vol. i. p. 224.
¶ Geol. Cheltenham, p. 60.

Bodies, from a Quarry in Fairford-Field, North-east of the Town, Gloucestershire."*

It is remarkable that here as well as in other localities of the Great Oolite, and in the famous Corallian locality of Steeple Ashton in Wiltshire, the Corals have been obtained from the ploughed fields. The explanation may be that while no stone worth quarrying is to be obtained, yet the number of Corals has naturally attracted attention. Mr. R. F. Tomes mentions that a large number of Corals were collected near Fairford by Miss Slatter, "whose attention was first directed to them by the appearance of numerous corals scattered over the surface of a ploughed field. Subsequently a great many unworn and beautiful examples were obtained, from excavations made for the purpose of collecting specimens."†

The position of the Coral-Bed was thus stated by Dr. Lycett: "At the base of the Cornbrash, near Fairford, is a stratum of marl which has also yielded a profusion of Corals in a fine state of preservation"; and he adds (in a footnote) "The position of this coralline stratum has been determined by my friend Mr. [John] Jones, of Gloucester."‡ Writing in 1858, the Rev. P. B. Brodie referred to the bed as probably connected with the Forest Marble or perhaps the Cornbrash, but he added "the locality has been kept secret, and few collectors are acquainted with it."§

In 1888 Mr. T. J. Slatter kindly directed me to the famed spot. He described the bed as a lenticular deposit, almost as white as chalk-marl; and varying in thickness from a few inches to about 2 feet. He regards it as the base of the Forest Marble and as probably on the horizon of the Bradford Clay: and therefore somewhat later in date than the Coral-bed of Caps Lodge, near Burford. I regard it as belonging to the Great Oolite. The Fairford Corals include the following species:—

Bathycœnia Slatteri.
Cryptocœnia microphylla.
—— tuberosa.
Isastræa explanulata.
—— gibbosa.
—— limitata.
Microsolena excelsa.
Montlivaltia fairfordensis.
Stylina solida.
Thamnastræa Lyelli.
—— Waltoni.
Thecosmilia Slatteri.

*Anabacia complanata* is so rare that only one example from this locality had come under the notice of Mr. Tomes.

The Fairford Corals occur in a ploughed field about ¼ mile east of Honeycomb Leaze, and a little west of an old Barn. A shallow pit (now filled up) at one time exposed the Coral-bed, but most of the specimens have been obtained from the soil ploughed up in the field. Judging by the Geological Survey Map (published in 1857) the bed occurs at about the junction of the Cornbrash and Forest Marble, but this view is not confirmed by an examination of the ground. The Cornbrash is exposed to the south, about

* Nat. Hist. Foss. England, Tome ii. p. 75.
† Quart. Journ. Geol. Soc., vol. xxxix. p. 170.
‡ The Cotteswold Hills, 1857, p. 54.
§ Geologist, vol. i. p. 43.

¼ mile east of Blackford Barn, and north of the road; and it is again exposed on the east, by the bend of the road or field-track near the main road between Quenington and Milton End. Clayey ground immediately beneath the Cornbrash indicates the presence of the Forest Marble clays. The ground immediately around the Barn yields slabs of Forest Marble, and not Cornbrash; but I was informed that trial-holes had shown there was no good stone there, a fact that receives some confirmation from the thickening of the Forest Marble clays towards the west, in the quarry south of Pilham Lodge. The northern slope of the ploughed field in which we find the Coral-bed, yields fragments of rock like Great Oolite; and I obtained specimens of *Isastræa limitata* and *Thamnastræa.*

The most important evidence of the age of the Coral-bed is obtained from the quarry immediately west of Honeycomb Leaze, where on top of the Great Oolite, and beneath the Forest Marble, there is a rubbly bed, that yields Corals. The following is the section at Honeycomb Leaze, about 2 miles north-west of Fairford:—

| | | Ft. | In. |
|---|---|---|---|
| | Brown loamy soil, with bits of limestone | 1 | 0 |
| Forest Marble - | Flaggy oolite with bluish tinges - | 1 | 8 |
| Great Oolite (Upper Division). | Rubbly bed with *Ostrea*, *Rhynchonella*, and Corals, *Stylina*, &c. | | |
| | Pale oolites, much split up: some beds very fine-grained - - 4 6 to | 5 | 6 |

In addition to *Stylina* there were also calcitic Corals like those found in the field where the Fairford Corals have been obtained; but most of my specimens were poorly preserved.

The top beds of flaggy oolite are seen again in the road south of Honeycomb Leaze. A quarry north of Honeycomb Leaze copse showed the following beds:—

| | | Ft. | In. |
|---|---|---|---|
| Forest Marble - | Blue shelly limestone like Forest Marble. *Pecten annulatus* - - - | 0 | 6 |
| Great Oolite (Upper Division). | Oyster-bed, with *Ostrea Sowerbyi*, *Lima cardiiformis*, *Rhynchonella*, *Terebratula maxillata*, masses of calc-spar (? calcitic corals) - - | 1 | 0 |
| | Rubbly beds of oolitic and shelly limestone - - - - - -<br>Hard white oolitic limestone and compact limestone with scattered oolitic grains - - - - - -<br>Fine and pale oolite like Minchinhampton Stone, passing down into tough shelly oolitic limestone - | 3 | 0 |
| | Grey sandy and oolitic rock (like Stonesfield Series) - - - | 1 | 6 |

A third quarry, to the W.N.W. of the last, and on the north side of the road, showed about 5 feet of grey sandy and feebly oolitic limestones, overlaid by oolitic beds with lignite. The surface-beds were much disturbed, presenting appearances like "Trail." The stone itself reminded me of the Great Oolite basement-beds (Stonesfield Series) of the neighbourhood of Bisley.

Between Northleach and Shipton-under-Wychwood the Great Oolite has yielded important beds of freestone in its lower division. The general sequence of the beds is difficult to determine in many places, but it is as follows :—

| | | | Ft. | In. |
|---|---|---|---|---|
| Great Oolite. | White Limestone. | White limestones, shelly and more or less oolitic, with occasional beds of marl and brown limestone; with two or more fossil-beds with Corals, Gasteropods, *Lima cardiiformis*, *Terebratula maxillata*, &c. - - | 12 | 0 |
| | Marly Beds | Marls with bands of oolite and clays; with *Ostrea*, *T. maxillata*, *Serpula*, &c. - - - - | 18 0 to 25 | 0 |
| | Freestone | Pale flaggy and shelly oolite, and current-bedded white oolitic limestone and marl - - Obliquely bedded oolite (freestone); coarse and shelly in places, with *Clypeus Mülleri*, *Isastræa*, &c. - - - | 12 0 to 20 | 0 |
| | Stonesfield Beds. | Fissile sandy limestone and marl about | 4 | 0 |

The general section compares well with that seen in the Hampen Cutting (p. 292), although there is a considerable diminution in the thickness of the White Limestone and of the Freestone. Near Northleach many Corals have been obtained from the ploughed fields.

It is not improbable that in this neighbourhood the Forest Marble rests on different portions of the Great Oolite. The quarry at Hensgrove in Wychwood Forest, showed (at the base of the Forest Marble) an irregular white oolitic and marly limestone with pebbly portions, that appears to be a *remanié* bed of Great Oolite; and a section west of Burford noted by Prof. Hull, affords similar evidence, with also waterworn fossils.*

Prof. Hull has stated that in the neighbourhood of Northleach, "the greater portion of the Stonesfield slate, or lower zone, passes into an oolitic freestone."† That the series is to a certain extent an interchangeable one, is borne out by the evidence afforded by the railway-cuttings between Chipping Norton and Hook Norton, where beds resembling Stonesfield Slate overlie beds of oolite; but over great part of the Gloucestershire area, beds of a slaty character occur at the base of the freestone.

Prof. Hull notes a quarry east of Leygore Farm, north-east of Northleach, which showed slaty beds at the base of the Great Oolite, as follows‡ :—

* Geol. Cheltenham, p. 63.
† *Ibid.*, p. 55.
‡ *Ibid.*, p. 56.

| | | | Ft. | In. |
|---|---|---|---|---|
| Great Oolite. | Freestone | Coarse shelly oolite, obliquely laminated - - - - - | 2 | 2 |
| | | White oolitic marl - - - | 0 | 4 |
| | | White argillaceous oölite - - | 0 | 6 |
| | Stonesfield Beds. | Grey calcareous slaty sandstone - | 1 | 0 |
| | | Brown and white sandy marl - - | 0 | 5 |
| | | Grey sandy limestone - - - | 2 | 0 |

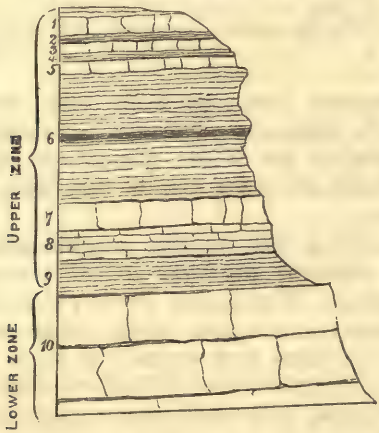
South-east of Sherborne, and north of the fifth milestone on the high road between Northleach and Burford, the following beds were shown :—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite (Lower Division). | Coarse flaggy and shelly oolite, with marly layers, slightly false-bedded - | 8 | 0 |
| | Obliquely bedded freestone, coarse and fine oolite in pale-buff and brown bands; seen to a depth of - - - | 6 | 0 |

*Placunopsis socialis* was the only fossil which I obtained here. A quarry in Sherborne Park was described by Prof. Hull.*

Fig. 86.

*Section at the Windrush Quarries, Gloucestershire.* (Prof. E. Hull.)




| | | Ft. | In. |
|---|---|---|---|
| Great Oolite - | 1. Loose white argillaceous limestone | 1 | 6 |
| | 2. Parting of marly shale - - | 0 | 6 |
| | 3. Thin-bedded brown calcareous sandstone - - - - | 0 | 8 |
| | 4. Yellow slaty marl - - - | 0 | 8 |
| | 5. Brown calcareous sandstone, very fossiliferous - - - | 1 | 0 |
| | 6. Yellow, brown, and white sandy marl, with a parting of stone - | 10 | 0 |
| | 7. Hard sandy limestone, slightly oolitic - - - | 2 | 6 |
| | 8. Soft sandy oolite - - - | 2 | 6 |
| | 9. Marls and shales - - - | 2 | 6 |
| | 10. Fine white oolite (freestone) coming out in large blocks - - | 7 | 0 |

* Geol. Cheltenham, p. 57.

North of Barrington Park a quarry showed about 7 feet of false-bedded freestone, somewhat shattered in places, with softer marly beds on top. Very fine and coarse white oolitic grains run in irregular bands through the stone. Good squared building-blocks are here obtained. The only fossils I found were *Ceromya striata* (?), *Lima gibbosa*, and *Rhynchonella concinna*.

The once famous Windrush quarry is situated to the south-west of the village, and the stone has been obtained by mining. The distance from the railway, has no doubt affected the working of the stone, for comparatively little was being obtained at the period of my visit. The following section of the beds was given by Lonsdale* :—

| | | | Ft. | In. |
|---|---|---|---|---|
| Great Oolite. | Upper Division. | Rubbly limestone | 1 | 0 |
| | | Brownish marlstone | 6 | 0 |
| | | Rubbly limestone | 4 | 0 |
| | | Pale sandy marl | 3 | 0 |
| | | Rubbly marlstone | 0 | 6 |
| | | Light-coloured clay | 0 | 6 |
| | Lower Division. | Rag and freestone | 15 | 0 |
| | | Sandy laminated grit (Stonesfield Beds). | | |

The above section differs a good deal in detail from the general one given by Prof. Hull (Fig. 86). The thickness of the workable stone at Windrush does not exceed 11 feet: but there is an alternation of shelly rock (Rag) and freestone. The freestone is of good quality. The White Limestone has been quarried on the south side of the high road, near the old freestone quarry.

At Little Barrington, half a mile east of the New Inn, south-east of the village, the following section was seen :—

| | | Ft. | In. |
|---|---|---|---|
| | Brown brashy clay-soil. | | |
| Great Oolite. | Rubbly oolite | 1 | 6 |
| | Yellowish marly clay | 0 | 6 |
| | White oolitic limestone, coarse and fine-grained. Shelly oolite in 4 layers | 6 | 0 |
| | Brown oolite, closely-packed grains | 1 | 0 |

Faulted against these beds were the following strata :—

| | | Ft. | In. |
|---|---|---|---|
| Forest Marble. | Reddish brown clay - about | 3 | 0 |
| | Brown, pale grey and bluish-grey fissile shelly oolite, with clay-galls: thin-bedded and false-bedded with layers of marly clay; *Ostrea*, &c. | 12 | 0 |

The Great Oolite above described, presents some characters akin to the White Limestone division: possibly there may be a blending of the two divisions, as I have noted to be the case at Hampen, and some of the beds in that case may belong to the Marly beds of the Upper Division. (See p. 293.)

On the Oxford and Burford road, about a mile east of Burford, the following section was to be seen :—

* Proc. Geol. Soc. vol. i. p. 415; see also Hull, Geol. Cheltenham, p. 57.

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite (Upper Division). | Rubble - - - - - - | 3 | 0 |
| | Thin beds of white limestone more or less oolitic - - - - - | 1 | 0 |
| | Rubbly marl and limestone - - | 1 | 2 |
| | Hard white shelly limestone - - | 0 | 4 |
| | White limestone - - - | 1 | 6 |
| | Ditto (browner at base): full of univalves, *Natica*, &c. - - - | 1 | 6 |
| | Pale brown limestone, very oolitic - | 1 | 3 |

A quarry to the north-west of this, "at the meeting of the Oxford and Shilton Roads above Burford," yielded a number of fossils, recorded by Prof. Hull, including *Natica*, *Nerinæa*, *Ceromya concentrica*, *Corbis*, *Isocardia*, *Lucina*, *Myacites*, *Pecten annulatus*, *Pholadomya Heraulti*, *Thracia*, *Trigonia*, *Terebratula maxillata* (abundant), *Echinobrissus*, &c.*

A little east of Westwell, near Burford, the following section was exposed: †—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite (Upper Division). | Rubble and grey marly clay, more or less disturbed. | | |
| | White limestone, very finely oolitic in places: Corals - - - - | 5 | 0 |

North-east of Westwell and south of Mount Pleasant, the following section showed beds on a lower horizon:—

| | | | Ft. | In. |
|---|---|---|---|---|
| Great Oolite. | Upper Division—Marly Beds. | Dark brown or black clay - } Rubble of marly oolitic limestone and marl - } | 2 0 to 3 | 0 |
| | | Yellowish marly clay, full of oysters - } Black clay, with large flattened specimens of *Terebratula maxillata* - - } Marly clay, full of oysters - - } | 2 | 0 |
| | | Bluish-grey limestone, very shelly and slightly oolitic, with *T. maxillata* (flattened) - - - - | 0 | 10 |
| | | Impure marly clay with *T. maxillata*, *Serpula*, and many oysters - - | 1 | 0 |
| | | Pink and grey current-bedded oolitic marly limestone, with shelly layers at base - - - - - - | 1 | 1 |
| | Lower Division—Freestone. | Pale shelly oolite - - - - | 0 | 9 |
| | | Tough, pale, and somewhat flaggy oolite | 1 | 6 |

It will be interesting, as well as important, to give the full details of the strata passed through in the Burford boring, for reference has already been made to the subject in the volume dealing with the Lias (p. 221). The grouping of the beds differs from that published elsewhere; but it is possible that too great a thickness is assigned to the Inferior Oolite. There may, as at Swinbrook, be no partings of clay between Great and Inferior Oolite. The boring was commenced about 350 feet above sea-level.

* Geol. Cheltenham, pp. 63, 67.

† See also section by Hull, Geol. Cheltenham, p. 64.

*Details of Strata passed through in a boring at Burford Signett, south of Burford.*

[Boring north of stream; west of the plantation to the west of Sturt Farm; and east of the bend in the road south of Signett.] 1875–77.

| | | Thickness. Ft. | In. | Depth. Ft. | In. |
|---|---|---|---|---|---|
| Great Oolite. 62 ft. 6 in. | Surface soil and rubble | 9 | 10 | — | |
| | Yellow and blue clay | 3 | 9 | 13 | 7 |
| | Blue clay with bands of yellow stone | 13 | 1 | 26 | 8 |
| | Blue clay and pebbles | 2 | 0 | 28 | 8 |
| | Blue clay | 9 | 4 | 38 | 0 |
| | White Lias | 2 | 6 | 40 | 6 |
| | Blue Lias | 1 | 0 | 41 | 6 |
| | White Lias | 8 | 8 | 50 | 2 |
| | Yellow freestone | 6 | 4 | 56 | 6 |
| | Lias | 4 | 0 | 60 | 6 |
| | Freestone | 0 | 6 | 61 | 0 |
| | Lias | 1 | 6 | 62 | 6 |
| Inferior Oolite? 27 ft. 0 in. | Limestone | 27 | 8 | 90 | 2 |
| Upper Lias. 82 ft. 2. in. | Blue clay | 33 | 4 | 123 | 6 |
| | Do. with fossils and metal | 25 | 1 | 148 | 7 |
| | Clay without fossils | 13 | 2 | 161 | 9 |
| | Clay with crystals [? selenite] | 9 | 11 | 171 | 8 |
| Middle Lias. 98 ft. 1 in. | Soft green lias with fossils and shells, large Belemnite | 3 | 0 | 174 | 8 |
| | Lias with fossils | 0 | 6 | 175 | 2 |
| | Clay }<br>Clay with bed of stone } | 56 | 10 | 232 | 0 |
| | Clay with two bands of irony sandstone | 37 | 9 | 269 | 9 |
| Lower Lias. 447 ft. 4 in. | Clay with shells. At 280 feet, *Ammonites capricornus*, *Cardium truncatum*, *Avicula*, *Pecten*, *&c.* | 30 | 9 | 300 | 6 |
| | Clay with band of shelly limestone | 18 | 2 | 318 | 8 |
| | Harder clay | 30 | 8 | 349 | 4 |
| | Stiff clay with metal }<br>Harder clay } | 9 | 0 | 358 | 4 |
| | Clay with shells and metal | 8 | 5 | 366 | 9 |
| | Clay with shells, *Cardinia attenuata* at 373 | 12 | 10 | 379 | 7 |
| | Clay with two stone-beds | 20 | 7 | 400 | 2 |
| | Stone and clay with fossils, *Gryphœa*, *Hippopodium ponderosum*, *Lima pectinoides* | 6 | 10 | 407 | 0 |
| | Clay with pebbles [? nodules] *Cardinia ovalis* | 5 | 7 | 412 | 7 |
| | Clay with band of septarian limestone, *Lima pectinoides* | 17 | 2 | 429 | 9 |
| | Very soft clay, *Pentacrinus*, &c. | 10 | 1 | 439 | 10 |
| | Clay | 35 | 2 | 475 | 0 |
| | Clay with occasional bands of limestone | 227 | 4 | 702 | 4 |
| | Jointed limestone | 6 | 9 | 708 | 4 |
| | Clay | 2 | 9 | 711 | 1 |
| | Limestone | 4 | 0 | 715 | 1 |
| | Shale | 2 | 0 | 717 | 1 |

| | | Thickness. Ft. | In. | Depth. Ft. | In. |
|---|---|---|---|---|---|
| Rhætic Beds and New Red Sandstone Series. | Soft shale and clay | 32 | 0 | 749 | 1 |
| | Black shale | 1 | 0 | 750 | 1 |
| | Green Marl | 6 | 0 | 756 | 1 |
| | Sandstone | 1 | 0 | 757 | 1 |
| | Green gritty marl | 50 | 9 | 807 | 10 |
| | Limestone | 0 | 3 | 808 | 1 |
| | Variegated marls with gypsum | 375 | 11 | 1184 | 0 |
| Coal-measures | | 226 | 0 | 1410 | 0 |

The details of the Burford section are given partly from a record in the Museum of Practical Geology, communicated by Lieut.-Col. F. Bolton, R.E., and partly from another MS. The fossils were identified by Mr. Etheridge. Particulars have also been published by Mr. C. E. De Rance,* and by Mr. Etheridge:† the details varying in each case. In the Warwick Museum there is a core of "Coal shale" from a depth marked 1,174 feet.

The beds of Great Oolite to a depth of about 50 feet, no doubt belong to the Marly beds of the Upper Division. Prof. Hull has remarked that the total thickness of this upper portion is probably little short of 100 feet:‡ it is quite 75 feet, and the full thickness of the Great Oolite may not be less than 100 feet.

North-west of Burford Signett, the Upper Division of the Great Oolite was shown in the following section:—

| | | | Ft. | In. |
|---|---|---|---|---|
| Great Oolite. | White Limestone. | Close-grained rubbly oolite | 4 | 0 |
| | | White oolitic limestone / Do. more earthy | 2 | 4 |
| | Marly Beds | Irregular bed of grey and greenish carbonaceous clay / Hard white and pinkish limestone slightly oolitic | 3 0 or 4 | 0 |
| | | Brown more or less shelly oolite: passing down probably into Freestone | 3 0 or 4 | 0 |

The lower beds are hard and are employed for building-purposes. The beds on the whole are much fissured and tumbled, as if faulted.

The upper beds of Great Oolite, together with clays that present some of the characters of the Great Oolite Clay, and some of the fossils of the Bradford Clay, were shown, as follows, in a quarry about half-a-mile south-west of Burford church:—

| | | Ft. | In. |
|---|---|---|---|
| | Brown clayey and stony soil | 1 | 0 |
| Forest Marble (= Bradford Clay?) | Grey, greenish-grey and brown clay, with thin layers of gritty and shelly limestone: *Avicula, Ostrea acuminata, O. lingulata, O. gregaria, O. Sowerbyi, Rhynchonella, Serpula,* &c. | 3 | 6 |
| | Ferruginous marly and racy bed, with interrupted masses of hard brown shelly oolite at base | 1 | 0 |

* Rep. Brit. Assoc. for 1878, p. 384; Trans. Manchester Geol. Soc., vol. xiv. p. 437.

† Pop. Science Review, ser. 2, vol. iii. p. 290.

‡ Geol. Cheltenham, p. 64.

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite (Upper Division). | Hard brown oolites - - - | 2 | 6 |
| | White fine-grained oolite - - | 1 | 7 |
| | Brown fine-grained and rather earthy oolites. | | |

An excellent section of the Great Oolite Series was exposed to the south-west of Holwell, near Burford, in a large excavation for brick-clays. It was as follows:—

| | | Ft. | In. |
|---|---|---|---|
| | Brown clayey soil. | | |
| Great Oolite (Upper Division). | Blue and brown shelly oolite. | | |
| | Fissile limestone, smooth beds, imperfectly oolitic - - 2 0 to | 5 | 0 |
| | (Sharp line.) | | |
| | Pale grey marly clay - - 1 0 to | 1 | 6 |
| | Fissile false-bedded pale bluish and brown oolite, with marly seams in places - - - 2 0 to | 2 | 6 |
| | Pale grey marly clay (used for marling land), with thin beds of blue marly and shelly limestone - - - | 8 | 6 |
| | Blue and brown shelly oolite with ochreous galls - - - ; False-bedded flaggy marly and shelly oolite - - - - - | 1 | 6 |
| | Grey marly clay - - - | 0 | 8 |
| | Bluish shelly and marly oolite with *Rhynchonella*, *Ostrea*, &c. - - ; Thick bed of pale false-bedded and current-bedded shelly oolite, blue at base - - - - - | 3 | 0 |
| | Blue marly clay; used for bricks, &c. for estate purposes only (pale buff or whitish bricks and drain-pipes are manufactured) - - - | 5 | 6 |

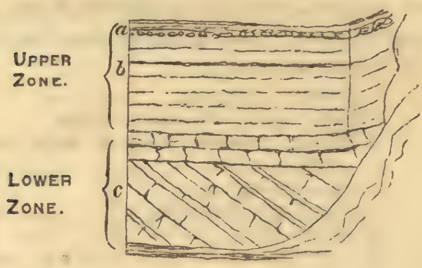
The lowest thick beds have much the appearance of Great Oolite freestone, especially at a short distance, but the lower part of the rock is very blue and shelly like Forest Marble. At first I was inclined to group all the strata with the Forest Marble, but on further consideration I think they belong mainly to the Marly beds beneath the White Limestone, as seen at Milton, and elsewhere, and which have been proved in the upper part of the Burford boring, and in a boring at Witney. The basement portion of the White Limestone occurs on top.

North-west of Swinbrook, east of Burford, a quarry showed the following section:—

| | | | Ft. | In. |
|---|---|---|---|---|
| | | Clay and rubble - - - - - | 2 | 0 |
| Great Oolite. | Upper Division. | Hard grey earthy and gritty limestone - | 1 | 0 |
| | | Bluish oolitic marly bed - - - | 1 | 6 |
| | | Brown and yellow oolitic marl - - | 12 | 0 |
| | | Oolite with *Rhynchonella concinna* - | 1 | 0 |
| | | Brown and grey oolitic marl - - | 2 | 0 |
| | | Brown oolitic limestone (irregular) - | 0 | 8 |
| | Lower Division. | Fissile current-bedded oolite - - | 0 | 8 |
| | | White oolite - - - - | 1 | 2 |
| | | Pale oolite, with large scattered grains of oolite - - - - - | 2 | 6 |
| | | Thin clayey seam - - - - | 0 | 6 |
| | | False-bedded oolitic freestone: in thick beds, much jointed in places (inclination of bedding as in Fig. 87) - - | 9 | 0 |

Fig. 87.

*Section in the Great Oolite, Swinbrook, Burford.*
(Prof. E. Hull).




| | | | | Ft. | In. |
|---|---|---|---|---|---|
| | | | Soil - - - - - - | 0 | 4 |
| Great Oolite. | Upper Division. | a. | White rubbly limestone - - | 0 | 3 |
| | | b. | Soft yellow and white marl and shale, with thin partings of stone - - | 8 | 0 |
| | Lower Division. | c. | White shelly oolitic freestone - | 9 | 0 |

Here we find it difficult to mark any real plane of separation between the Upper and Lower divisions, for we might well take it immediately above the remarkably false-bedded oolitic freestone. A section at this locality, differing in the record of the thickness and character of the upper beds, was described by Prof. Hull (Fig. 87), who marked the junction of the Upper and Lower "Zones" of the Great Oolite as noted above.* This junction probably corresponds with that which I have taken in the section at Milton (p. 307). Prof. Hull observes that the lowest beds of the Great Oolite at Swinbrook, consist of "Yellow sandy oolite, full of oblique lamination, and splitting into slabs;" and these rest on the Clypeus Grit of the Inferior Oolite.†

The Freestone near the base of the Great Oolite, has been extensively worked on Taynton (or Tainton) Down, about a mile N.N.W. of the village, and half a mile west of the second mile-stone on the Burford and Stow road. The stone has attained a considerable reputation. Numerous old pits are to be found, like the "hills and hollows" of other famous stone-districts, and these are now obscured by talus or overgrown by the plantations. The stone indeed is now but little quarried, and in 1887 the refuse only was being worked in places. In the openings which I saw the stone was exposed to depths of from 5 to 12 feet. It sometimes "pitches" at high angles of from 10° to 40° as in the section at Swinbrook, and this, though mainly the result of false-bedding, is perhaps partly due to disturbance, for the beds (so far as could be determined) lie very irregularly, and they are shattered and probably faulted in places. Further remarks on the Taynton Stone will be given in the Chapter on Economic Products (p. 479).

* See Geol. Cheltenham, p. 56.
† *Ibid.*, p. 59.

What may be termed Taynton or Milton Stone, is now largely quarried in the same neighbourhood, to the north-east of the old Taynton quarries, at Milton in the parish of Shipton-under-Wychwood. The following is the section in Grove's quarry, Milton; but the upper beds down to the "small land-stones," are noted on the authority of Mr. R. F. Tomes, as they were not clearly exposed at the time of my visit:—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite. Upper Division (White Limestone and Marly Beds.) | Surface-soil and shattered stone | 3 | 0 |
| | White fine-grained, slightly oolitic stone, with fragments of Corals and *Nerinæa* | 3 | 0 |
| | Bluish marly clay | 2 | 8 |
| | Coral-bed: hard fine-grained and pale limestone | 2 | 7 |
| | Marly clay | 1 | 0 |
| | Oolite; rubbly where near surface ("small land-stones") | 1 | 6 |
| | Marl | 1 | 6 |
| | Brown shelly oolite ("White Rag": yielding good lime) | 3 | 0 |
| | Grey and brown clay | 1 | 0 |
| | Fissile oolite | 1 | 0 |
| | Brown marly clay<br>White rubbly marl | 3 | 0 |
| | Pale grey slightly oolitic limestones ("Blue Rag": road-stone) | 1 | 6 |
| | Grey clayey and oolitic marl | 1 | 6 |
| | Indurated oolitic marly beds ("Bastard White Rags")<br>Marly clay<br>Blue clay<br>Brown clay with *Ostrea Sowerbyi* and *Rhynchonella concinna* (abundant) | 10 | 0 |
| Lower Division (Freestone). | Fissile and false-bedded oolite with marly patches, *Ostrea*, and *Rhynchonella* | 3 | 0 |
| | Rubbly beds of oolite and marl | 2 | 6 |
| | Fissile oolite (1 ft., passing down into pale oolite (freestone) much jointed | 6 | 0 |
| | Poor freestone | 2 | 0 |
| | Marl. | | |
| | | 49 | 9 |

The measurements given by Mr. Tomes amount to $54\frac{1}{2}$ feet, but the thickness assigned to the freestone-beds was about 5 feet more than that recorded by myself. The fossils that have been noted are as follows:*—

† Natica formosa.
† Nerinæa.
† Ceromya undulata ?
Cypricardia.
Modiola.
Pecten vagans.
† Terebratula maxillata.
† Clypeus Mülleri.
Solaster Moretonis.
Adelastræa.
Anabacia complanata.
Chorisastræa obtusa.
Cryptocœnia.
† Isastræa gibbosa.
—— limitata.
Microsolena excelsa.
Montlivaltia caryophyllata.
Thamnastræa Lyelli.

* Tomes, Quart. Journ. Geol. Soc., vol. xli. p. 171; see also Hull, Geol. Cheltenham, p. 58.

† The species so marked were obtained by myself, and identified by Messrs. Sharman and Newton; the remaining species have been recorded by Mr. Tomes and others.

On Shipton Down, north-west of Widley Wood, on the borders of Wychwood Forest, I noted the following section :—

| | | Ft. | In. |
|---|---|---|---|
| Forest Marble. | Brown clay. | | |
| | Rubbly marl with *Rhynchonella* - | 3 | 0 |
| | Irregular false-bedded oolitic limestone 0 10 to | 1 | 0 |
| | Clay - - - - - | 1 | 0 |
| | Bands of oolitic limestone - - | 0 | 4 |
| | Stiff dark grey racy and ferruginous clay | 1 | 6 |
| Great Oolite (Upper Division). | Rotten oolitic marly bed - - | 0 | 9 |
| | Brown oolitic and shelly limestone - | 1 | 10 |
| | Nodular marly parting | | |
| | White imperfectly oolitic limestones - | 2 | 8 |
| | Oolitic marly stone: Fossil-bed, with Corals, &c. - - - - | 1 | 3 |
| | Hard brown shelly limestone - - | 1 | 6 |

I obtained the following fossils :—

Pleurotomaria.
Trochotoma
Lima cardiiformis.
Modiola imbricata.
Pecten annulatus.
Isastræa limitata.
Thamnastræa.

An adjoining pit showed the following section :—

| | | Ft. | In. |
|---|---|---|---|
| | Rubble, tumbled stone and brown clay | 2 | 6 |
| Great Oolite (Upper Division.) | Rubble and hard oolitic shelly marl: with fine specimens of *Terebratula maxillata* - - - - | 3 | 0 |
| | Hard grey and white, somewhat compact, oolite - - - - | 1 | 0 |
| | Brown oolitic stone - - - | 1 | 6 |

A section by Caps Lodge, about 1½ miles north-east of Burford, is noted by Mr. Tomes: this also shows the position of the Coral-bed. He remarks that "The general facies of the corals at this place much resembles that of the Fairford Corals."* (See p. 297.)

The following section was shown in a quarry at Hensgrove, Wychwood Forest :—

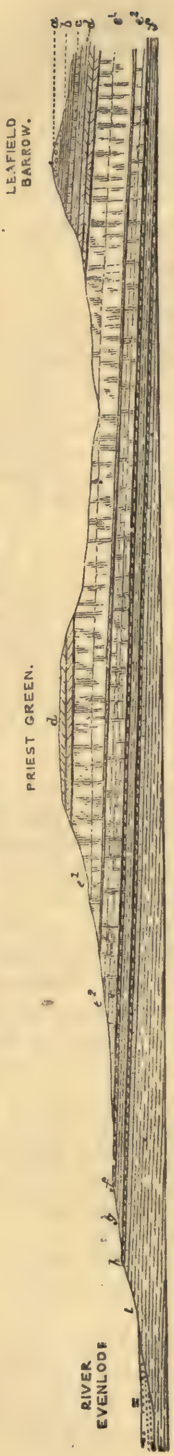
| | | Ft. | In. |
|---|---|---|---|
| Forest Marble. | False-bedded grey and pale buff shelly and oolitic limestone with galls of clay | 4 | 6 |
| | Blue and grey marly clay; with base of irregular white oolitic and marly limestone with nodular (? pebbly) stones. *Strophodus* - - - - | 1 | 3 |
| Great Oolite (White Limestone). | White oolite: very shelly bed, with Gasteropods - - - - | 1 | 6 |
| | Hard white more or less oolitic rock, the grains here and there more prominent and scattered in finer oolitic base - | 3 | 6 |

The clay is irregular, so that in places the limestone of the Forest Marble rests directly on the Great Oolite. The irregular

* Quart. Journ. Geol. Soc., vol. xxxix. p. 170.

FIG. 88.

*Section from the River Evenlode to Leafield Barrow, Oxfordshire.* (Prof. E. Hull.) (Horizontal scale, 3 inches to 1 mile; Vertical scale, 6 inches to one mile).




*x.* Alluvium.
*a.* Drift Gravel.
*b.* Oxford Clay.
*c.* Cornbrash.
*d.* Forest Marble.
*e*[1]. Upper beds of Great Oolite.
*e*[2]. Lower beds of Great Oolite.
*f.* Inferior Oolite.
*g.* Upper Lias Clay.
*h.* Middle Lias: Marlstone.
*l.* Middle and Lower Lias Clays.

marly bed seems to be part of the Great Oolite, in a somewhat *remanié* condition.

The accompanying section (Fig. 88) will serve to show the general relations of the strata in the Wychwood area.

The White Limestone has also been quarried near Minster Lovel, but the beds are not very well shown. They are much fissured and shattered near the surface. Some Fish-remains have been found in the top beds.*

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* See W. S. Horton, Geologist, vol. iii. p. 252.

# CHAPTER XI.

## GREAT OOLITE SERIES.

### Great Oolite and Stonesfield Slate—

### (Local Details *continued*).

### Stonesfield Slate.

No place is richer in geological associations than Stonesfield. Its very name savours of the earth's crust, and indeed the ground has yielded, since the Roman occupation at any rate, the shelly and oolitic tilestones known as Stonesfield Slates, while the fossils have attracted attention for 200 years or more. Plot speaks of the "Flat-stone" of *Stunsfield,* and the beds have been worked along the sides of the valleys to the south, south-west, and west of the village (south of Hillburn Farm). The open works, with levels driven into the hill-sides, having for the most part exhausted the accessible material, shafts have been sunk in and about the village to various depths, ranging from 20 to nearly 70 feet, according to the thickness of the overlying strata. The village itself, and the lands to the south and west, are therefore riddled with shafts and levels, and great heaps of waste material remain to attest the work that has been done.

The "slates" are of three kinds; brown calcareous sandstone, grey and slightly oolitic calcareous sandstone, and blue and grey oolitic limestone. The strata yielding these materials are of variable nature, usually from 2 to 3 feet in thickness, and not exceeding 6 feet; and from one to three layers, in different places, yield suitable stone.

The only partially open working that I have seen, was situated at Red Hill, on the eastern side of the valley between Fawler and Hillburn Farm. Here the "slate" was exposed, although worked underground in the hill-side. The following section was shown:—

| | | | Ft. | In. |
|---|---|---|---|---|
| Great Oolite (Lower Division). | | Alternations of oolitic limestone and marl | 3 | 0 |
| | | Marl with thin films of sandy limestone: *Pecten vagans* and *Rhynchonella concinna* | 6 | 0 |
| | | Roof Bed: grey oolitic and sandy limestone (that does not split, and is of no use) | 2 | 0 |
| | Stonesfield Beds. | Shaly bed | 0 | 6 |
| | | Stone worked for "slate"—grey sandy and oolitic limestone | 1 | 0 |
| | | Shaly bed. | | |

The slate-mine (belonging to Mr. Barrett) on the eastern side of the village of Stonesfield is one of the deeper pits. The shaft is sunk 66 feet, and blocks of stone are raised with the aid of a windlass and of a stout rope, to which a plain wooden stage is affixed by means of a hook and a curved iron rod. The workmen usually descend into the pit by sliding down the rope, pick in hand. I found it impossible to study the characters of the strata in descending the shaft by means of the stage, for one hand must be employed in holding the rope, and the other in holding a candle. The rocks passed through were beds of limestone with here and there layers of marl. At least two layers of marl, each about 3 feet thick, were penetrated; and at one time after much rain, such copious streams were thrown out by these marl-beds, that it was impossible to make use of the shaft. The water was eventually shut out by cutting away the limestones for some distance above the springs, and filling up the spaces around the shaft with clay.* From the bottom of the shaft the stone is worked in levels, 3 to 5 feet in height, driven in for some distance, and widened as the stone is taken away: then the roof is supported by walls built up of the waste stone.

The roof of the mine is formed of hard and somewhat false-bedded oolite, known as Rag, and the following is the sequence of beds :—

| | | FT. | IN. |
|---|---|---|---|
| Stonesfield Beds | RAG. | | |
| | TOP SOFT: marly bed about | 0 | 5 |
| | POT LID and OVER HEAD: blue-hearted sandy limestone with few oolitic grains | 0 | 9 |
| | RACE: calcareous sandy bed with some pot-lids - 0 7 to | 0 | 8 |
| | LOWER HEAD: blue-hearted sandy limestone with oolitic seams | 0 | 9 |
| | BLOCK: soft sandy bed, "no good." | | |

The Pot-Lid bed is a concretionary and impersistent formation, being mainly a flaggy calcareous sandstone, that comes out in rounded and oval or irregular shaped masses of different dimensions. Its place is taken by the Over Head bed, which is not so concretionary in nature, and consists of grey calcareous sandstone with seams of oolite.

The Race contains some "pot-lids," and these may be found at the base adhering to the Lower Head.

The Lower Head is a fairly regular bed, but not so good a stone for "slate" as the Pot-Lid bed.

The general characters of the Great Oolite at Stonesfield, may best be learnt from the old section given by Fitton. The Upper and Lower Divisions shade into one another, as they do at Swinbrook, near Burford, and at Milton; but we no longer find any important bed of freestone, like that of Taynton and Milton. Freestone has been obtained at Pudlecote, near Charlbury, but nowhere in the region north and north-east of Stonesfield, do we find any freestone in the Great Oolite that has attained the repute of the Bath stone, the Minchinhampton stone, or the Taynton stone. The Stonesfield Beds appear to be overlapped in a north-easterly direction, and locally the lower beds of the Great Oolite consist largely of marls. The higher beds of the Great Oolite near Stonesfield, consist of white limestones and

* A well at Mr. Barrett's house, adjoining the pit, is said to be 30 feet deep, and is rarely short of water.

marls, which are very fossiliferous in places; yielding *Nerinæa Eudesi, Astarte angulata, Ostrea Sowerbyi, Terebratula maxillata* and Corals. Further reference will be made to these beds.

The following is the section of a shaft at Stonesfield, recorded in 1827 by Fitton:—*

| | | | Ft. | In. |
|---|---|---|---|---|
| Great Oolite (Upper Division). | | Rubbly limestone - - - - - -<br>Clay with *Terebratula maxillata, Rhynchonella obsoleta, Pecten fibrosus* - - - - -<br>"Rock": limestone - - - - - -<br>Blue Clay - - - - - -<br>"Rock": oolite - - - - - | 32 | 0 |
| | | Blue or greenish clay; it effervesces slightly with acids, and falls to pieces in water like fuller's earth | 5 | 0 |
| Great Oolite (Lower Division). | | "Rag": oolitic limestone, fine-grained, with casts of spiral univalves and bivalves; and coarse soft calcareous stone, more or less oolitic [forming the roof of the drift or horizontal gallery where the slate is dug] - - - - - - - - | 25 | 0 |
| | Stonesfield Beds. 5 ft. 3 in. to 6 ft. | "Soft-stuff," yellowish very sandy clay, including thin courses of fibrous gypsum - - - - - | 0 | 6 |
| | | "Upper Head," composed of sand, of various consistency and fineness of grain, containing towards the lower part large flat spheroidal concretions (called "Pot-lids"), of calcareous grit, pervaded by oolitic particles, these pot-lids furnish the best stone; the rock, with all the other useful stone of the pits, bears the common name of "Pendle." It includes pebbles of hard sparry oolitic stone† 1 3 to | 1 | 6 |
| | | "Manure" or "Race," slaty friable sand-rock, calcareous and micaceous | 1 | 0 |
| | | "Cap" and "Lower Head"; the upper portion having a concretional form like that of the Pot-lids. The rock in both cases varies, from a very compact and fine-grained grit, effervescing strongly with acids, to a stone of which the larger portion consists of oolitic particles. The greater number of fossils, including Mammalian remains, *Trigonia impressa, Rhynchonella obsoleta,* &c. appear to have been procured from these beds - - 1 6 to | 2 | 0 |
| | | "Bottom-stuff."—Coarser calcareous grit, with oolitic particles [base not seen] - - - - - - | 1 | 0 |

The Stonesfield Slate has yielded a rich and interesting suite of fossils, and specimens may now be obtained from the spoil-heaps, or from the "slatters" who keep at their cottages numerous specimens for sale.

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* Zool. Journal, vol. iii. 1828, p. 412; Owen's Palæontology, p. 307, and ed. 2, p. 344. See also Conybeare and Phillips, Geol. Eng. and Wales, pp. 203, &c.

† In the Museum of Practical Geology there is a small slab of oolitic Stonesfield Slate, with a vein of calc-spar that traverses the rock, and also an included pebble.

Many references to the strata and their fossils will be found in the writings of Buckland,* Phillips,† J. F. Whiteaves,‡ W. S. Horton,§ Prof. Hull,‖ and others.

Of the fossils of the Stonesfield Slate, exceptional interest will be found in the remains of Mammalia; and these were first recognized by Cuvier in 1818, from a specimen obtained by W. J. Broderip. This at the time was referred to the genus *Didelphys.*¶ So startling was the discovery that a long controversy was stirred up on the subject. The geological age of the stratum was questioned by Constant Prevost, and when this was settled by Fitton, the zoological affinities of the fossils were disputed by Agassiz, De Blainville, and R. E. Grant. De Blainville indeed proposed the name *Amphitherium* on account of the "ambiguous nature" of the specimens, but he thought they most likely belonged to Saurians; while in the "Athenæum" the name *Botheratiotherium Bucklandi* was suggested, by Edward Charlesworth, for the supposed *Didelphys.* Although the true nature of the fossils was pointed out by Cuvier, Buckland, and Valenciennes, yet the matter was not finally set at rest until after 1838, when Owen published his observations on the original specimens, and on others that had since been obtained.**

Mammalian remains are indeed exceedingly rare in the Stonesfield Slate, about one specimen on the average being obtained in the course of ten years. The supposed bones of birds, noted by the Rev. J. Dennis,†† are now regarded as belonging to Ornithosaurians.

Of the more abundant Saurian remains, bones and teeth of *Megalosaurus* are occasionally obtained, and Chelonian scutes are also found from time to time. Phillips notes the occurrence of *Teleosaurus,* but observes that the remains are more abundant in higher strata of the Great Oolite. He also states that egg-like bodies, which may be Reptilian, occur at Stonesfield.‡‡ Examples of these have been named *Oolithes sphæricus,* by Mr. Carruthers.

Fish-remains are abundant, and some of them were known to the early geologists as "*Bufonitæ*" or Toad-stones.§§ The occurrence of *Ceratodus* is most interesting, for the genus now exists in the rivers of Queensland; and, as remarked by Mr. Smith Woodward, it is "the sole undoubted record of the occurrence of the genus in the Jurassic rocks of Europe,"‖‖ although it appeared on the scenes in Rhætic times.

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* Trans. Geol. Soc., ser. 2. vol. i. p. 390.

† Geol. Oxford, &c., p. 167.

‡ Rep. Brit. Assoc. for 1860, p. 104.

§ Geologist, vol. iii. p. 251.

‖ Hull, *Ibid.*, p. 304; Geol. Woodstock, p. 18.

¶ Buckland, Trans. Trans. Geol. Soc., ser. 2, vol. i. p. 391.

** *Ibid.*, vol. vi. p. 47; Brit. Fossil Mammals and Birds, pp. 30, &c.; Athenæum, Nov. 24, 1838, p. 841. See also E. S. Goodrich, Quart. Journ. Micros. Sci., vol. xxxv. p. 407.

†† Geologist, vol. vi. p. 109; see also Bowerbank, Quart. Journ. Geol. Soc., vol. iv. p. 2; and Phillips, Geol. Oxford, &c., p. 229.

‡‡ Phillips, *op. cit.*, p. 194; Carruthers, Quart. Journ. Geol. Soc., vol. xxvii. p. 447.

§§ J. Woodward, Nat. Hist. Foss. England, tome 2, p. 108. See also H. Woodward, Geol. Mag. 1893, p. 247.

‖‖ Proc. Geol. Assoc., vol. xi. p. 291.

The more abundant Mollusca are *Gervillia acuta, Lima* (several species), *Modiola imbricata, Pecten annulatus, P. lens, P. vagans,* and *Trigonia impressa.* Of Brachiopoda, *Rhynchonella concinna* is common. Plant-remains and Insect-remains also occur. The accompanying list will best show the nature of the Fauna and Flora.

STONESFIELD SLATE MAMMALS.

FIG. 89.

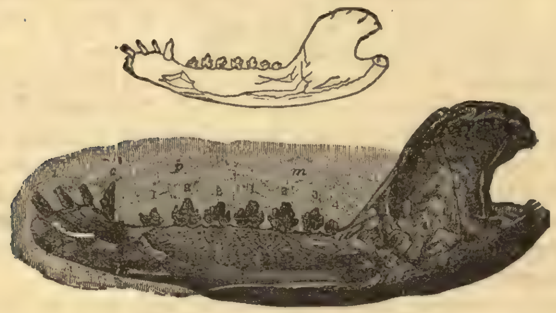

FIG. 90.

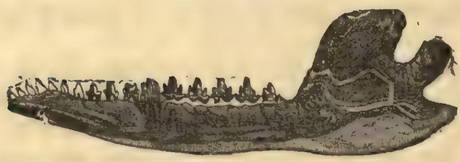

FIG. 89. Phascolotherium Bucklandi, *Broderip.* Lower jaw and teeth.

FIG. 90. Amphilestes Broderipi, *Owen.* × 2. Lower jaw and teeth.

## LIST of FOSSILS from the STONESFIELD SLATE of STONESFIELD.*

### MAMMALIA.

*Marsupiala.*

Amphilestes Broderipi.†
Amphitherium Prevosti.
Amphitylus Oweni.
Phascolotherium Bucklandi.

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* Specimens thus marked ( × ) were obtained by myself and identified by Messrs. Sharman and Newton. The majority of species recorded are those given by authorities previously mentioned, or described in the volumes of the *Palæontographical Society*, or preserved in the Museum of Practical Geology. See also Hull, Geol. Woodstock, p. 19; Green, Geol. Banbury, p. 14.

† Phillips mentions that the original specimen of *Amphilestes* (*Amphitherium*) *Broderipi*, was found by Joshua Platt, an able collector, about the year 1764, and it came into the possession of Sir Christopher Sykes during his residence at Oxford. It was afterwards brought into notice by Phillips, and described by Owen. See Geol. Oxford, &c., p. 230.

### *Insectivora.*

Stereognathus ooliticus.

## Reptilia.

### *Ornithosauria.*

Rhamphocephalus Bucklandi.
—— depressirostris.

### *Dinosauria.*

Megalosaurus Bucklandi.

### *Crocodilia.*

Steneosaurus brevidens.
—— ? Geoffroyi.
Teleosaurus Geoffroyi.
—— subulidens.

### *Plesiosauria.*

Cimoliosaurus erraticus.

### *Chelonia.*

Protochelys (Testudo) Stricklandi.

## Pisces.

Acrodus leiodus.
Aspidorhynchus crassus.
Asteracanthus acutus.
—— semisulcatus.
Belonostomus ? leptosteus.
Caturus ? pleiodus.
Ceratodus Phillipsi.
Ctenolepis cyclus.
Ganodus Bucklandi.
—— dentatus.
—— falcatus.
—— neglectus.
—— Oweni.
—— psittacinus.
—— rugulosus.
Hybodus apicalis.
—— dorsalis.
—— grossiconus.
—— levis.
—— marginalis.
—— polyprion.
Ischyodus Colei.
Ischyodus emarginatus.
Lepidotus tuberculatus.
—— unguiculatus.
Leptacanthus semistriatus.
—— serratus.
Leptolepis disjectus.
Macrosemius brevirostris.
Mesodon (Pycnodus) biserialis.
—— Bucklandi.
—— ? oblongus.
—— rugulosus.
—— tenuidens
Nemacanthus brevis.
Pholidophorus ? minor.
Pristacanthus securis.
Scaphodus heteromorphus.
Strophodus lingualis.
—— magnus.
—— tenuis.
Undina ?

## Mollusca.

Ammonites discus. (Fig. 119.)
—— gracilis.
—— Waterhousei.
Aptychus.
Belemnites aripistillum.
—— bessinus.
Nautilus Baberi.

Alaria.
Amberleya nodosa.
Deslongchampsia Eugenei.
Fibula eulimoides.
Natica intermedia.
—— Michelini.
—— Verneuili.
Neridomus hemisphæricus.
—— minutus.
Nerinæa Stricklandi.
Nerita Buvignieri.
—— costulata.
—— rugosa.
Neritopsis striata.
Patella lata.
—— nana.
—— Roemeri.
—— rugosa.
Pseudomelania (Eulima) communis.
Trochus obsoletus.
—— spiratus.
Anatina plicatella.
Astarte angulata.
—— pumila.
—— squamula.
—— Wiltoni.
Cardium Stricklandi.
—— subtrigonum.
× Corbis?
Corbula involuta.
Exogyra auriformis.
Gervillia acuta.
—— islipensis.
—— monotis.
—— ovata.
—— subcylindrica.
Gresslya peregrina, var. rostrata.
× Hinnites abjectus.
Hippopodium.
Inoceramus Fittoni.
Lima cardiiformis. (Fig. 75.)
—— duplicata.
—— impressa.
—— pectiniformis.
Modiola compressa.
× —— imbricata.
—— solenoides.
—— sowerbyana. (Fig. 10.)
—— tenuistriata.
Myacites calceiformis
Mytilus sublævis.
Opis lunulatus.
Ostrea acuminata. (Fig. 65.)
× —— flabelloides.
—— gregaria.
—— Sowerbyi. (Fig. 95.)
Pecten annulatus.
—— fibrosus.
—— lens. (Fig. 123.)
× —— michelensis.
—— retiferus.
—— vagans. (Fig. 122.)
Perna rugosa.
Pholadomya acuticosta.
Pholas.
Pinna ampla.
—— cuneata.
Placunopsis socialis.
Pteroperna pygmæa.
Quenstedtia oblita.
Tancredia brevis.
—— extensa.
—— mactræoides.
—— similis.
Thracia amygdaloidea.
× Trigonia impressa.
—— Moretoni.
—— pullus.
× Unicardium.

BRACHIOPODA.

Rhynchonella concinna. (Fig. 77.)
—— obsoleta.
Terebratula maxillata. (Fig. 78.)

CRUSTACEA.

Eryon Stoddarti.
Glyphea rostrata.
Prosopon mammillatum.
Pollicipes ooliticus.

### INSECTA.

*Coleoptera.*

Blapsidium Egertoni.
Buprestis Bucklandi.
Curculioides.
Prionus ooliticus.

*Neuroptera.*

Hemerobioides giganteus.
Libellula Westwoodi.

*Hemiptera.*

Palæontina oolitica.*

### ANNELIDA.

Vermilia quinquangularis.

### ECHINODERMATA.

Acrosalenia spinosa.
Astropecten cotteswoldiæ.
—— —— var. stonesfieldensis.
—— Wittsi.
Clypeus Ploti. (Fig. 30.)
Echinobrissus clunicularis. (Fig. 128.)
Hemicidaris Stokesi.
Polycyphus normannus.
Pseudodiadema Parkinsoni

### ACTINOZOA.

Anabacia complanata.
Thamnastræa Lyelli.

### PLANTS.

*Monocotyledons.*

Pandanocarpum (Kaidacarpum) ooliticum.
Yuccites (Palæozamia) megaphylla.

*Coniferæ.*

Araucarites Brodiei.
Thuytes divaricatus.
× Walchia Williamsonis.

*Cycadeæ.*

× Cycadinocarpus (Carpolithes) lindleyanus.
Ptilophyllum acutifolium (Palæozamia taxina).

*Filices.*

Pachypteris lanceolata.
Pecopteris approximata
—— diversa.
Pecopteris incisa.
Sphenopteris plumosa.
Tæniopteris angustata

* Regarded as a butterfly by Mr. A. G. Butler, Geol. Mag., 1873, p. 2, 1874, p. 446. See also S. H. Scudder, Mem. Amer. Assoc., vol. i. p. 99, 1875.

The beds seen in the cutting near Ashford Bridge on the Great Western railway (Worcester branch), are as follows:—

| | | | Ft. | In. |
|---|---|---|---|---|
| Great Oolite. | Upper Division | Rubble of oolite, marl, &c. | | |
| | | Fissile and false-bedded oolites and marls - - - - Oolitic limestone, with Corals - | 15 | 0 |
| | | Marly and carbonaceous oolite - Clay and sandy shales, with *Ostrea Sowerbyi* - - - - | 5 | 0 |
| | | Pale-grey limestone with *Nerinæa Eudesi, Astarte angulata*, &c. - | 1 | 0 |
| | Lower Division | Fissile and shelly oolite, with *Nerinæa* at top - - - | 6 0 to 8 | 0 |

The section has been described by John Phillips and others*; and more recently by Mr. R. F. Tomes† who obtained from the Coral Bed, *Astrocœnia Phillipsi, Cryptocœnia Pratti, Isastræa gibbosa, I. limitata, Montlivaltia, Thamnastræa Lyelli*, &c. He also obtained *Cyathophora Bourgueti* from the bed above the *Nerinæa*-limestone. A number of Gasteropods and other fossils have also been obtained, by Mr. T. J. Slatter, from the Great Oolite in this cutting: they include *Fibula variata, F. eulimoides, Natica Michelini, Neridomus minutus, Ataphrus discoideus, Delphinula alta*, and *Solarium varicosum*. Many other fossils, together with *Cypricardia nuculiformis*, and *C. rostrata* have been recorded by Mr. Whiteaves, who placed the fossiliferous beds in the Lower Division of the Great Oolite. (See p. 250.) The stratigraphical evidence does not enable me to correlate the beds definitely with those of Milton. The bed with *Astarte angulata* may be the top of the Lower Division; but the species is found elsewhere at higher horizons, and I am inclined to include the bed in the Upper Division. The lowest bed of oolite may perhaps represent the Taynton freestone, for as remarked by Mr. Tomes, all the beds "overlie the Stonesfield Slate, which is under the line of railway." On the Geological Survey Maps the beds are shown to be faulted on the west, against the Inferior Oolite and Lias.

The Upper Division of the Great Oolite has been exposed in railway-cuttings eastwards towards Handborough station; and again in a quarry by Whitehill Wood, north of North Leigh. In the quarry, the uppermost beds were not accessible, but I saw the following sequence:—

| | | Ft. | In. |
|---|---|---|---|
| Forest Marble ? - | Rubble. Dark clay. | | |
| | Greenish and white rubbly marl. | | |
| | Pale earthy limestone. | | |
| | Grey marly clay - - - | 4 | 0 |
| | Hard pale earthy limestone - - | 1 | 3 |

* Phillips, Quart. Journ. Geol. Soc., vol. xvi. p. 116; A. Gaudry, Bull. Soc. Géol. France, ser. 2. tome x. p. 594. (I am indebted to Mr. Walford for calling my attention to M. Gaudry's paper); J. F. Whiteaves, Rep. Brit. Assoc. for 1860, p. 105.

† Tomes, Quart. Journ. Geol. Soc., vol. xxxix. p. 171; T. Beesley, Banburyshire Nat. Hist. Soc., Excursion to Stonesfield, 1882.

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite (Upper Division). | Sandy marl, with bands of earthy and shelly limestone - - - - | 5 | 0 |
| | Oolitic limestone - - - - | 2 | 0 |
| | Blue and brown clay - - - - | 0 | 4 |
| | Hard brown oolitic and shelly stone - | 0 | 3 |
| | Oolite - - - - - - | 3 | 0 |
| | Greenish marl - - - - | 2 | 0 |
| | Hard brown oolitic stone - - | 1 | 0 |
| | White and pinkish shelly and oolitic limestones - - - - | 8 | 0 |

This section includes higher beds than those noted at Ashford Bridge, and they evidently belong to the series of White Limestones and Marly beds above the Freestone of Taynton: such as may be seen at Milton, and to some extent in the quarries west of Burford, north-west of Burford Signett, and again at Swinbrook.

The mass of the Great Oolite between Milton and Woodstock appears to be of a very variable character, and the Lower Division is probably much attenuated.* A well at Clinch's Brewery, Witney, was dug for 32 ft. 6 in., and a boring afterwards was carried to a further depth of 19 feet through alternate bands of clay and rock. (See also p. 372.)

### *Woodstock.*

The following section was shown in a quarry north-east of the railway-station at Handborough:—

| | | Ft. | In. |
|---|---|---|---|
| | Rubble of Cornbrash (perhaps slipped over higher beds of Forest Marble) - | 1 | 0 |
| Forest Marble - | Hard shelly limestone - - - | 3 | 0 |
| | Grey clay with "race" - - | 4 | 0 |
| Great Oolite (Upper Division). | Compact brown limestone - - False-bedded and fissile oolite, with thin partings of clay, and layers of hard shelly and blue-hearted limestone in places. Fish-remains (palatal teeth) - - - | 12 | 0 |

The beds here assigned to the Great Oolite appear to correspond with those referred to the same formation in the quarry north-east of Bladon† (p. 373).

In this area near Woodstock and to the north of the town, in the valleys of the Glyme and Dorne, the upper beds of the Great Oolite (which form the plateau north of Woodstock), consist mainly of limestones, more or less shattered and fissured, and with only occasional thin layers of marl: they may be about 30 feet thick. A section south of Wootton showed the following beds:—

* See also Green, Geol. Banbury, p. 23.

† Some fossils from Bladon are recorded by Prof. Green, Geol. Banbury, p. 25.

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite (Upper Division). | Rubble - - - 2 0 or | 3 | 0 |
| | Marl - - - - - | 0 | 6 |
| | Limestone - - - - | 6 | 6 |
| | Marl - - - - - | 0 | 4 |
| | Limestone with *Nerinæa*-bed at base - | 6 | 6 |
| | Marl - - - - - | 0 | 6 |
| | Rubbly limestone, seen to depth of - | 6 | 0 |

Similar beds were exposed by the Pheasantry on the road from Wootton to Glympton, and also to the east of Wootton.

Beneath these upper limestones there is a series of alternating limestones and marls, which are shown in the road-cutting north of the stream, between Wootton and Woottondown Farm: these intermediate beds may be about 25 feet thick. The lower beds of Great Oolite from near Linch Farm to Purgatory, consist mainly of marl with only an occasional band of limestone: and these are probably not less than 25 feet thick. (See p. 324.)

The railway-cuttings on the branch railway to Woodstock showed the following succession of beds beneath the Forest Marble (See Fig. 108, p. 374):—

| | | Ft. | In. |
|---|---|---|---|
| Forest Marble - | Blue clays, with impersistent beds of flaggy, shelly, and oolitic limestone. | | |
| Great Oolite (Upper Division). | Oolites, presenting a somewhat mottled appearance (like some beds of Cornbrash), with pale-grey, blue, and greenish tinges, due to irregular staining and weathering: *Nerinæa* (abundant), *Ostrea* and Corals - 1 6 to | 2 | 0 |
| | Limestone - - 1 0 to | 1 | 6 |
| | Shelly limestone, with *Astarte*, *Gervillia*, and some Gasteropods (resembling shelly bed near Akeley, Bucks) | 1 | 0 |
| | Pale grey earthy limestone (blue-hearted) - - - - - ; Compact limestones with scattered grains of oolite - - - | 4 | 0 |
| | Green and grey racy clay, passing down into black carbonaceous and racy clay with much lignite 3 6 to | 6 | 0 |
| | Earthy oolitic limestone, with *Cyprina*, *Ostrea Sowerbyi*; and gritty oolitic clay - - - - - | 5 | 0 |
| | Clay, *Ostrea* abundant - - - | 1 | 8 |
| | Slightly oolitic limestone, compact and shelly - - - 1 8 to | 2 | 0 |
| | Oolitic limestones - - 4 0 to | 4 | 6 |
| | Fossil bed: Marly limestone, occasionally oolitic, with *Terebratula maxillata* very abundant (all sizes and conditions), *Lima cardiiformis*, &c. 3 0 to | 4 | 0 |

The section, which I had the advantage of studying on one occasion with Prof. Green, compares very well with that seen to the south-west of Enslow Bridge. The Fossil Bed merges up irregularly into the bed above. The green and black clay recalls some beds of the Great Oolite Clay of the country to the north-east. It is difficult however to correlate the beds with those of the Bladon quarry (p. 373): indeed we can only consider that the limestones of the Great Oolite vary much in character, and that there may be some evidence of overlap and reconstruction at the base of the Forest Marble, suggesting local unconformity. This may be the case, at Enslow Bridge near Kirtlington and Bletchington, where there are several fine sections, which have been rendered famous by the descriptions of Phillips* and others.

The section south-west of Enslow Bridge, on the western side of the River Cherwell, is as follows :—

| | | Ft. | In. |
|---|---|---|---|
| | Soil. | | |
| Forest Marble | Flaggy oolitic limestone. | | |
| | Bands of soft pale marl and darker grey marly clay with "race" and lignite. Lumps of marly oolitic limestone (? *remanié* Great Oolite) occur near the base - - - - | 7 | 0 |
| Great Oolite (Upper Division). | Hard brown oolitic limestone, fissile in places - - - 1 0 to | 1 | 6 |
| | Fine-grained compact and earthy oolite, blue-hearted (good building-stone) 1 0 to | 1 | 8 |
| | Marly layer (impersistent) - - | 0 | 3 |
| | Compact earthy limestone, slightly oolitic, containing *Terebratula maxillata* in shelly layer, and Corals 1 8 to | 1 | 4 |
| | Greenish-grey and dark blue racy clay and ferruginous oolitic marly clay, with lignite: *Ostrea*, &c. at base, also Selenite - - - 3 0 to | 3 | 6 |
| | Hard rubbly-looking and slightly oolitic stone (with markings like the Dagham Stone) - - - - | 1 | 6 |
| | Marly and slightly oolitic stone, much jointed: merging into bed below - | 4 | 6 |
| | White marly limestone: Terebratula-bed with *T. maxillata*; *Lima cardiiformis, Ostrea, Trigonia*, not so abundant - - - - 4 0 to | 5 | 0 |
| | Marly and ferruginous layer - - | 0 | 4 |
| | White oolitic limestone, with occasional *Terebratula maxillata* - - - | 1 | 3 |
| | Buff finely oolitic sandy limestone - | 2 | 0 |
| | Ferruginous shelly and slightly oolitic stone—(base not seen), about - | 6 | 0 |

The Stone extends down to the river-level, and the lower beds were formerly worked. Since I noted the above section, the quarry has been closed.

The Forest Marble was said to burn to a stronger lime, but to require more fuel than the Great Oolite.

Phillips has noted a further series of beds beneath; including 16 feet of limestones and clays. He remarks that "several of these oolitic [limestone] beds occasionally become marl in this and other quarries. Beneath is a marly and sandy series, the

* Phillips, Quart. Journ. Geol. Soc., vol. xvi. p. 118; Geol. Oxford, &c., p. 152; and Hull, Geol. Woodstock, p. 21.

supposed equivalent of the Stonesfield beds." This general succession agrees with that I have previously noted (p. 320).

South of Bletchington station, and on the western side of the railway, there is a succession of quarries, where the lower beds of the Forest Marble and the Great Oolite are well shown. It will be useful to record the general section to show the variable nature of the beds, and the difficulty in fixing any uniform plane of division between the Forest Marble and the Great Oolite: it is as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Forest Marble | Rubble.<br>Blue-hearted shelly and oolitic limestone, with lignite and clay-seams<br>False-bedded oolitic and shelly limestone, with clay-galls - - | 8 | 0 |
| Great Oolite (Upper Division). | Hard white finely oolitic, shelly and compact limestone (blue-hearted): Building-stone - - 1 6 to | 2 | 6 |
| | Dark green and greenish-grey clay with "race," and lignite; and bands of ferruginous and shelly oolite: *Ostrea Sowerbyi* - - 4 6 to | 5 | 6 |
| | Pale and iron-stained shelly and oolitic marly limestone, harder and more compact at top - - - | 4 | 2 |
| | Hard white marly limestone: Fossil Bed*: with *Natica intermedia, Fibula variata, Cypricardia, Unicardium, Terebratula maxillata, Thamnastræa*, &c. - - - - - | 2 | 6 |
| | Grey marl - - - - | 1 | 4 |
| | Pale oolitic limestone - - - | 3 | 0 |
| | Limestone, partially oolitic - - | 3 | 0 |
| | Pale shelly oolite - - - | 3 | 0 |
| | Oolite - - - - - | 4 | 0 |

Phillips at one time took the greenish clay with *Ostrea*, as the base of the Forest Marble.† A similar bed however occurs in the section on the Woodstock branch railway, well below beds of Great Oolite; and again south-west of Enslow Bridge, below one of the fossil-beds yielding *Terebratula maxillata*, &c. It will be noticed that we have a greater thickness of beds assigned to the Great Oolite at Enslow Bridge, and there near the base of the Forest Marble we find lumps of marly oolitic limestone, as at Hensgrove, Wychwood Forest, suggesting some local erosion of the strata.

Tracing the beds to the quarry on the eastern side of the railway (see p. 373), the Forest Marble there rests on hard grey and iron-stained oolite, exposed to a depth of 4 feet, which may be the bed below the green clay in the section west of the railway. If this be the case we have further evidence of the discordance

* This bed may be compared with Beds 15 or 23 in the section near Hook Norton, p. 330; and the fossils may be compared with those recorded from the cutting at Ashford Bridge (p. 318).

† Quart. Journ. Geol. Soc., vol. xvi. p. 118; see also Geol. Oxford, &c., pp. 152, 154.

between Forest Marble and Great Oolite. The section was not deep enough to prove the point; and it is quite possible that the top bed of Great Oolite, west of the railway, has expanded in thickness; greenish marly and racy clay was, however, shown above the stone-beds in an old quarry a little east of Bletchington railway-station, and the evidence thus tends to prove that the Forest Marble rests on different members of the Great Oolite.

Near Islip the Great Oolite has been exposed at the base of the Forest Marble in several faulted and inlying tracts* (see p. 376). The beds consist of pale and more or less oolitic limestones and marls, and are much false-bedded in places.

The first specimens of *Cetiosaurus* from near Enslow Bridge, were obtained from the railway-cuttings, in 1848, by Strickland†: and these included a femur 4 ft. 3 in. long. Twenty years later Phillips obtained other remains of this huge saurian, to which the name *Cetiosaurus oxoniensis* was given; and among the remains, a femur measuring 5 ft. 4 in. in length, was familiarly known as the "magnum bonum" of Phillips. He has fully described these, and also other specimens from Glympton and Chipping Norton. In reference to the remains from Kirtlington, Phillips notes that the bones "have been drifted, yet not so much as to have suffered by attrition." He adds, that "they lie in, or rather appear to constitute, a bone-bed, whose basis is clay, with abundance of carbonaceous matter and small masses of wood.' The bed is evidently, that noted as greenish-grey clay, in the sections at Enslow Bridge and Bletchington (Kirtlington); and it has yielded also *Avicula, Astarte, Ostrea Sowerbyi*, and *Terebratula maxillata.*

Prof. Prestwich remarks that bones are found at different levels. He obtained a bone of *Cetiosaurus* within two feet of the Cornbrash, and he thinks that the immense femur (before mentioned) should be assigned to the base of the Forest Marble.

Remains of *Teleosaurus* were obtained at Enslow Bridge (south of Kirtlington) a little below the *Terebratula*-bed; and also at Kidlington. As remarked by Phillips, the heads of this Saurian are found in beds below those containing the large bones of *Cetiosaurus.* Many other fossils have been obtained from the Great Oolite of this area, including *Ammonites subcontractus:* and a list, on the authority of J. F. Whiteaves, has been published.‡

To the north-west of Woodstock, a large area is occupied by the Great Oolite, as previously mentioned (p. 319). There are sections here and there to the south of Ditchley Park, at Wootton, Kiddington, west of Steeple Barton and Maiden Bower; and the pits show white limestones, oolites and marls, which in places are very fossiliferous.§ (See Fig. 91, and p. 163.)

* Green, Geol. Banbury, pp. 35, 36.

† Proc. Ashmolean Soc., 1848, p. 19; Memoirs of Strickland, p. 185; Phillips, Geol. Oxford, pp. 6, 249, 251, &c.; Prestwich, Geology, vol. ii. pp. 208, 211.

‡ Green, Geol. Banbury, p. 23; Whiteaves, Rep. Brit. Assoc. for 1860, pp. 105, 106.

§ Hull, Geol. Woodstock, pp. 21, 22.

At Glympton and Steeple Barton, Corals have been obtained from the ploughed fields: they include *Cryptocœnia Pratti*, *Isastræa limitata*, &c.* Their occurrence at Steeple Barton was noticed by Plot, while Charles Faulkner of Deddington obtained many specimens from Glympton. Specimens of *Cetiosaurus* have also been obtained from Glympton, and named *C. glymptonensis*.

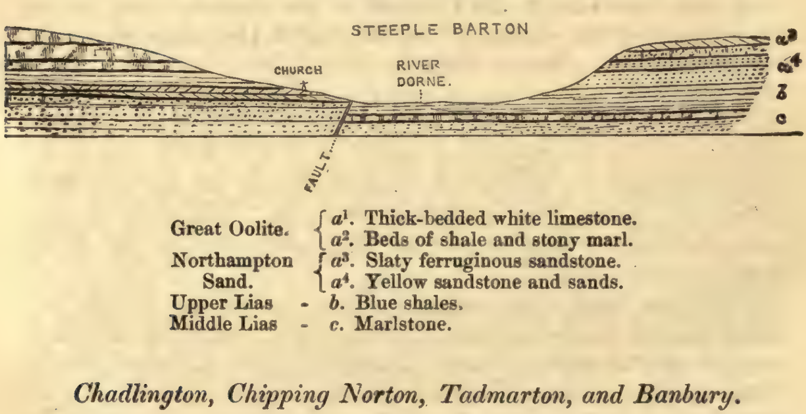
Prof. Hull notes that at Tackley the upper beds of the Great Oolite consist of white limestone, resting upon about 20 feet of shales and marls: and these beds have been exposed in the railway cuttings to the east of the village, and in quarries at Berring's Wood, south of Over Kiddington. Allusion has already been made to the argillaceous beds that in this district occur beneath the main mass of Great Oolite limestones (p. 320): these shales and marls contain the following fossils† :—

| | |
|---|---|
| Modiola. | Pholadomya. |
| Ostrea Sowerbyi. | Terebratula. |
| Pecten annulatus. | Rhynchonella concinna. |

Other fossils from the Upper Division of the Great Oolite in this area have also been obtained by the Geological Survey.‡

FIG. 91.

*Section across the Dorne, Steeple Barton, Oxfordshire.*
(Prof. E. Hull).




| | |
|---|---|
| Great Oolite. | $a^1$. Thick-bedded white limestone. |
| | $a^2$. Beds of shale and stony marl. |
| Northampton Sand. | $a^3$. Slaty ferruginous sandstone. |
| | $a^4$. Yellow sandstone and sands. |
| Upper Lias - | *b*. Blue shales. |
| Middle Lias - | *c*. Marlstone. |

*Chadlington, Chipping Norton, Tadmarton, and Banbury.*

In the western portion of this area at Chadlington Down, and towards Lyneham Barrow, the Great Oolite on the Geological Survey Map, has not been properly separated from the Inferior Oolite, as it is for the most part in the tract to the north embraced by Quarter Sheet 45 N.W. Nor is this in all cases an easy task. (See p. 146.)

The Great Oolite, as before mentioned, rests indifferently on various members of the Inferior Oolite, and we have evidence in

* Tomes, Quart. Journ. Geol. Soc., vol. xxxix. p. 171.
† Hull, *op. cit.*, Green, Geol. Banbury, p. 17.
‡ Green, *op. cit.*, p. 23.

that formation of important beds of limestone (Chipping Norton Limestone), that mark a higher horizon than the Clypeus Grit of the Cotteswolds. This Chipping Norton Limestone is far from fossiliferous, it is variable in character, and becomes very sandy in places, and we cannot always, in the small quarry-sections, determine with certainty the precise age of some of the oolites. Detailed mapping on the 6-inch scale can alone settle some of the uncertainties.

The basement-beds of the Great Oolite Series consist, in many places, of flaggy and shelly oolite, with *Nerinæa*, overlying dark grey or black clay with "race" and marl (a few feet thick). Lumps (apparently rolled) of limestone, form at the base a *remanié* bed, not unlike that which is here and there seen on top of the Great Oolite, at its junction with the Forest Marble. The name "Rift Bed" has been locally applied by Mr. E. A. Walford, to this bottom layer, which rests irregularly on different members of the Inferior Oolite. Much tufaceous rubble sometimes accompanies it, and the clay fills rifts or hollows of the underlying strata. In part, this Rift Bed may be due to dissolution of the underlying beds, as the infillings sometimes occur in irregular pipes, as well as in joints of the stone-beds.

Mr. Tomes and Mr. Walford have noted the occurrence of the Coral, *Cyathophora Bourgueti*, in the "rifted" bed on top of the Inferior Oolite in the Hook Norton railway-cutting.* This species has also been found by them in the Great Oolite (above the Stonesfield Slate-beds) in the Ashford Bridge railway-cutting, near Stonesfield. (See p. 318.)

At Chipping Norton, remains of *Cetiosaurus* have been obtained from the local basement-bed of the Great Oolite Series; and it was probably in the flaggy and shelly oolite in "Smith's quarry," at Sarsden, that a humerus of *Cetiosaurus* was obtained by Earl Ducie, for it was "imbedded in the rock"; the beds in that quarry have also yielded remains of the Ornithosaurian, *Rhamphocephalus depressirostris*.†

At Enslow Bridge, the remains of *Cetiosaurus* come from the higher beds of the Great Oolite, while Ornithosaurians elsewhere occur in the Stonesfield Slate. Palæontological evidence is not a certain guide for fixing horizons in the Great Oolite. At the same time, I cannot help thinking, on stratigraphical grounds, that from the area of Stonesfield, northwards to Chipping Norton, and Hook Norton, the basement-beds of the Great Oolite itself, are not everywhere on the same horizon, and that some layers are impersistent and overlapped by higher stages.

The section at the old lime-kiln, north of Castle Barn, and south-east of Sarsden, was as follows‡:—

---

* Quart. Journ. Geol. Soc., vol. xxxix. pp. 172, 230.

† Phillips, Geol. Oxford, p. 274; Huxley, Quart. Journ. Geol. Soc., vol. xiv. p. 658.

‡ See p. 153 of this Memoir; also Hull, Geol. Woodstock, p. 16.

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite | Flaggy and shelly oolite with *Pecten* - | 2 | 0 |
| | Marly bed. | | |
| Inferior Oolite ? (Chipping Norton Limestone ?). | Hard brown false-bedded sandy oolite (used for dry-walling) - - | 5 | 6 |
| | Soft grey oolitic marl, merging into bed above, but impersistent: Gasteropods (*Natica* ? &c.) poorly preserved - - - - - - | 1 | 8 |
| | Brown ferruginous oolite, passing down into fine-grained sandy oolite, and fine and coarse-grained oolitic "freestone": some of the lower beds are burnt for lime - - - | 15 | 0 |

The general sequence of beds between Sarsden quarry and the Camp on the south, is probably as follows, but the sections on which it is based are small and isolated:—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite | Greenish clays, marls, and white oolitic limestone, with *Ostrea Sowerbyi*, *Rhynchonella concinna*, *Terebratula maxillata*, and Corals (*Isastræa*) - | 5 | 0 |
| | Shelly and flaggy oolite, with *Pecten*, and lignite - - - - | 7 | 0 |
| | Oolitic marly bed, and racy clay with *Ostrea acuminata*, and *O. Sowerbyi* - | 4 | 6 |
| Inferior Oolite? | Brown oolitic and sandy limestone (Chipping Norton Limestone ?) - | 22 | 0 |

The thicknesses given are those actually noted in the several exposures.

A section south-west of Chadlington Down Farm has already been described. (See Fig. 47, p. 152.) There the basement-clay of the Great Oolite rests unconformably on the Chipping Norton Limestone, for higher beds of that rock were shown beneath the clay on the eastern side of the quarry. From the overlying beds of Great Oolite, Mr. Hudleston, Mr. Walford, and Mr. J. Windoes have obtained many fossils. These higher beds of Great Oolite have also been exposed to the south of Chadlington Down Farm, and in quarries on either side of the road to the north-west of the Farm. The disused quarry on the western side of the road was known as "Keck's quarry"; another quarry is situated about two miles east of the Farm; and there are others along the road to the south of Glime Farm. The beds comprise nearly 20 feet of shelly oolitic limestones and marls, overlying false-bedded oolites, and they yield *Nerinæa Eudesi*, and other Gasteropods, *Cardium Stricklandi, Homomya, Lima cardiiformis, Myacites, Ostrea acuminata, O. Sowerbyi, Pecten, Rhynchonella concinna, Terebratula maxillata, Cidaris, Acrosalenia, Anabacia,* &c.*

South of Enstone, and again to the north-west, we find the local basement-beds of the Great Oolite to consist of oolitic rubble, dark clay, and marl, and flaggy oolite and compact lime-

* Hudleston, Proc. Geol. Assoc., vol. v. p. 385; and E. A. Walford, Warwicksh. Nat. Club, March 14, 1882, pp. 20–27.

stone with *Nerinæa,* resting on false-bedded sandy and oolitic limestones (Chipping Norton Limestone). Dark clay occurs here and there in crevices of the oolite, and owing probably to the effects of dissolution on these sandy limestones, they appear in places much broken up and tumbled like some of the "broken" Purbeck Beds. These basement-beds yield *Ostrea acuminata* and *O. Sowerbyi;* and in the quarry near the 70th milestone on the road from Enstone to Chipping Norton, I obtained from them, *Amberleya nodosa, Nerinæa Eudesi, Astarte, Unicardium,* and a Crocodilian tooth. A good section of the local basement-beds of the Great Oolite, with the Rift-Bed, was exposed in one of the quarries west of Swerford, as pointed out to me by Mr. Walford. (See p. 159.)

He has also obtained evidence of slaty beds (like those in the railway-cutting at Langton Bridge), about 20 feet beneath the surface at Fulwell, south of Enstone.

We now come to the somewhat complex region of Chipping Norton, to which reference has already been made in a chapter on the Inferior Oolite (p. 146). This locality, like Enslow Bridge and Glympton, has been noted as a place of sepulture of some of the giant-bones of *Cetiosaurus.* Caudal vertebræ of this Saurian were for the first time discovered at Chapelhouse, about a mile north-east of Chipping Norton, as early as 1825, by John Kingdon;* but the genus was not named and described until 1841, by Owen.

One of the more noteworthy sections at Chipping Norton is that known as the Cetiosaurus Quarry, and Padley's Quarry, where the section which I saw was as follows:—

| | | Ft. | In. |
|---|---|---|---|
| | Soil with pebbles of quartz and quartzite. | | |
| Great Oolite | False-bedded and current-bedded oolite, pale and close-grained: *Trigonia,* &c. - - - - Brown oolitic limestone, with *Modiola, Ostrea acuminata, Pecten,* and *Trigonia* - - - | 5 | 0 |
| | Grey shelly clay and yellowish marl, full of *O. acuminata* and *O. Sowerbyi* | 1 | 6 |
| | Greenish grey and brown shelly clay with much "race" and marly layers: *O. acuminata* and *O. Sowerbyi* (abundant) and *Modiola* - - - - | 1 | 6 |
| | Ferruginous marly bed in which remains of *Cetiosaurus* have been obtained† - - - - | 1 | 0 |
| Inferior Oolite (Chipping Norton Limestone). | Brown and pale oolite: sharply jointed false-bedded and current-bedded, the the lower beds tougher and siliceous [Mr. Hudleston notes rolled spines of *Acrosalenia,* fish-teeth, &c.] about | 12 | 0 |

* Phillips, Geol. Oxford, p. 245; Ann. Phil. ser. 2. vol. x. p. 229.

† Owen, Proc. Geol. Soc., vol. iii. p. 457. Mr. Hudleston says that bones have been found in blue clay at a higher horizon in this series. Proc. Geol. Assoc., vol. v. p. 384.

According to Mr. Hudleston, the surface here is 715 feet above sea-level, and about 60 feet above the Upper Lias. Some of the specimens of *Ostrea acuminata* reminded me of the forms that occur in the Fuller's Earth near Weymouth.

The junction between the clays, and the Chipping Norton Limestone, is irregular and apparently unconformable. This is partly due to disintegration of the surface of the limestone, partly perhaps to irregular upheaval; but the top of the limestone is capped in places with rubbly and partly rounded masses of brown oolitic limestone, that might have been so shaped by subaërial weathering. As Mr. Hudleston remarks, "Here there is a definite line and a thorough physical break." In the argillaceous series, "we may have the representative of the Black Clay of Langton Bridge." He adds that the Chipping Norton Limestone below, may represent rather higher beds than those exposed at Langton Bridge, "the argillaceous series being transgressive over different beds of the Inferior Oolite."* The dark clay of Langton Bridge occurs at the base of the Stonesfield series. (See p. 331.)

West of Chipping Norton a somewhat similar section was to be seen, agreeing also with that on Chastleton Hill. A quarry near Handbrake on Chastleton Hill, showed the following section:—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite | Brown clay, flaggy beds and rubble of oolitic limestone, with *Nerinæa*, *Terebratula maxillata*, &c. - - | 1 | 6 |
| | Flaggy oolitic limestone - - | 1 | 0 |
| | Brown and bluish-grey marly clay and tufaceous marly and oolitic rubble: *Ostrea acuminata*, *O. Sowerbyi*, *Rhynchonella*, *Terebratula* - - - | 3 | 0 |
| Inferior Oolite | Oolitic and sandy limestones (Chipping Norton Limestone) - - - | 10 | 0 |

The stone-beds of the Inferior Oolite are much shattered, and the "rifts" or "swillies" are filled with clay.

A somewhat similar section near Oakham, to the north-east, was described by Prof. Hull, the basement-limestone, there quarried for building-stone, being however referred to the Great Oolite.† He mentions that in a quarry near the gate of Daylesford Park, the basement-clay "is associated with thin bands of sand and gravel," probably like the oolitic rubble in the above section.‡

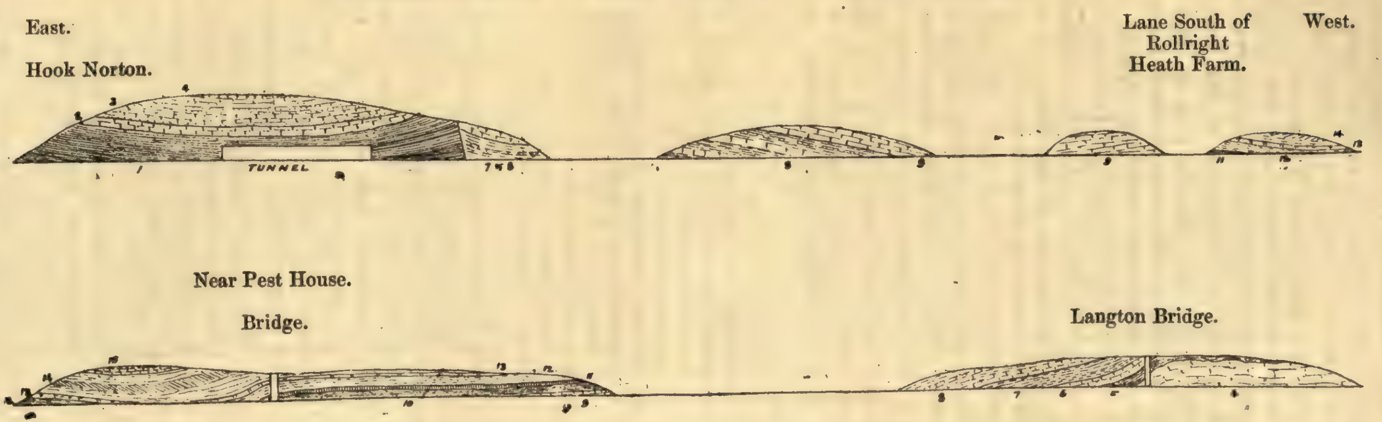
The railway-cuttings between Chipping Norton and Hook Norton have opened up a number of interesting sections, including Cornbrash, Forest Marble, Great and Inferior Oolites and Lias: and the beds have been described by Mr. T. Beesley, Mr. Hudleston, and Mr. E. A. Walford. The cuttings in the Great Oolite, aided by adjoining quarries, give the following sequence: the details being those noted by myself, and the species which I

* Proc. Geol. Assoc., vol. v. p. 385.
† Geol. Cheltenham, p. 59.
‡ *Ibid.*, p. 60.

FIG. 92.

*Sections along the Banbury and Cheltenham Railway, between Chipping Norton and Hook Norton, Oxfordshire.*

(Distance 4 miles. Vertical Scale, 60 feet to half an inch.)




15. Cornbrash.
14. Blue shales with inconstant bands of oolitic and sandy limestone - } Forest Marble.
13. Blue shelly oolitic limestone with lignite - } Forest Marble.
12. Clay with *Ostrea Sowerbyi* - } Forest Marble.
11. Grey earthy limestone with *Gervillia Waltoni* - } Great Oolite.
10. Black clay - } Great Oolite.
9. Pale earthy and oolitic limestones - } Great Oolite.
8. Marls and limestones - } Great Oolite.
7. Fissile "slaty" beds } Stonesfield Slate Series
6. Oolite - } Stonesfield Slate Series
5. Clay.
4. Chipping Norton Limestone } Upper Division } Inferior Oolite Series.
3. Sandy Beds - } Upper Division } Inferior Oolite Series.
2. Lower Division - } Inferior Oolite Series.
1. Upper Lias Clay.

collected having been determined by Messrs. Sharman and Newton :—

| | | Ft. | In. |
|---|---|---|---|
| Forest Marble 3 ft. 6 in. (See also p. 375.) | 27. Brown clay and débris of shelly oolitic limestone (Forest Marble) | 1 | 0 |
| | 26. Yellowish-marly clays with hard marly lumps: *Ostrea Sowerbyi*, *Gervillia* (? *rémanié* bed) - - | 2 | 6 |
| Great Oolite 56 ft. 7 in. | 25. Grey earthy marl and hard white marly limestone, oolitic in places; with some Gasteropods, and *Astarte*, *Gervillia Waltoni*, *Lucina*, *Modiola*, *Myacites*, *Ostrea*, *Unicardium varicosum*, *Serpula*, *Acrosalenia Wiltoni*, &c. - | 3 | 6 |
| | 24. Greenish and bluish-black clay - | 4 | 9 |
| | 23. Creamy white and blue-hearted marly and shelly limestones, indistinctly oolitic: with Gasteropods, *Astarte*, *Cardium subtrigonum*, *Cyprina*, *Neæra*? *Unicardium*, and occasional Saurian Bones (seen in cutting west of Hook Norton tunnel) about - | 8 | 6 |
| | 22. Hard brown shelly oolitic limestone with spines of Echini - - | 1 | 0 |
| | 21. Rubbly more or less oolitic marls and marly clays, in harder and softer bands: *Ostrea* - - | 6 | 0 |
| | 20. Hard greenish and bluish-grey oolitic limestone: *Ceromya*, *Homomya gibbosa* - - - | 2 | 9 |
| | 19. Brown and greenish calcareous sand with lignite: Crocodilian tooth - - - - | 0 | 10 |
| | 18. Marl with *Ostrea*, *Terebratula maxillata* (crushed) - - - | 0 | 8 |
| | 17. Tough impure grey and blue-hearted oolitic limestone, marly and less oolitic at base: *Lima cardiiformis*, *Pecten*, *T. maxillata*, *Rhynchonella concinna*: (fossils more abundant in upper part) - - - - | 6 | 0 |
| | 16. Greenish-grey marly clay - - | 2 | 6 |
| | 15. Hard grey marly bed full of bivalves, and with some Gasteropods and Echini: *Natica*, *Cardium cognatum*, *C. subtrigonum*, *Cyprina*, *Ceromya concentrica*, *Homomya gibbosa*, *Isocardia minima*, *Modiola imbricata*, *Lucina bellona*, *Ostrea acuminata*, *O. Sowerbyi*, *Pecten vagans*, *Pholadomya Heraulti*, *Thracia curtansata*? *Unicardium*, *Rhynchonella concinna*, *Acrosalenia*, *Echinobrissus* and *Holectypus* (seen in second cutting east of Langton Bridge) - - - | 5 | 6 |
| | 14. Hard oolitic limestone with many Gasteropods, *Nerinæa*, &c. - | 2 | 9 |
| | 13. Grey marl fossiliferous in places - | 3 | 6 |

| | | Ft. | In. |
|---|---|---|---|
| | 12. Pale earthy limestone - - | 1 | 8 |
| | 11. Marl with *Ostrea acuminata* and *O. subrugulosa* - - -<br>10. Fissile sandy limestone: *Ostrea, Rhynchonella* - - - | 1 | 0 |
| | 9. Rubbly and fossiliferous oolitic marl with "race": *Modiola imbricata, Ostrea Sowerbyi, O. gregaria, Rhynchonella concinna, Terebratula maxillata* (fine and large examples) - - - | 5 | 0 |
| | 8. Earthy oolitic limestone - - | 0 | 8 |
| Stonesfield Slate Series 17 ft. 5 in. | 7. Fissile calcareous and slightly micaceous sandstone - - | 1 | 2 |
| | 6. Flaggy and more or less fissile oolite and calcareous sandstone, current-bedded, in pale grey and whitish bands - - - | 5 | 0 |
| | 5. Current-bedded shelly oolitic limestones and marly beds, with "race" and *Ostrea*: ripple-marked on surface of top-bed - | 4 | 0 |
| | 4. Grey marly clay with *Rhynchonella concinna* - - - - | 2 | 3 |
| | 3. Hard shelly and current-bedded oolites, with marly band - | 5 | 0 |
| Fullonian (Fuller's Earth). | 2. Dark bluish-black clay, with *Ostrea acuminata* and *O. Sowerbyi* about 6 0 to | 20 | 0 (?) |
| Inferior Oolite - | 1. Chipping Norton Limestone. See p. 151.) | | |

For the guidance of those who may be interested in studying the sections, the following detailed notes are given.

Beds 1 to 10 were exposed in the railway-cutting east of Langton Bridge, and beds 3 to 6 again in an adjoining quarry south of the railway.

The second cutting east of Langton Bridge showed beds 12 to 15, resting on clay possibly the same as bed 11.

A quarry east of the road, south of the railway and south of the Lime-kiln, showed beds 6 to 9, highly inclined towards the north; bed 9 here being rich in specimens of *Terebratula maxillata*, &c. They were overlaid by beds seen in the road-cutting immediately north, consisting of creamy limestones and marls, from which I obtained *Ostrea acuminata* and *O. subrugulosa*. Still, higher, there were fine oolitic limestones, together representing beds 11 to 14, the actual thickness of which was not clearly determinable.

Beds 23 and 24 were shown in the Lime-kiln quarry, where they dip towards the S.S.E., suggesting a synclinal arrangement, if indeed the beds be not faulted on the south.

The long cutting, west of the Hook Norton tunnel-cutting, showed a clear sequence of beds 14 to 23, resting on clayey strata: the top beds represent the mass of the White Limestone.

Beds 20 to 23 were shown in the cutting east of the lane south of Rollright Heath Farm, and beds 23 to 27, &c. were shown in the cutting on the west side of the same lane, and in that near the Pest House.

The cutting adjoining the western end of Hook Norton tunnel, showed Upper Lias, &c. faulted against the Great Oolite. These latter beds were much obscured, but there were marly clays with bands of earthy shelly and oolitic limestone, and an oyster-bed with *Ostrea acuminata, O. Sowerbyi, Cyprina, Rhynchonella concinna*, &c. These beds, I believe, represent those numbered 10 to 14, and perhaps as low as No. 8. Details were noted by Mr. Beesley, who, however, regarded the beds as belonging to the base of the series, with the Inferior Oolite below them.* This view, however, was opposed by Mr. Hudleston,† whose grouping coincides with that now adopted.

The total thickness of the beds here assigned to the Great Oolite (Nos. 3 to 25), measures 74 feet. It is remarkable that this agrees within one foot with the measurement (73 feet) made by Mr. T. Beesley and Mr. E. B. Tawney,‡ because in one or two instances definite measurements were not to be made when I saw the sections.

It will be noticed that there is a considerable proportion of marl in the Great Oolite, amounting indeed to about half of its mass.

It should be mentioned that the thickness assigned by Mr. Hudleston, to the "Black Clay," and underlying marly clay is only 5 ft. 7 in.: Mr. Beesley notes this as 6 ft. 9 in., but it is mentioned that the thicknesses vary within short distances. I certainly saw a greater thickness on the east side of Langton Bridge, but have queried the amount as the beds may have been partially slipped. Referring to this "argillaceous series," Mr. Hudleston remarks that it seems "almost unconformable to the underlying beds." This indication of unconformity, which is afforded by the irregular character of the junction between the clay and underlying limestone, may be compared with that seen in the section at the Cetiosaurus quarry at Chipping Norton. Mr. Hudleston adds that "It may be doubted whether this dividing Clay can be exactly referred either to the Upper Estuarine or to the Fuller's Earth."§ Considering that it is overlaid by beds of Stonesfield Slate character, as in the cuttings noted along the railway between Bourton-on-the-Water and Andoversford (see p. 293), we cannot but group the clay with the Fullonian. At no other locality to the east or north-east do we find any beds that we can definitely assign either to the Stonesfield Slate or Fuller's Earth—if represented in point of time they are included in the Upper Estuarine Series.

There can be no doubt that the beds grouped as Stonesfield Slate Series occupy the position of the beds at Stonesfield; but it is noteworthy that we have current-bedded shelly oolites below the slaty beds instead of above them as in other localities near Burford and Notgrove. It is not unlikely therefore, as suggested by Mr. Walford, that the slaty beds here are developed at a somewhat higher horizon in the series than elsewhere; but at all places the development of "slate" is uncertain and irregular.

Lignite and obscure plant-remains occur in some of the beds. A large *Clypeus* was noted by Mr. Hudleston, and Mr. Walford obtained from the higher beds a number of Polyzoa (*Diastopora ventricosa*) which were found around a piece of water-logged coniferous wood. Mr. G. R. Vine, who described the Polyzoa, counted from 20 to 30 layers of them, representing successive

* Proc. Geol. Assoc., vol. v. p. 172.
† *Ibid.*, p. 388.
‡ *Ibid.*, p. 179.
§ *Ibid.*, pp. 381, 385. See also Beesley, *Ibid.*, p. 172.

growths of colonies of the organism.* A band with *Thamnastræa Lyelli* was noted by Mr. Beesley, about the horizon of beds 15 to 17, and he has collected many other fossils, including *Cypricardia bathonica, Pecten annulatus, Trigonia,* &c.†

The upper beds are of considerable interest. We may take bed 25 as the top of the Great Oolite. It is noteworthy as yielding *Gervillia Waltoni* somewhat abundantly, as well as an *Astarte,* identified as *A. angulata* by Mr. Hudleston, who refers to the bed as the "*Angulata-bed,*" and compares it with a band in the section at Kirtlington.‡ This species occurs also at Ashford Bridge and Minchinhampton. Mr. Beesley has recorded a number of fossils from this *Astarte*-bed, including species of *Cerithium, Natica, Nerinæa, Cardium, Corbula, Cyprina, Cypricardia, Macrodon hirsonensis, Pteroperna,* &c.§

Fossil-beds here as elsewhere occur at varying horizons in the Great Oolite, and it appears impossible to mark any limits for the Upper and Lower Divisions of the formation, to compare with those noted in Gloucestershire.

A section at the lime-kiln, Traitor's Ford, about 2½ miles north-west of Hook Norton, showed the following section:—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite - | Rubble. | | |
| | Marly limestone, with casts of lamellibranchs. | | |
| | Pale shelly oolite (the lower part yields the best lime, employed for white-washing, &c.) - - - - | 4 | 0 |
| | Hard blue-hearted oolitic limestones - | 3 | 0 |
| | Marly beds. | | |

The only fossils I obtained were *Lima cardiiformis,* and *Echinobrissus Griesbachi*?

The beds may be about the horizon of those numbered 17 and 18 in the railway-cuttings (p. 330); and higher beds (=18 to 21) were shown east of the lane, where clayey beds of considerable thickness are associated with the limestone.

A quarry about three-quarters of a mile S.S.E. of Hook Norton Leys Farm, showed the junction of the Forest Marble and Great Oolite. The beds, which undulate considerably and are much broken up at the surface, were as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Forest Marble - | Flaggy and shelly limestones with lignite - - - - - | 1 | 8 |
| | Marl and grey clay, with *Ostrea Sowerbyi,* &c. - - - - | 1 | 6 |
| | Hard blue and grey shelly limestones, and gritty limestone with marly patches; current-bedded in places - | 1 | 9 |

* Walford, Warwicksh. Nat. Club, March 14, 1882; Vine, Quart. Journ. Geol. Soc., vol. xxxvii. p. 385.

† Proc. Geol. Assoc., vol. v. p. 175. See also Tomes, Quart. Journ. Geol. Soc., vol. xxxix. p. 173.

‡ Proc. Geol. Assoc., vol. v. pp. 386, 387.

§ *Ibid.*, pp. 177, 178.

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite | Pale grey and white soft limestones and marls; shelly in places | 3 | 6 |
| | Tough pale-grey gritty and shelly limestone - 0 6 to | 1 | 10 |
| | Brown and greenish clay, with *Ostrea Sowerbyi*, and ferruginous gritty marl. | | |
| | Pale marl passing down into pale oolitic limestone, the lower part ferruginous | 7 | 0 |

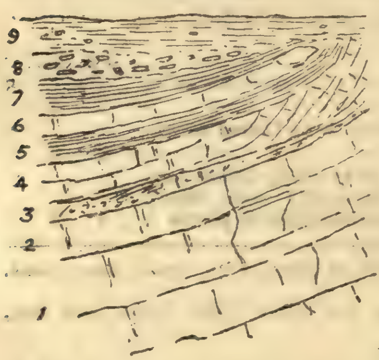
These beds of Great Oolite may be compared with those numbered 23 to 25 in the railway-section (p. 330).

In a quarry north-west of Bacon Farm, south of Swalcliffe, the beds were highly inclined, dipping towards the south, and the following section was shown, (Fig. 93):—

| | | Ft. | In. |
|---|---|---|---|
| Soil | 9. Brown clay. with a few stones | 3 | 0 |
| Forest Marble | 8. Rubble of oolite | 1 | 0 |
| | 7. Greenish clay with "race" | 5 | 0 |
| | 6. Blue shelly and slightly oolitic limestone (like Forest Marble) | 1 | 0 |
| | 5. Shaly clay, with *Ostrea* at base | 1 | 3 |
| Great Oolite | 4. Compact pale-grey limestone, becoming marly and shelly, blue and oolitic towards the base, where it resembles Forest Marble 2 2 to | 2 | 6 |
| | 3. Fossil Bed: Clay with indurated marly layers, *Cardium*, *Gervillia*, *Modiola*, *Ostrea Sowerbyi*, *Unicardium varicosum*, *Terebratula maxillata*, and Lignite | 0 | 8 |
| | 2. Pale compact limestone, with ferruginous stains, and some Gasteropods | 1 | 3 |
| | 1. Marly oolitic and shelly limestones | 5 | 6 |

Fig. 93.

*Section at Swalcliffe, south-west of Banbury.*




I take these beds to belong to the upper part of the Great Oolite, and the Forest Marble; but absolute confidence in correlation is not, in my opinion, possible. A little to the east of this quarry, a small excavation showed pale limestone with brown oolitic grains, yielding *Nerinæa* and other Gasteropods also *Myacites*, *Nucula*, *Pholadomya*, and Corals.

The upper beds of the Great Oolite were also shown in a quarry to the north-west of Epwell, and east of Broomhill Farm. The section was as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Soil, &c. | Brashy clay with bits of *Ostrea*, and *remanié* greenish and brown clay 2 0 to | 3 | 0 |
| Great Oolite | White marl with Echini | 1 | 0 |
| | Pale marly oolite. Coral Bed with *Thecosmilia*? | 1 | 0 |
| | Rubbly marl | 0 | 8 |
| | Pale oolite | 0 | 10 |
| | Marly layer, impure earthy and oolitic bed | 0 | 4 |
| | Hard grey oolite | 1 | 6 |

A quarry known to local geologists as the Forest Marble Pit, on the hill north of Lower Tadmarton, affords evidence of the junction of Great Oolite and Forest Marble with a very irregular line of demarcation. The section was as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Forest Marble | Stiff brown and stony clay, resting in "pipes" on bed below | 1 | 6 |
| | Thin reddish-brown shelly limestones | 0 | 4 |
| | Grey shelly marl | 1 | 0 |
| | Fissile shelly oolite (blue-hearted) | 1 | 4 |
| | Hard compact grey limestone, with *Modiola* | 1 | 4 |
| | Brown and pale-grey flaggy shelly and earthy limestone, with *Ostrea*, &c. | 0 | 5 |
| | Grey marly and shelly clay, with *Gervillia*, *Ostrea Sowerbyi*, &c.: of irregular thickness | 1 | 0 |
| | Blue-black clay, with lignite; tapering away northward 0 1 to | 2 | 6 |
| | Greenish-grey and ferruginous marly and nodular (*remanié*) bed 0 6 to | 1 | 6 |
| Great Oolite | Compact pale pink and grey limestone, obscurely oolitic, with worn and bored surface | 2 | 4 |
| | Pale oolitic limestones | 2 | 4 |
| | Shelly oolite (used for building-stone). | | |

According to Mr. Beesley the oolite at the base has been quarried to a depth of 10 feet. He notes that remains of *Teleosaurus* were obtained from the Great Oolite of this quarry.* The compact grey limestone here taken as the top of the Great Oolite, appears to correspond with that at Swalcliffe (p. 334); but correlation is hazardous.

A somewhat similar section was exposed at the lime-kiln north of the Fulling Mill, west of Broughton. There I obtained *Ostrea costata* and *O. subrugulosa* from the clays overlying the Great Oolite; and from the Great Oolite, *Natica*, *Cardium*, and *Pholadomya*; Mr. Beesley notes other fossils.

At the Tadmarton Lime-kiln, lower beds of Great Oolite are worked to the depth of about 12 feet. They comprise pale earthy and slightly oolitic limestones, and hard and soft marls, resting on a hard blue-hearted shelly oolitic limestone, and covered by a

* Proc. Geol. Assoc., vol. iii. p. 202, and Proc. Warwickshire Field Club, 1872, p. 31.

rubble of oolite. The beds occur below the oolite (freestone) of the "Forest Marble pit" (p. 335). Fossils are veıy abundant in the soft limestones and marls, and I obtained the following species :—

| | |
|---|---|
| Natica globosa. | Ostrea subrugulosa. |
| —— pyramidata. | Pecten annulatus. |
| —— Stricklandi. | —— rigidus. |
| Anatina siliqua. | —— wollastonensis. |
| Arca. | Pholadomya deltoidea ? |
| Ceromya concentrica. | —— Heraulti. |
| Corbula involuta ? | —— socialis. |
| Cypricardia. | Thracia curtansata. |
| Isocardia minima. | Terebratula maxillata. |
| Leda lachryma. | Acrosalenia Wiltoni. |
| Myacites. | Echinobrissus clunicularis. |
| Opis. | —— Griesbachi. |
| Ostrea costata. | —— Woodwardi. |
| —— Sowerbyi. | Holectypus. |

The assemblage may be compared with that found in bed 15, of the railway-cutting west of Hook Norton (p. 330).

Many fossils have also been collected by Mr. Beesley, including besides many of the species mentioned, *Astarte*, *Cyprina*, *Modiola*, and Crustacean remains (*Glyphea*).*

These beds occur approximately on the horizon of beds 11 to 16 in the section near Hook Norton.

Beds of Great Oolite have been observed on Constitution Hill, to the W.S.W. of Banbury. They comprise alternations of marl and limestone with *Ostrea* and *Rhynchonella concinna*, resting on oolite and marl, together little more than 12 or 15 feet thick; beneath which come the sandy beds of the Inferior Oolite. Sections have been recorded by Mr. Beesley, on whose authority the above notes are given.†

South-west of Dane Hill, south of Deddington, the road-cutting showed the following beds:—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite | Oolitic and shelly marls. | | |
| | Rubbly limestone, oolitic: *Modiola imbricata*, *Myacites*, and *Terebratula maxillata*. | | |
| | Yellowish marl and clay - - | 1 | 6 |
| Inferior Oolite ? - | Sandy limestone, with *Ostrea*. | | |

At the Lime-kiln, west of the road, higher beds were shown as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite | Rubble and clay (disturbed). | | |
| | Rubbly marl and yellowish sand. | | |
| | Pale earthy and oolitic limestone (Coral Bed) - - - - - | 1 | 2 |
| | Hard shelly oolitic limestone: *Nerinæa*, *Trigonia* ? - - - - | 3 | 0 |
| | Blue-hearted earthy and oolitic limestone - - - - - | 1 | 0 |

* Proc. Geol. Assoc., vol. iii. pp. 201, 202.

† Proc. Warwickshire Field Club, 1872, pp. 26, 30; see also Green, Geol. Banbury, p. 25.

These beds recall the White Limestones, which are so well seen in the country near Glympton to the south-west.

The lower beds of the Great Oolite in this region, were shown in a quarry at North Aston, east of the "Fox and Crown." The section was as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite | Hard imperfectly oolitic and sandy limestone; even-bedded and somewhat shelly - - - - | 0 | 6 |
| | False-bedded rotten marly and slightly oolitic limestone and marls: with Gasteropods and Lamellibranchs, *Ostrea Sowerbyi*, &c. - - - - - | 5 | 0 |
| | Hard brown shelly and oolitic limestones (like Forest Marble) - | | |
| | Marly bed with numerous Lamellibranchs, *Trigonia*, &c. - - | 1 | 0 |
| | Tough impure and very shelly limestone merging into beds below - | 1 | 0 |
| | Massive beds of tough brown oolitic and shelly limestone (blue-hearted), with an impersistent bed of soft white or cream-coloured earthy limestone - - - - - | 4 | 0 |
| | False-bedded hard brown ferruginous sandy and oolitic limestone - - | 1 | 6 |

Below these beds there occur a layer of black clay, and then sand and ironstone of Inferior Oolite age, according to Mr. Beesley, and Mr. E. A. Walford.

The general aspect of these beds, and especially of the lower strata, is not unlike beds of the Inferior Oolite (Chipping Norton Limestone); but the evidence tends to show that only Great Oolite is exposed. From the lowest beds of limestone seen in the quarry Mr. Walford obtained *Nerinæa Eudesi, Ceritella parvula, Cerithium costigerum* and other fossils of Great Oolite character. From the upper beds he obtained *Cyprina loweana, Trigonia costata, Modiola gibbosa*, &c.*; and I have found *Cypricardia caudata* and *Thracia curtansata*? It is possible that some of the fossils recorded by Mr. T. R. Polwhele from near Deddington, may have been obtained from this locality.†

The further consideration of the Great Oolite is postponed until after the Forest Marble has been described; for in the area to the north-east other subdivisions of the Great Oolite Series are recognized, and they are best treated together.

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* Warwicksh. Nat. Club, March 14, 1882.
† See Green, Geol. Banbury, p. 12.

# CHAPTER XII.

## GREAT OOLITE SERIES.

### Forest Marble and Bradford Clay.

### (Bradfordian.)

### General Account of the Strata.

In the old Forest of Wychwood (or Whichwood) to the north-east of Burford in Oxfordshire, certain beds of shelly oolitic limestone are quarried here and there for road-metal and for building walls. A century ago the stone was employed locally for chimney-pieces in farm-houses and cottages, and being polished for the purpose, it was known in the country round as the Forest Marble. This name was adopted in 1799 by William Smith, as a geological term for the strata, which he found to rest on the Great Oolite and to be overlaid by the Cornbrash: but like other of Smith's terms, it was, I believe, first published in 1813 by the Rev. Joseph Townsend.

No formation with which we have to deal is more variable in its particular characters than the Forest Marble, though taken as a whole it forms a fairly well-marked division, extending from the Dorsetshire coast near Bridport and Weymouth inland to the neighbourhood of Buckingham.

The beds consist of shelly oolitic limestones, and thin flaggy limestones generally much false-bedded, and they comprise also clays and shales with thin layers of gritty limestone. In some places thicker beds of gritty or sandy limestone are intercalated with the limestones, especially in the upper part; and in others, considerable beds of buff or brown sand appear, with layers and large concretionary masses or doggers of calcareous sandstone.

More often the mass of blue shelly and oolitic limestones constitutes a middle division, being overlaid and underlaid by shales and clays. The lower clays near Bradford-on-Avon and other places contain at their base an abundance of fossils; and this division, though nowhere of great thickness, constitutes what is known as the Bradford Clay.

The thickness of the Forest Marble near Bridport and Weymouth is about 80 or 90 feet; near Sherborne, in Dorsetshire, 130 feet; near Bath and Cirencester, about 100 feet; while in Oxfordshire it is rarely so much as 50 feet thick, and in some places not more than 12 or 15 feet. Further to the north and north-east, we find occasional beds that may represent the strata, as near Blisworth; but shelly limestones of similar character occur apparently at different horizons in the Great Oolite Series, as at Alwalton near Peterborough, so that different stratigraphical divisions become needful in that area.

### *Organic Remains.*

Among the fossils of the Forest Marble (including the Bradford Clay) Lamellibranchs and Brachiopods are the more abundant.

Some of the shelly limestones are mainly composed of Oyster-shells, while layers largely made up of *Rhynchonella*, *Terebratula*, and other Brachiopods are met with. Occasionally we find thin layers crowded with minute Gasteropods. Insects have only been very rarely noticed, although the proximity of land is indicated by the common occurrence of lignite, by worm-burrows and the tracks of invertebrate animals. Some masses of lignite are bored by *Pholas* and *Lithodomus*. Saurian remains are but rarely met with; but bones of *Cetiosaurus*, &c. have been obtained. Fish-remains in the form of palatal teeth are abundant, the more common forms belonging to *Strophodus*. Among the Cephalopoda, *Ammonites discus* (Fig. 119, p. 432) and one species of *Nautilus* have been obtained, though rarely. The Gasteropoda are represented by *Actæonina*, *Monodonta*, *Nerita*, *Trochus*, *Turbo*, &c., but they seldom occur in profusion. Polyzoa are by no means rare. The Crustacea include the old Crab *Palæinachus*, and a number of Ostracoda. Annelida are met with here and there. Of Echinodermata, *Apiocrinus*, *Acrosalenia*, and *Cidaris* are most frequently found. Corals and Sponges are rare; Foraminifera are fairly abundant in some localities, and will probably be found in most places when pains are taken to look for them. There are however few species peculiar to the Forest Marble, and of the characteristic and common forms none are confined to the strata.

FOREST MARBLE (BRADFORDIAN) FOSSILS

FIG. 94.

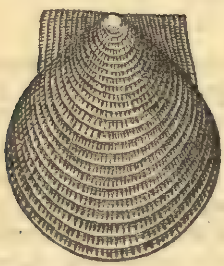


FIG. 95.

FIG. 96.

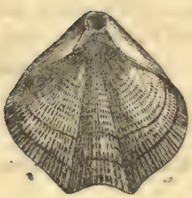


FIG. 97.

FIG. 98.

FIG. 94. Pecten annulatus, *Sow.* $\frac{1}{3}$.
,, 95. Ostrea Sowerbyi, *Lyc.* $\frac{2}{3}$.
,, 96. Terebratula coarctata, *Park.* $\times$ 2.
,, 97. Waldheimia digona, *Sow.* $\times$ 2.
,, 98. Apiocrinus Parkinsoni, *Schloth.* $\frac{1}{3}$.

Reference has been made (p. 254) to the zones adopted by Oppel. We cannot follow him in separating the Bradford Clay from the Forest Marble: broadly speaking if we take a Brachiopod, the zone of *Waldheimia digona* would best apply to the Forest Marble and Bradford Clay; and if an Ammonite be taken, we might adopt the zone of *Ammonites discus,* although the species is too rare to be of service in the identification of the strata. It is better, from a zonal point of view, to include the Forest Marble with the Great Oolite and Fullonian formation As a stratigraphical term the name Bradfordian may be employed generally for the Forest Marble and Bradford Clay *

The following may be regarded as the common and characteristic fossils of the Bradfordian or Forest Marble series† :—

Strophodus magnus.
Avicula costata.
Cyprina islipensis.
—— loweana.
Lima cardiiformis. (Fig. 75.)
—— duplicata.
Modiola furcata.
—— imbricata.
Nucula Menkei.
Ostrea gregaria.
—— lingulata.
—— Sowerbyi. (Fig. 95.)
Pecten annulatus. (Fig. 94.)
—— lens. (Fig 123.)
—— vagans. (Fig. 122.)
Trigonia pullus.
Unicardium varicosum.
Rhynchonella concinna. (Fig. 77.)
—— obsoleta.
—— varians. (Fig. 67.)
Terebratula coarctata. (Fig. 96.)
—— maxillata. (Fig. 78.)
Waldheimia cardium.
—— digona. (Fig. 97.)
Terebellaria ramosissima.
Apiocrinus Parkinsoni. (Fig. 98.)

The surfaces of many of the thin bands of sandy limestone that occur in the upper and lower clayey divisions of the Forest Marble, are often traversed by remarkable tracks, evidently due in some cases to animals, such as Crustacea, that must have crossed the sandy and calcareous mud before it had time to solidify.‡ Worm-throws and burrows have also been noted.

Ripple-marks are abundant on some of the calcareous sandstones. In the limestone and also in the sandstones, there are many ochreous clayey inclusions or clay-galls, as they are sometimes called. These perhaps originate from clay-pebbles formed contemporaneously by the breaking up of some argillaceous stratum.

The shells in the limestones, both Lamellibranchs and Brachiopods, often exhibit a purplish tinge. Of the comminuted shells that form a large part of the limestone, *Ostrea* is the main constituent, *Pecten* also occurs; showing in this as in other cases

* The name Bradfordian was used by Lycett in 1863, Supp. to Great Oolite Mollusca, Palæontograph. Soc., p. 64.

† A list of fossils from the Bradford Clay in particular, is given on p. 353.

‡ Some of these tracks are like the "Zopfplatten" (Pig-tail plaits) figured and described in Quenstedt's Jura, Tab. 46, fig. 1, and p. 334. See also G. P. Scrope, Proc. Geol. Soc., vol. i. p. 317; and Journ. Roy. Inst., vol. i. p. 538, and Plate V.; Figure 1 of Scrope's Plate may be compared with that of a Crustacean track given by Sir J. W. Dawson, Quart. Journ. Geol. Soc., vol. xlvi. p. 598; see also p. 612; and Prestwich's Geology, vol ii. p. 210.

the preservation in current-bedded deposits of shells composed mainly of calcite.

The formation generally bears evidence of its deposition in shallow waters, under marine conditions ;* indications of estuarine characters, if we may judge by the presence of variegated clays, are more distinctly met with when we pass beyond the limits of the Forest Marble, and reach its approximately equivalent strata of Great Oolite Clay.

## LOCAL DETAILS.

### *Weymouth to Bridport.*

We first meet with the Forest Marble along the centre of the Weymouth anticline, in a somewhat faulted tract extending from Radipole to Langton Herring. The oldest strata exposed here belong to the Fullonian (Fuller's Earth), which is shown on the banks of the Fleet south of the last-named village. The upper part of that formation consists of about 6 feet of clay, with bands of pale earthy and flaggy limestone; and this is overlaid by a very fossiliferous band of earthy marl about 2 feet thick, which constitutes the base of the Forest Marble series, and represents the horizon of the Bradford Clay of Wiltshire. This fossiliferous band contains in such abundance *Rhynchonella Boueti* and *R. varians*, that it may be spoken of as a *Rhynchonella*-bed. It is best exposed on the margin of the Fleet at a spot known as Herbyleigh (or Herbury), where it is overlaid by clays and shaly limestones; and it may also be seen on the borders of the West Fleet, south-west of Langton Herring. I examined this portion of the coast in 1884, when I was accompanied by Mr. Henry Keeping, who had previously visited this very rich collecting ground, although its importance had not been generally recognized. Some species of Brachiopoda had however been formerly collected from the neighbourhood by Mr. J. F. Walker and Mr. Darell Stephens, and from Radipole by R. Damon; and the species were regarded as suggestive of the presence of the Bradford Clay.† Later on in the same year, I traced this *Rhynchonella*-bed, westwards near Burton Bradstock and Eype, and the fossils collected are tabulated in the list given on p. 344.

We have no clear section, in this most southern region, of the entire series of beds composing the Forest Marble, but the sequence at Radipole and Langton Herring appears to be the same as that exhibited in the cliffs near Bridport Harbour. We find an upper division (beneath the Cornbrash) of blue, brown, and greenish-grey clay with thin leaves of limestone and occasional bands or lenticular beds of shelly limestone and nodules of "race" (shown in places to a depth of 8 feet, but doubtless much thicker). Then there is a central division, of hard shelly limestone and false-bedded flaggy and sandy oolite, with occasional ochreous galls and lignite; beds which are quarried for local building-

† See also De le Beche, Mem. Geol. Survey, vol. i. p. 285.

‡ T. Davidson, Supp. to Jurassic Brachiopoda (Pal. Soc.), p. 156; Damon, Geol. Weymouth, 1884, p. 15; and H. B. W., Proc. Geol. Assoc., vol. ix. p. 207.

purposes and road-metal, and occasionally for lime-burning (shown to a depth of 10 feet, but probably nearly 20 feet thick). At the base there is a considerable thickness of clays and limestone-shales with thin bands of shell-limestone, resting on the *Rhynchonella*-bed. With the exception of *Ostrea* and *Rhynchonella*, fossils are abundant only in this basement-bed. The stone-beds are well shown in a scarp that extends above West Bexington towards Swyre, and there are quarries at Cogdon, Bredy, North Hill, and Bothenhampton.

At Bothenhampton the shelly limestones have been largely worked for a long period, and the hill-side to the south of the village is scarred with old pits. Here the stone has been procured, along the dip-slope: for the beds are inclined northwards towards the village, where they are faulted against the Middle Lias. This fault is a continuation of that seen in the cliff east of Eype mouth, where the downthrow must be at least 425 feet. (See Fig. 41, p. 52, of the Memoir on the Lias.)

The quarries at Bothenhampton afford some of the best sections of the Forest Marble in this country. The sections show the following beds:—

| | | Ft. | In. |
|---|---|---|---|
| Forest Marble | Brown clay and soil - - 5 0 to | 6 | 0 |
| | Bluish-grey iron-stained and marly clays, with "race," laminæ of sandy limestone, and thin flags of blue shelly limestone - - - | 14 | 0 |
| | Bluish-grey oolitic shell-limestone; false-bedded and with ochreous nodules, lignite, and impersistent clay-seams. Fossils with purplish tinges, including *Cyprina loweana*, *Lima duplicata*, *L. cardiiformis*, *Pecten annulatus*, *P. lens*, *P. vagans*, *Ostrea Sowerbyi*, and fragments of *Apiocrinus Parkinsoni* - - | 6 | 0 |
| | Alternations of blue marly clay and shell-limestone, with lignite - - | 5 | 0 |

The clays above the mass of limestones are somewhat disturbed in places, owing to their slipping along the dip-slope.

The junction with the basement beds of the Cornbrash was to be seen in a lane-cutting south of Bothenhampton church, where grey earthy limestones and marls with *Avicula echinata*, &c., rest on a thin series of flaggy shell-limestones and clays that form the upper part of the Forest Marble.

The Forest Marble is well shown in the West Cliff* between Bridport Harbour and Eype mouth, overlying the Fullonian formation or Fuller's Earth, and occupying a basin-shaped depression in that deposit. The junction with the Fuller's Earth is here marked by a band of hard fissile white marl, 2 ft. 6 in. to 3 feet in thickness, which forms a prominent band in the cliff. Above come 8 to 10 feet of bluish-yellow marl, with a layer of hard fissile white marl in places: these beds may be included with the Fuller's Earth. The next bed is a hard sandy marl, stained

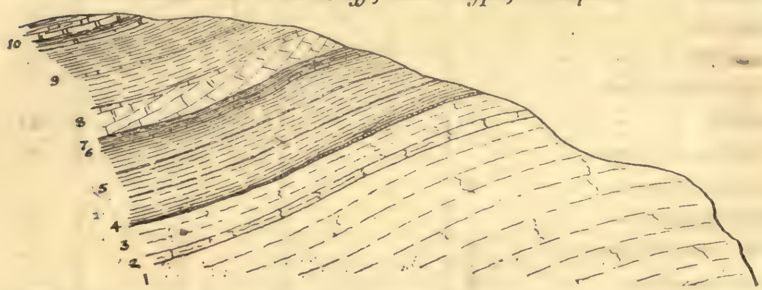
* Called Watton Hill by Buckland and De la Beche, Trans. Geol. Soc., ser. 2, vol. iv. p. 29.

reddish-brown, and containing many fossils. It forms a dark band in the cliff, at the base of the Forest Marble, and is the *Rhynchonella*-bed previously noticed near Langton Herring. It is again found in the cliffs above the Fuller's Earth at Cliff End east of Burton Bradstock.

At West Cliff the Forest Marble is about 80 feet in thickness. No traces of Cornbrash are now observable, although a small outlier was indicated on the Geological Survey Map (see p. 437): but its former presence denotes that the total thickness of the Forest Marble does not exceed 90 feet, and this accords with measurements made at Bothenhampton.

FIG. 99.

*Section at West Cliff, near Eype, Bridport.*




The divisions of the Forest Marble on the Dorsetshire coast are as follows (see Fig. 99):—

| | | FT. | IN. |
|---|---|---|---|
| Cornbrash. | | | |
| Forest Marble | 10. Flaggy blue limestone, showing ripple-marks, and clay or shales, with "race": the limestone, preponderating - - - | 10 | 0 |
| | 9. Clays with "race," shaly limestone, thin shelly limestone and thin leaves of sandy limestone, ferruginous in places: the clay preponderating - - - | 20 | 0 |
| | 8. False-bedded shell-limestones, sandy and oolitic in places, with irregular clay-seams, many ochreous galls, lignite: and with *Pecten*, *Ostrea*, and fragments of *Apiocrinus* - - 10 0 to | 15 | 0 |
| | 7. Grey clay (not persistent) - - | 3 | 0 |
| | 6. Hard white or grey marl, with thin seams of bluish shelly limestone - | 0 | 6 |
| | 5. Blue flaggy limestone-shales, and blue and yellow clays, with thin layers of calcareous grit covered with curious markings - - | 30 | 0 |
| | 4. Hard sandy marl stained reddish-brown: *Rhynchonella*-bed, with *Pecten vagans*, *Terebratula maxillata*, *Rhynchonella varians*, *R. Boueti*, *Serpula*, &c. - - | 1 | 2 |
| Fullonian (Fuller's Earth). | 3. Bluish-yellow marl, with impersistent band of hard fissile white marl - - - - | 9 | 0 |
| | 2. Hard fissile white marl - - | 2 | 9 |
| | 1. Grey marls, seen to thickness of - | 80 | 0 |

## LIST OF FOSSILS FROM THE FOREST MARBLE OF SOUTH DORSETSHIRE.*

E. Eype.
B Bothenhampton (collected by J. Rhodes).
C. Cliff End, Burton Bradstock; Bredy Hill; and Puncknoll.
H. Herbyleigh and Langton Herring.
R. Radipole.

| — | Lower Shale. | | | | Limestone. | | | | Upper Shale and Lime-stone. |
|---|---|---|---|---|---|---|---|---|---|
| Saurian remains - - - | | | | | | B | | | |
| Hybodus - - - - | | | | E | | | | | |
| Lepidotus - - - - | | | | | | B? | | | |
| Strophodus - - - - | | | | E | | B | | | B |
| Amberleya capitanea - - | | | | | | B | | | |
| Ceritella - - - - | | | | | | | | | B? |
| Cerithium costigerum - - | | | | | | | | | B |
| Littorina Phillipsi - . - | H | | | | | | | | |
| Nerita Buvignieri - - - | | | | | | | | | B |
| Pleurotomaria burtonensis - | H | B | | | | | | | |
| Turbo burtonensis - - - | H | | | | | | | | |
| —— sp. - - - - - | | | | | | | | | B |
| Anatina - - - . | | B | | | | | | | |
| Astarte fimbriata - - - | | | | | | | | | B? |
| —— sp. - - - - | | B | | | | | | | |
| Avicula costata - - - | H | | | | H | | | | B |
| Corbula attenuata - - - | | | | | | B | | | |
| —— Buckmani - - - | | | | | | | | | B? |
| Cyprina loweana - - - | | | C | | H | B | | | |
| Gervillia acuta - - - | | B | | | | | | | |
| —— sp. - - - - | H | | | E | | | | | |
| Leda lachryma - - - | | B | | | | | | | |
| Lima cardiiformis - - - | | | C | E | | B | C | | B |
| —— duplicata - - - | | | C | | | B | C | | B |
| Lucina burtonensis - - | | | C | | | | | | |
| Modiola furcata - - - | H | | | E | | | | | |
| —— imbricata - - - | | | | | | B | | | |
| Mytilus pectinatus - - | H | B | | | | | | | |
| Ostrea costata - - - | | | | | | B | | | |
| —— flabelloides - - - | H | | | | | | | | |
| —— gregaria - - - | | | | | | | | | B |
| —— lingulata - - - | H | | | | | B? | | R | |

* See also list by Wright, Quart. Journ. Geol. Soc., vol. xii. p. 310. A few specimens noted in that list may have come from the Cornbrash. The species above enumerated were collected mostly by myself.

## Fossils from Forest Marble of South Dorset.

| — | Lower Shale. | | | | Limestone. | | | | Upper Shale and Lime-stone. |
|---|---|---|---|---|---|---|---|---|---|
| Ostrea Sowerbyi - - - | | | | E | | B | C | | B |
| — subrugulosa - - - | | | | | | | | | B |
| Pecten annulatus - - - | | | | | | B | | | |
| — fibrosus - - - | | | | | | | | | B |
| — lens - - - - | | | | E | | B | C | R | B |
| — rigidus - - - - | | | | | | B | | | |
| — rushdenensis - - - | | B | | | | | | | |
| — vagans - - - - | H | B | | E | | B | | | B |
| Trigonia Moretoni - - - | H | | C | | | | | | |
| — pullus - - - - | | | | | | B ? | | | |
| — scarburgensis - - | | | | | H ? | | | | |
| — sculpta - - - - | | | | | H | B | | | |
| — undulata - - - | | | | | | | | | B |
| — sp. - - - - - | | | | E | | | | | |
| Unicardium varicosum - - | | | | | | B | | | |
| — sp. - - - - - | | B | | | | | | | B |
| Rhynchonella Boueti - - | H | B | | E | | | | | |
| — concinna - - - | | | | | H | B ? | | | |
| — Morièrei - - | | | C ? | | H ? | | C ? | | |
| — obsoleta - - - | | | | | | B ? | | | |
| — spinosa, var. bradfordensis - | | B | | | | | | | |
| — varians - - - | H | | C | E | | | C | | |
| Terebratula coarctata - - | H | B | | | | | | | |
| — maxillata - - - | H | | | E | H | B | | | |
| Waldheimia digona - - | H | | | E | H | | | | |
| — obovata - - - | H | B | C | E | H | | | | |
| Diastopora diluviana - - | H | | | E | H | | | | |
| Entalophora straminea - - | | B | | | | B | | | |
| Stomatopora dichotomoides - | H | | | | | | | | |
| Serpula intestinalis - - | H | B | C | E | | | | | |
| — tetragona - - - | | B | | | | B | | | |
| — tricarinata - - - | H | | C | | H | | | | |
| Acrosalenia spinosa - - | H | | | | | | | | |
| — sp. - - - - - | | B | | | | B | | | |
| Cidaris bradfordensis - - | H | | | | | | | | |
| Apiocrinus Parkinsoni - - | H | | | | H | B | | | B |
| Pentacrinus Milleri - - | | | | | | | C ? | | |
| — sp. - - - - - | | B | | | | | | | B |
| Montlivaltia - - - | | B | | | | | | | |
| Thecosmilia - - - | | B | | | | | | | |
| Peronella pistilliformis - - | H | | | | | | | | |

*Beaminster to Sherborne.*

Leaving the neighbourhood of Bridport and Weymouth, where the strike of the Forest Marble is east and west, we find the outcrop concealed for some distance by the Cretaceous rocks. About a mile north of Beaminster a small area of Forest Marble was mapped by H. W. Bristow, and he also observed an inlying mass by the village of Rampisham. A specimen of lignite from Rampisham, now in the Museum of Practical Geology, shows borings of *Lithodomus*.

North of this tract we come upon the main outcrop of the Forest Marble, and this although displaced and interrupted here and there by faults, forms the most prominent of the well-marked escarpments in the Jurassic rocks of Dorset and south-east Somerset. (See Fig. 134, p. 460.)

The general section of the strata does not differ materially from that exhibited at Eype and Bothenhampton, but nowhere until we approach Bradford-on-Avon, has any exposure been observed of the *Rhynchonella*-bed, though it is probable that a careful search in some of the lane-cuttings may reveal its presence. Birts Hill and Abbots Hill, south of Pendomer, and the ridge on which Hardington stands, form the westerly portion of the main escarpment. Quarries may be seen here and there in the stone-beds, but they exhibit few features that call for special remark. Near East Field, Hardington, the stone includes occasional lenticular or spheroidal masses of sandy and oolitic limestone. The stone is quarried south of Yetminster, but some of the best material has been obtained from openings to the north of Long Burton village, south of Sherborne. Here we find from 12 to 15 feet of false-bedded shelly limestones, in layers from 2 to 9 inches thick, and overlaid by clay. The stone is much jointed and separated by partings of clay. The joints in places have been enlarged by meteoric agencies, and the spaces are filled with clay. *Ostrea Sowerbyi* is abundant, and species of *Pecten, Rhynchonella,* and a good deal of lignite occur.

The thickness of the Forest Marble of Dorsetshire has been stated by Bristow to be as much as 450 feet, but this was probably based on an estimate given by Buckland and De la Beche, who included the Fuller's Earth.* There is reason to believe that the formation attains its greatest thickness near Sherborne, where it forms the high grounds of Lillington and Gainsborough Hills. The following section in the road-cutting at West Hill, south of that town, indicates a thickness of about 130 feet. The upper portion was measured by H. W. Bristow, and the lower portion (subsequently) by myself:—

* Trans. Geol. Soc., ser. 2, vol. iv. p. 29; Bristow, in Report Coal Commission, vol. ii. p. 456.

| | | Ft. | In. |
|---|---|---|---|
| Cornbrash | Rubbly limestone, with *Avicula echinata.* | | |
| Forest Marble | Pale clay passing down into blue marl - | 50 | 0 |
| | Hard grey gritty limestone - - | 1 | 6 |
| | Sandy clay with thin beds of shale - | 9 | 0 |
| | Calcareous grit embedded in foxy sand: very hard band, splitting into flags, which have a blue core - | 9 | 0 |
| | Clay with thin bands of stone - - | 12 | 0 |
| | Hard calcareous grit - - - | 1 | 0 |
| | Fissile shelly and oolitic limestone 10 0 to | 12 | 0 |
| | Bluish-grey and yellow mottled clays, with thin layers of gritty limestone, showing tracks of invertebrata - | 30 | 0 |
| | Hard blue-hearted limestone - - | 0 | 9 |
| Fullonian (Fuller's Earth). | Clay - - - - - - | 6 | 0 |
| | Shelly layer with *Ostrea.* | | |
| | Hard earthy marl. | | |
| | Shaly clays. | | |

The lowest beds grouped with the Fuller's Earth were not very clearly exposed. The beds of calcareous grit and gritty limestone (noticed by Bristow) are of interest, as indicating the local development of beds of this character, which are of importance at Charterhouse Hinton and other places.

### *Sherborne to Wincanton.*

The escarpment of the Forest Marble, which is displaced by a fault to the east of Sherborne Park, continues from Holt Hill, north of Bishops Caundle by Bullstake Hill to Bowden. Here the shelly and oolitic limestones have been quarried for ages—the "Bowden Marble" having had a local repute; and beneath about 10 feet of clays, with thin beds of limestone, we find about 20 feet of very shelly and slightly oolitic limestones, the upper beds of which are reckoned the best.

The limestones at Bowden are shown in greater thickness than elsewhere, and yet in the railway-cutting (L. & S.W.R.) less than one mile to the north, no prominent mass of limestones is apparent. The junction with the Cornbrash is shown west of Templecombe station, and thence we pass (westwards) through upwards of 50 feet of shales and marly clays with thin bands of shelly limestone and fissile earthy limestone. Some of these limestone-bands, which are false-bedded, expand in thickness westwards, but they appear to be of an inconstant character and to be developed on slightly different horizons.

The cuttings in the lower beds are so much obscured that no details can be made out. It is however remarkable that the mass of limestones seen at Bowden, does not manifest itself, for the beds could hardly be concealed beneath the top-soil of the cuttings. Moreover further north at Windmill and Charleton Hills, near Charleton Horethorne, the limestones appear in force: so that although the Forest Marble is an uncertain formation, subject to abrupt changes, it may be that the limestone-beds along the line of the railway, are cut out by a fault that runs obliquely across the strike. Some of the thin layers of limestone in this cutting were crowded with minute Gasteropods, but the species were not determinable.

The following fossils were collected by Mr. J. Rhodes and myself at Templecombe junction :—

| | |
|---|---|
| Cerithium. | Ostrea |
| Dentalium. | Pecten annulatus. |
| Astarte. | —— rigidus. |
| Avicula costata ? | —— vagans. |
| Corbula. | Placunopsis socialis. |
| Leda lachryma. | Trigonia pullus ? |
| Lima duplicata. | Rhynchonella obsoleta. |
| Modiola. | Waldheimia digona. |
| Nucula. | Serpula tetragona. |

### *Wincanton to Frome.*

The Forest Marble has in old times been quarried to the west of Wincanton, by Bratton church; and in recent years it has been worked near Holebrook House, where soft sandy beds and clay-seams occur among the shelly and oolitic limestones. Quarries again are met with at Higher Knoll, south of Redlinch, where the shelly and oolitic limestones are shown to a depth of 15 feet. Little or no clay occurs here between the stone-beds, but they are rough and irregular, much fissured and coated with lime-wash and stalactitic deposits. The lower clayey beds were exposed in the lane leading towards Shepton Montague.

Continuing along the outcrop, through Redlinch Park, we find occasional quarries; those situated to the north of Scale Hill, south-east of Batcombe, exhibiting about 12 feet of false-bedded oolitic and shelly limestone with horizontal bands of clay, separating these obliquely bedded masses of stone, as seen in sections near Cirencester. The thickness of the Forest Marble here was estimated at 42 feet by De la Beche, but it is probably more than twice as great.*

West of Lineham's Barn, to the south of Wanstrow, and again to the south-east of the village, near Studley Farm, there are quarries showing from 7 to 12 feet of false-bedded shelly and oolitic limestone, and decomposed shelly and sandy limestone. South-east of West Cranmore the beds rise in a bold escarpment, and this extends by Cloford and Marston Bigot to Frome. At Cloford the thickness of the Forest Marble was estimated to be 130 feet by Bristow.

It will be noticed that in this neighbourhood as we approach the Mendip Hills, and onwards towards Cirencester, the occurrence of sandy beds in the Forest Marble is a marked feature.

At Bull's Quarry, Marston Bigot, the stone has been worked along the dip-slope, but although the openings are now abandoned, we may observe clay and thin stone, resting on thick and thin false-bedded oolitic and shelly limestone, with beds of yellow sand and streaks of laminated clay.

* Mem. Geol. Survey, vol. i. pp. 280, 285.

The Forest Marble forms the high ground on which the town of Frome is built. The shelly limestones, which are of a durable nature, form an escarpment that extends from Innox Hill, by the railway-station, through the town, and westwards from Gibbet Hill towards Marston: thus forming a sort of amphitheatre, which overlooks the vale of Fuller's Earth clay and rock, &c.

Both south and north of Phœnix Hall, Frome, the stone (locally called Frome Stone), has been dug to depths of from 12 to 15 feet or more: it consists of false-bedded oolitic limestone, with clayey and sandy layers. The stone, from a few inches to 1 foot in thickness, is employed for building walls, for flagstone, &c.; and many houses in Frome are built of it, for it stands the weather well.

South of Frome Station we find, in a quarry and in the railway-cutting, about 20 feet of false-bedded oolitic and shelly limestone with clay-seams, overlaid by greenish clay and stone-beds; and in the cutting south of Southfield Farm, shelly and oolitic limestone and the overlying clays are exposed, but no traces of Cornbrash were to be seen. East of Frome Station, the railway-cutting showed the upper Forest Marble clays, with thin films of calcareous grit.

*Frome to Charterhouse Hinton.*

In the area between Frome and Bradford-on-Avon we find the most interesting development of the Forest Marble, including the fossiliferous beds at the base, known as the Bradford Clay, and also the sands and hard calcareous sandstones of Charterhouse Hinton and other places.

So variable are the beds seen in different sections, that it is exceedingly difficult to correlate them and draw up a general table of sequence. This was attempted by Lonsdale, but the sections he gives in support of his subdivisions, tend to prove rather the variable character of the strata than any regular or persistent sequence. The following may be taken to be the general assemblage of beds:—

| | | Ft. | In. |
|---|---|---|---|
| Cornbrash. | | | |
| Forest Marble | 5. Clays with bands of false-bedded limestone - - - - | 15 | 0 |
| | 4. Sands and concretionary masses of calcareous sandstone (Hinton Sandstone) - - - - | 30 | 0 |
| | 3. Shelly and oolitic limestone - - | 12 | 0 |
| | 2. Clays and shelly limestones - - | 20 | 0 |
| | 1. Clay with fossiliferous bed at base (Bradford Clay) - - - | 10 | 0 |
| Great Oolite. | | | |

The above table does not differ essentially from the succession given (about the year 1800) by William Smith,* nor from that more elaborately stated by Lonsdale.† The beds however are

* Memoirs of W. Smith, by J. Phillips, p. 59.
† Trans. Geol. Soc., ser. 2, vol. iii. p. 255.

not so largely worked as was the case 40 and more years ago, and we have to rely on fewer sections to build up our sequence.

The lowest beds are rarely exposed, but clays with *Waldheimia digona* were proved in the Coal-boring south-west of Buckland Denham and north of Barrow Hill. In quarries in this neighbourhood we may see flaggy calcareous sandstones with ochreous clayey galls, separated by beds of laminated clay and sand. Slabs of the rock show ripple-marks and tracks of invertebrate animals. These beds were exposed to a depth of 10 feet, in a quarry one mile south-west of Buckland Denham; and they occur above layers of thin shelly and oolitic limestone, that were exposed in a deep lane north of the village. Lonsdale placed these sandy beds in the lowest part of the Forest Marble, but they appear to me to be approximately on the horizon of the Hinton Sandstone. Shells have been noticed in the sands of this neighbourhood.*

Two shafts were sunk near Buckland Denham about a mile apart, by Mr. James Oxley of Frome. After passing through the Bradford Clay, Fuller's Earth Series, and Inferior Oolite (of which no details are preserved), the Lias was reached at depths of 160 to 240 feet, and from 60 to 80 feet of Lower Lias, &c. was penetrated before the Rhætic Beds were touched.†

Old quarries along the scarp by Kingsdown north of Mells, indicate about 10 feet of good stone; shelly oolitic limestone, capped by 2 feet of rubbly beds. On the exposed faces of the stone the beds have become much decomposed.

Further north, near Ammerdown Cottages, we find about 6 feet of fissile false-bedded shelly, oolitic, and sandy limestones, alternating with yellow sands. Again to the north-west of Kinglands Farm, between Kilmersdon and Faulkland, a large pit had been excavated to a depth of about 40 feet, through false-bedded flaggy limestone with clay bands, into a series of hard stone beds alternating with sands. These beds yield few fossils, but *Ostrea Sowerbyi*, *Terebratula maxillata* (occasionally), *Rhynchonella*, and a good deal of lignite may be obtained. In this region the shelly and oolitic limestones appear to blend with sandy strata, the latter becoming more distinct and the former less prominent, between Norton St. Philip and Charterhouse Hinton. That the more sandy strata occur above the mass of the shelly and oolitic limestones, is indicated by a pit between Cock road and Port way, to the south-west of Laverton. Nearer to Laverton a quarry showed 8 feet of strata, comprising alternations of shelly and oolitic limestone and shelly and sandy limestone, with buff sands streaked with clay.

To the south-east of Hinton Field Farm, south of Charterhouse Hinton, there is a pit to which I was conducted in 1886 by the Rev. H. H. Winwood. The following beds were exposed:—

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* A. C. Crutwell, Geology of Frome, 4to Frome, 1881, p. 16.
† *Ibid.*, p. 14, and Geol. Mag. 1874, p. 96.

| | | Ft. | In. |
|---|---|---|---|
| Forest Marble | Buff sands with large concretionary masses or "doggers" of calcareous sandstone. Some of the beds are very fissile. Lenticular masses and thin seams of loam occur here and there, in which some Foraminifera and an Ostracod were found* | 24 | 6 |
| | Sand and another layer of stone (not worked) - - - 8 0 or | 10 | 0 |

These beds are the "Hinton sand and sandstone" of William Smith, the name being employed by him about the year 1800, and being published in 1813 by the Rev. Joseph Townsend.†

Lonsdale who has given a particular account of these beds, remarks that "Patches or small almond-shaped nodules of soft clay are often imbedded in the stone; and on being removed, by exposure to the weather, the emptied cells give it a vesicular appearance. Organic remains are not universally disseminated through the grit, but in some localities they are sufficiently numerous to compose the principal part of the block or stratum and convert it into an impure shelly limestone."‡

At Ridge or Rudge near Westbury, in Wiltshire, a pit showed the following section:—

| | | Ft. | In. |
|---|---|---|---|
| Forest Marble | Clays, flaggy, sandy and shelly limestones, and marls; Thick bed of shelly limestone; Clay and sand | 7 | 6 |
| | Fine white and buff calcareous sand with large "doggers" of concretionary sandstone. Clayey streaks occur near the top | 12 | 0 |
| | (Water at base of pit.) | | |

The upper beds are somewhat tumbled and irregular. The sandy beds evidently represent the Hinton Sandstone, and some of the concretionary masses, as remarked by Lonsdale, assume the form of "pot-lids."

East of Telisford, just above Vaggs Hill Farm, we find hard compact and rather gritty limestone, surmounted by clays, which underlie the Cornbrash. A quarry east of Farleigh showed the same succession, as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Forest Marble | Clay with "race" and thin bands and films of sandy limestone | 6 | 0 |
| | Sandy and slightly oolitic limestone with calcareous sandy layers; false-bedded towards the base | 6 | 0 |
| | Blue and grey shelly oolitic limestone | 4 | 0 |
| | Soft rotten shelly oolite, with clay-galls | 1 | 0 |

* See T. R. Jones, and C. D. Sherborn, Geol. Mag., 1886, p. 273.

† Memoirs of W. Smith, p. 59; and Townsend's Character of Moses, p. 15.

‡ Trans. Geol. Soc., ser. 2, vol. iii. p. 256.

A number of fossils were obtained by W. Walton of Bath, from a shelly marl exposed in a "cutting opposite Wick Farm-house, made in forming the new Warminster Road, west of Farleigh."*

### *Bradford-on-Avon to Corsham.*

### Bradford Clay.

The Bradford Clay came into notice during the latter part of the 18th century, on account of the local abundance of the Crinoid, now known as *Apiocrinus Parkinsoni.* The fragments of the stalk and body of this fossil were called "Coach-wheels," by the quarrymen, and many of these being obtained by the Rev. Benjamin Richardson, from a quarry at Berfield (Burfield or Bearfield) on the north side of Bradford-on-Avon, the fossil came to be known as the "Berfield fossil" and "Bradford Encrinite."† The name "Pear Encrinite" was also given from the form of the calyx and upper stem-joints. The earliest reference to it appears to be in the work of Walcott, but it was first figured and described by Parkinson.‡

The deposit was originally mentioned by William Smith as "Clay over Upper Oolite," and the term Bradford Clay, derived from Bradford-on-Avon in Wiltshire, seems to have been first used by J. De Carle Sowerby in 1823.§

As a formation the Bradford Clay (like the Stonesfield Slate) is local and insignificant: it consists of pale grey marly clay with thin layers of tough limestone and calcareous sandstone, and it usually includes a rich fossil-bed at the base. It may in fact be looked upon as the local basement-bed of the Forest Marble. It could not be separately laid down on the Geological Survey map, and was considered by Prof. Hull,‖ as by Lonsdale, to be simply a local division of the Forest Marble.

Although the fossils that particularly characterize the bed, are not always present, yet we have evidence that the horizon extends southwards to the Dorsetshire coast, and northwards to the neighbourhood of Cirencester.

In the district around Bradford-on-Avon, the most southerly evidence of the bed is that noticed in the Coal-boring at Buckland Denham. It has been observed also at Farleigh and near Broadfield Farm, Charterhouse Hinton. Sections are now to be seen at Upper Westwood, by the lime-kilns south of Bradford-on-Avon, and by the Melksham road, east of the town; those to the north of the town at Berfield, being closed. Nor are there

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* Supp. Monograph on the Mollusca from the Great Oolite, &c., by J. Lycett (Pal. Soc.), p. 118.

† Townsend, Character of Moses, p. 268.

‡ Organic Remains, vol. ii. 1808, p. 208; J. Walcott, Description and Figures of Petrifactions found in the Quarries, Gravel Pits, &c. near Bath. 8vo. London, 1779, p. 46.

§ Mineral Conchology, vol. v. 1823.

‖ Geol. Cheltenham, p. 69.

to be seen any openings that show the Bradford Clay in the escarpment north of Winsley.*

The thickness of the Bradford Clay does not exceed 10 feet at Bradford-on-Avon, but it has been estimated to be thicker near Farleigh, where however other portions of the Forest Marble have been doubtless included.

It seems evident that locally there was some pause in deposition between the Great Oolite and the Bradford Clay, for the Crinoids or "stone-lilies" must have flourished in clear water on the floor of Great Oolite, before the muddy sediments of the Bradford Clay were laid down. Moreover it has been noticed that some of the Crinoids have been covered with Serpulæ, and afterwards encrusted with Polyzoa.†

In other localities, when we get no distinctive evidence of Bradford Clay, there was probably no pause in deposition, no growth of Crinoids, and no accumulation of organic remains to form a fossil-bed. The Great Oolite and Forest Marble are then more or less interblended, and it is hard to say where the stratigraphical division should be made.

The fossils of the Bradford Clay include the following species:—

Arca minuta.
Avicula costata.
Corbicella subangulata.
Cyprina islipensis.
Lima duplicata.
Modiola furcata.
—— imbricata.
Nucula Waltoni.
Ostrea gregaria.
—— lingulata.
—— Sowerbyi.
Pecten vagans.
Rhynchonella concinna.
—— obsoleta.
—— varians.
Terebratula coarctata.
—— maxillata.
Waldheimia cardium.
—— digona.
Apiocrinus Parkinsoni.
Acrosalenia spinosa.
Cidaris bradfordensis.
Serpula grandis.
Terebellaria ramosissima.

A very fine collection of fossils from the Bradford Clay was made by J. Chaning Pearce, who residing for a time at Bradford-on-Avon, obtained splendid specimens of the "Bradford Encrinite," when the clay was removed from the surface of the stone during the working of the quarries.‡ Mr. William Cunnington also obtained many specimens.§ Some Foraminifera and Ostracoda have been procured from the marly clay above the fossil-bed.||

The best section I saw of the Bradford Clay, was shown to the south of Bradford-on-Avon, in a quarry north of the lane leading to Upper Westwood: it was as follows (see Fig. 100):—

* See William Smith, Strata Identified; and Lonsdale, Trans. Geol. Soc., ser. 2, vol. iii. p. 255.

† Witchell, Geol. Stroud, p. 82.

‡ See Proc. Geol. Assoc., vol. ix. p. 165; vol. xiii. p. 152. The Pearce Collection is now in the possession of Dr. J. C. Pearce at Ramsgate.

§ Mag. Wilts Nat. Hist. Soc., vol. vi. p. 10.

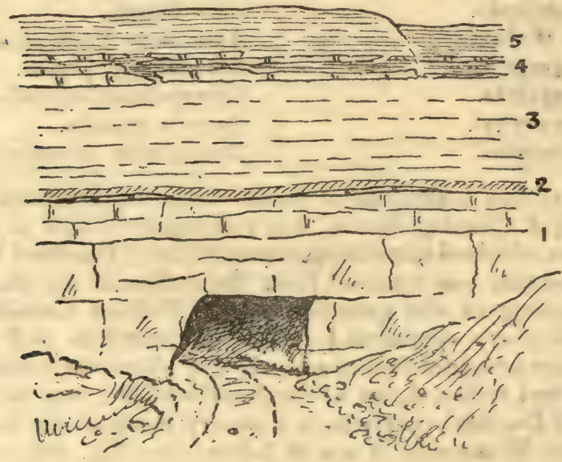
|| T. R. Jones and C. D. Sherborn, Geol. Mag. 1886, p. 273.

| | | | | Ft. In. |
|---|---|---|---|---|
| Forest Marble | 5. Clay and thin stone - - - - | | | 6 0 |
| | 4. False-bedded oolitic limestone - - | | | |
| Bradford Clay | 3. Grey marly clay much like the Fuller's Earth clay of Eype: few if any fossils - - - | | | about 10 0 |
| | 2. Fossil Bed. | Marly clay, here and there cemented into a tolerably hard bed by calcareous matter, and with an impersistent layer of shelly limestone (6 to 8 in.) at the base - - | 1 ft. 3 in. to 2 ft. | |
| Great Oolite | 1. Shelly oolite and hard brown marly oolitic limestone. | | | |

The Fossil-bed yields *Apiocrinus Parkinsoni*, *Pentacrinus* (fragments), *Waldheimia digona*, *Terebratula maxillata*, *T. coarctata*, *Rhynchonella concinna*, *R. obsoleta*, *R. varians*, *Avicula costata*, *Corbicella subangulata*, *Lima*, *Ostrea gregaria*, *O. Sowerbyi*, *Pecten vagans*, *Vermilia* (*Serpula*) *sulcata* ?, &c.

Fig. 100.

*Section near Upper Westwood, Bradford-on-Avon.*




Slabs of the shelly Forest Marble yield *Serpula*, *Rhynchonella*, *Ostrea Sowerbyi*, *Pecten vagans*, and *Cerithium*.

A section very similar to that above noted, was exposed by the Lime-kilns to the south-east. Here the beds, as noticed by Townsend, are at a much lower level than the same strata at Berfield. Evidently the fault traced on the Geological Survey map through Westwood village, should be continued further to the north-east, probably traversing obliquely the tunnel east of the Bradford-on-Avon railway-station.

Above the Bradford Clay near Bradford-on-Avon, we find beds of shelly and earthy limestone, with much clay and marl, and thin leaves of sandy limestone with curious tubicolar markings. Locally I saw no evidence of any thick series of limestones, and no evidence of the Hinton sand and sandstone. The beds at Westwood, and again at Frankley north of Bradford-on-Avon, are mainly argillaceous, with occasional bands of stone: so that the shallow wells sunk into this formation obtain but limited and uncertain supplies of water.

Further north, between Monkton Farley and Atford, the stone-beds are again of importance. Lonsdale noted 10 feet of "shelly limestone, split into thin layers obliquely to the plane of stratification," at the Wormwood quarry, on the high road from Bath to Devizes. Here there was no evidence of the Bradford Clay, for these beds rested directly on the Great Oolite freestone.* North of Atford, an old quarry showed the following strata :—

| | | Ft. | In. |
|---|---|---|---|
| Forest Marble | Brown sands with fissile concretionary masses of grey calcareous sandstone | 6 | 0 |
| | Thin flaggy and sandy beds, and false-bedded shelly oolitic limestones | 13 | 0 |

Water being held up at the base of the pit, indicated a clay-foundation. In this neighbourhood some of the beds have, in old times, been used as stone-tiles.

The occasional absence of the Bradford Clay (as an argillaceous deposit) was shown also at the stone-quarry north-east of Monkton Farley church, where about 15 feet of false-bedded brown shelly and sandy oolite, with sandy layers and ochreous galls, rested immediately on the Great Oolite. These shelly basement-beds on Farley Down, yield *Waldheimia digona, Ostrea Sowerbyi,* and *Rhynchonella.* On Bathampton Down, moreover, we find in the surface-strata of rubbly stone and marl, fragments of *Apiocrinus Parkinsoni,* spines of Echini, *Terebratula coarctata,*† *Rhynchonella, Lima duplicata, Ostrea Sowerbyi,* &c., that indicate traces of the Bradford Clay, or of strata equivalent to it. Hereabouts and at Corsham there is evidence of a more intimate connection between the Bradford Clay and Great Oolite than we find to be the case at Bradford-on-Avon.

In the railway-cuttings near Corsham station, the Forest Marble and Bradford Clay may be seen resting on the Great Oolite. This is the locality known as Pound Pill, from which W. Walton obtained many fossils. The Forest Marble consists of grey clays and shales with thin flaggy and gritty limestones, together with false-bedded flaggy oolitic and shelly limestones.

* Trans. Geol. Soc., ser. 2, vol. iii. p. 258.

† This species was figured by Walcott from specimens obtained from Kings Down and Hampton Down, near Bath.

These beds have been exposed in the cutting east of the station, and although now a good deal obscured, a thickness of about 50 feet may be traced as we proceed westwards. The junction with the Great Oolite is seen west of the station, and there we find laminated shaly beds, and grey and yellow marl, that yield the characteristic fossils of the Bradford Clay, resting on the Great Oolite. These basement-clays of the Forest Marble are thus found to be variable and impersistent in character; grey marly clays occurring in lenticular masses above the false-bedded Great Oolite, and becoming more and more interstratified with bands of dark grey limestone in their course westwards towards the tunnel. Hence it is difficult to follow the precise horizon of the Bradford Clay in this direction, and the band of fossiliferous clay appears to die out. In this way we can understand its absence at Monkton Farley.

The Great Oolite itself contains a lenticular bed of bluish-grey marly and oolitic clay 18 inches thick in places; and the mass of the rock exposed here, occurs in obliquely-bedded layers alternating with bands of harder oolite. The details of the junction were more readily to be noted in a quarry not far distant, near Brickers Barn.

Judging by well-sections the total thickness of the Forest Marble in this area is from 60 to 100 feet, the strata becoming thinner towards Chippenham, while they may be a little thicker near Atford. At Corsham the subdivisions proved in a boring for Messrs. Randell, Saunders, & Co., were as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Forest Marble | Brown and blue clay and shale | 37 | 6 |
| | Clay with bands of stone | 12 | 9 |
| | Hard blue stone | 6 | 7 |
| | Hard dead sand | 1 | 0 |
| | Stone and clay | 10 | 5 |
| Great Oolite | Hard and soft stone | 16 | 3 |
| | | 84 | 6 |

A pit north-west of Brickers Barn, Corsham, showed the following section*:—

| | | Ft. | In. |
|---|---|---|---|
| Forest Marble | Greenish marly and racy clay | 1 | 0 |
| | Very shelly and oolitic limestone (irregular and impersistent): with *Ostrea Sowerbyi*, *Cyprina islipensis* | 0 | 3 |
| | Oolitic and gritty limestone | 1 | 0 |
| | Shelly and oolitic limestone | 0 | 6 |
| | Grey marly and racy clay with thin layers of sandy limestone | 6 | 0 |
| | Hard blue oolitic and flaggy limestone | 0 | 6 |
| | Clays, and thin flaggy layers of sandy limestone with curious markings and perforations; and a thin shelly layer with *Apiocrinus Parkinsoni*, *Cidaris*, &c. These beds pass down into | | |

* See also Lonsdale, section at Cross Keys, 9½ miles from Bath towards Chippenham. Trans. Geol. Soc., ser. 2, vol. iii. p. 258.

| | | Ft. | In. |
|---|---|---|---|
| Bradford Clay | Grey marly clays with bands of hard grey marly and shelly limestone: with *Ap. Parkinsoni, Terebratula coarctata, T. maxillata, Waldheimia digona* (variable), *Rhynchonella concinna, R. obsoleta, Ostrea,* &c. - | 6 | 0 |
| Great Oolite - | Hard brown oolitic limestone - - - Buff shelly and oolitic limestones - - - | 6 0 to 7 | 0 |

From the Bradford Clay and Forest Marble at Corsham, I obtained the following fossils :—

Saurian bone.
Strophodus.
Actæonina.
Ataphrus (Monodonta) Labadyei?
Cerithium.
Nerinæa.
Astarte.
Avicula costata.
Cyprina islipensis.
Lima.
Modiola furcata.
—— imbricata.
Ostrea costata.
—— gregaria.
—— lingulata.
—— Sowerbyi.
Pecten vagans.
Unicardium varicosum.
Rhynchonella concinna.
—— obsoleta.
—— varians.
Terebratula coarctata.
—— flabellum.
—— maxillata.
Waldheimia digona.
Alecto.
Diastopora.
Heteropora.
Terebellaria ramosissima.
Apiocrinus Parkinsoni.
Acrosalenia spinosa.
Cidaris bradfordensis (spines).
Serpula.
Isastræa.

In the railway-cutting west of Laycock, a number of fossils were obtained by W. Walton, from the Forest Marble, "a cream-coloured clay, containing shells better preserved than usual."*

Traces of Forest Marble were observed in the valley, and in the cutting east of the railway-station at Trowbridge.†

### *Corsham to Malmesbury.*

The quarries north-west of Corsham, near Upper and Middle Pickwick, have been long since abandoned, but others are worked here and there as we proceed towards Cirencester.

The Bradford Clay has been noted near Giddy Hall, north-west of Biddestone, and again near Yatton Keynell, but it was not clearly exposed at the time of my visit to these localities in 1886: I obtained fossils however that proved its presence at Yatton Keynell. (See p. 269.) Further evidence of it occurs in the lane below West Keynton Church, where resting on the false-bedded Great Oolite, there was a bed of marly clay 2 to 3 feet thick, yielding *Waldheimia digona, Rhynchonella,* and other fossils. The Great Oolite here, as at Corsham, contains marly layers in its upper part, and these become more prominent near Cirencester, where there is a greater difficulty in separating the Great Oolite

* Lycett, Supp. Monograph on the Mollusca from the Great Oolite, &c., p. 118.
† R. N. Mantell, Quart. Journ. Geol. Soc., vol. vi. p. 312.

from the Forest Marble. Above the Bradford Clay at West Keynton we find beds of fissile and false-bedded oolite, resembling Great Oolite, but on the west and north-west side of the village, there are shallow quarries showing 4 or 5 feet of fissile shelly limestone and oolite, with ochreous galls and layers of grey clay. These beds yield crushed specimens of *Rhynchonella,* also *Terebratula maxillata, Ostrea lingulata, Pecten vagans,* spines of Echini, and joints of *Apiocrinus.* Northwards the Forest Marble occupies an extensive area around Badminton, on the dip-slope of the Cotteswold Hills.

Near Castle Combe and Yatton Keynell the stone-beds are very variable in character. To the west of Giddy Hall, we find false-bedded sandy and oolitic beds, quarried to a depth of about 16 feet, with 6 feet of grey clay at the base; and east of Castle Combe we find the oolitic and sandy beds surmounted by yellow sand and fissile calcareous sandstone, like the Hinton beds.

The highest beds of the Forest Marble were exposed south of Lower Stanton, near Stanton St. Quintin, where beneath the Cornbrash there occur blue clays with thin gritty layers, exhibiting the peculiar trails or tracks so characteristic of the Forest Marble. The evidence of this succession is confirmed by a section at Kington Bottom, near Kington St. Michael, recorded as follows, by Lonsdale* :—

| | | Ft. | In. |
|---|---|---|---|
| Cornbrash. | | | |
| Forest Marble | Clay - - - - - | 15 | 0 |
| | Sand containing large masses of calcareous grit, some of which are partially oolitic and shelly - - | 9 | 0 |

Near Malmesbury we find a considerable development of the sandy beds. A cutting by the railway-station showed thick beds of flaggy and concretionary sandstone, together with oolitic shelly limestones and white sands, resting on about 20 feet of flaggy calcareous grits and shales, the former showing ripple-marks and trails. On the road to Tetbury, north of Brokenborough, there is a large quarry showing the following beds :—

| | | Ft. | In. |
|---|---|---|---|
| Forest Marble | Blue and brown clay with thin layers of gritty limestone, and occasionally thicker irregular bands of calcareous sandstone - - - - | 10 | 0 |
| | False-bedded oolitic limestones, with much lignite, rotten ochreous galls, and partings of ochreous clay - | 12 | 0 |

The beds appear to rest on clay, as shown by the water held up at the bottom of the quarry. Fossils may be obtained, including *Pecten annulatus, Ostrea Sowerbyi, Rhynchonella,* &c. In this neighbourhood, and probably at this quarry, the Crab *Palæinachus longipes* was obtained by William Buy, and afterwards described by Dr. Henry Woodward.†

* Trans. Geol. Soc., ser. 2, vol. iii. p. 257.

† Quart. Journ. Geol. Soc., vol. xxii. p. 493.

Again in a quarry south of Newnton House, two miles S.E. of Tetbury, the following section was to be seen:—

| | | Ft. | In. |
|---|---|---|---|
| Forest Marble | Grey clay - - - - | 1 | 6 |
| | Calcareous sandstone with carbonaceous specks, and oolite: the former passing into sand, with impersistent hard beds which are flaggy and ripple-marked, and sometimes concretionary: the oolite at various horizons - - - - | 9 | 6 |

The general section in this part of Wiltshire may be stated to be as follows*:—

| | | Feet. |
|---|---|---|
| Forest Marble | Clays with thin bands of gritty limestone - - - - - - | 10 to 15 |
| | Sands and calcareous sandstone - | 5 to 10 |
| | Oolitic and sandy limestones, passing down into more shelly limestones and clays - - - - | 20 to 30 |
| | Bradford Clay - - - - | 2 to 6 |
| | Total thickness about | 60 |

### *Swindon and the London area.*

Towards Swindon the Forest Marble appears to be considerably reduced in thickness, as shown by the records of well-borings at Chippenham (see p. 507), and of a well-sinking made by the Great Western Railway Company at Swindon.

The Great Oolite was not actually proved at Swindon, but the fossils from the Forest Marble indicated the basement-portion of that formation, and we have evidence of only 33 feet of the strata. (See p. 515.) In this sinking the beds penetrated at depths of from 703 feet to 736 feet, proved to be Forest Marble. The fossils were chiefly obtained from the lowest part, about 730 feet, in the thin clay-partings of harder shelly rock: and the following species have been identified:—

Cerithium.
Arca.
Avicula.
Lima duplicata.
Modiola imbricata ?
Ostrea gregaria.
—— lingulata ?
—— Sowerbyi.
Pecten lens.
—— vagans.
Rhynchonella concinna.
Terebratula coarctata.
Waldheimia digona.
—— obovata.
Diastopora diluviana.
Entalophora straminea.
Terebellaria ramosissima.
Acrosalenia (spines and plates).
Cidaris (spine).
Pentacrinus scalaris.
Serpula tetragona.
—— tricarinata.
(Lignite).

I descended the shaft, in company with Mr. E. T. Newton, but it was not possible to note any details of the strata *in situ*. The

* See also Lonsdale, Proc. Geol. Soc., vol. i. p. 415; and Hull, Geol. parts of Wiltshire, &c., p. 16.

fossils indicate the presence of the Bradford Clay. A large amount of saline water was encountered in this sinking.* (See p. 515.)

In 1882 a deep boring was commenced at Richmond, and this was carried to a depth of 1,409 feet in 1884. At the depth of 1,151 ft. 6 in. a bed of hard oolitic limestone was proved, and thence to a further depth of 87 ft. 6 in., beds belonging to the Great Oolite Series were penetrated.

These beds rested on variegated marls and sandstones probably of Old Red Sandstone or Devonian age (though grouped by some with the New Red Sandstone); and they were overlaid by Cretaceous deposits, the basement-beds of which contained some materials derived from the underlying beds of Great Oolite.

The details of the Great Oolite Series have been recorded by Prof. Judd and Collett Homersham as follows† :—

| | | Ft. | In. |
|---|---|---|---|
| [Forest Marble and Bradford Clay.] | Dark oolitic limestone - - - - | 5 | 0 |
| | Pale marly limestones with scattered oolite grains, and many Foraminifera - - - - - | 22 | 6 |
| | Dark oolitic limestones - - - | 10 | 0 |
| | Shelly limestone with fewer oolite grains, and many Foraminifera - | 11 | 0 |
| | Compact limestone with scattered oolite grains, fragments of shells, &c. - | 5 | 0 |
| | Blue clay with bands of limestone and many fossils - - - - - | 3 | 6 |
| [Great Oolite.] | Oolitic and shelly limestone - - | 17 | 0 |
| | Band of fuller's earth - - - | 0 | 6 |
| | Fine-grained oolitic limestone with much pyrites, becoming sandy lower down; and at its base a fissile calcareous and micaceous sandstone resembling Stonesfield Slate; *Acrosalenia*, and other fossils - - | 9 | 0 |
| | Oolitic limestones with many fragmentary shells, *Ostrea Sowerbyi*, &c. - | 3 | 6 |
| | Limestone with fragments of shells, a few grains of quartz and particles of anthracite - - - - - | 0 | 6 |
| | | 87 | 6 |

The age of these beds was recognized by Prof. Judd, who has given a full list of the fossils: many of these were obtained from the blue clay, which perhaps represents the Bradford Clay at the base of the Forest Marble. I have ventured to group the strata in accordance with this view. Among the fossils recorded are *Terebratula coarctata*, *T. maxillata*, *Cidaris bradfordensis*, numerous Polyzoa, &c.

In his account of an Artesian Well-boring made at Messrs. Meux and Co.'s brewery in the Tottenham Court Road, London,

* Quart. Journ. Geol. Soc., vol. xlii. pp. 293, 298.
† *Ibid.*, vol. xl. pp. 741, &c.

Prof. Prestwich noticed that at depths of from 1,000 to 1,064 feet the bore-hole "passed into a rock having the appearance of an oolite, being composed of a fine calcareous grit in a calcareous paste." Charles Moore also noticed "intercalated beds of oolitic limestone, which, but for their density, might have passed for great deposits of Oolite." Nevertheless the fossils were considered to indicate the Lower Greensand.* Moore likewise identified small grains of coal in the basement-beds.

The details of this boring (1,000 to 1,064 feet) may be summarized as follows:—

| | | FT. | IN. |
|---|---|---|---|
| Forest Marble, Bradford Clay, and Great Oolite. | Light-coloured limestone - - | 1 | 0 |
| | Seam of quartzite pebbles - - | 0 | 6 |
| | Sandy limestone - - - | 3 | 6 |
| | Light-coloured limestone, with traces of fossils - - - - | 29 | 0 |
| | Marly sand - - - - | 1 | 0 |
| | Light-grey limestone, with numerous fossils - - - - - | 24 | 0 |
| | Light-grey oolitic-looking rock - | 2 | 0 |
| | Rubbly stone and clay - - - | 3 | 0 |
| | | 64 | 0 |

Prof. Judd (who subsequently examined the specimens) remarked that bands of marl apparently alternated with the more solid beds of oolitic limestone; and among the fossils, he was able to identify *Terebratula maxillata*, *Waldheimia digona*, *Cidaris bradfordensis*, *Acrosalenia*, Polyzoa, and many other specimens, showing that the same beds met with at Richmond were present under London.† He thought that some of the coaly fragments might possibly have been derived from layers in the Jurassic beds; but he has noted the occurrence of anthracite and pebbles of Coal-measure sandstone, in the basement-beds of the Great Oolite at Richmond.

In 1882 a deep boring for the Southwark and Vauxhall Water Company, was commenced near the railway-station on Streatham Common, Surrey. After passing through Tertiary and Cretaceous strata to a depth of 1,081 feet 6 inches (the lowest bed then reached being Gault), the bore-hole penetrated beds belonging to the Great Oolite Series: a fact announced by Mr. Whitaker, in 1888.‡ After passing through 38 feet 6 inches of flat-bedded Oolitic strata, red rocks of the character of Old Red Sandstone were entered, and these older rocks appeared to dip at angles of 20° to 30°.

The following details of the Oolitic strata are abbreviated from those recorded by Mr. Whitaker, from information furnished by Mr. J. W. Restler, and from notes made by Mr. E. T. Newton:—

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* Quart. Journ. Geol. Soc., vol. xxxiv. pp. 912, 915, 916.
† *Ibid.*, vol. xl. p. 745.
‡ Rep. Brit. Assoc. for 1888, p. 656; Geology of London, vol. ii. p. 226.

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite Series. | Hard grey and cream-coloured limestone, mostly crowded with oolite grains, and with bits of shells: *Ostrea acuminata?* - - - about | 8 | 6 |
| | Greenish-grey sandy rock - - | 1 | 0 |
| | Hard grey calcareous sandstone - | 1 | 6 |
| | Limestone with *Ostrea*, and ? clay - | 2 | 6 |
| | Greenish-grey sandy clay, with *Ostrea acuminata* and Crustacean claw - | 2 | 0 |
| | Rock and clay - - - - | 10 | 0 |
| | Clay with occasional hard bands of limestone, &c., and with oolite grains in some layers: *Astarte* and other fossils (not determined): oolitic limestone at base - - - - | 13 | 0 |
| | | 38 | 6 |

I had the advantage of seeing the rock-specimens, and noticed examples of oolite and also of calcareous sandstone with scattered grains of oolite, that closely resemble specimens of Forest Marble from Tetbury. Mr. Whitaker has doubtfully classed the beds with the Forest Marble. I may add that rocks of similar lithological character occur in the Stonesfield Series at Througham Field near Bisley; and having regard to the occurrence of *Ostrea acuminata* I am disposed to group the strata with the Lower Division of the Great Oolite. It is interesting to note that the beds belonging to the Great Oolite Series under London, approximate in character rather to the beds exposed in Wiltshire, than to those that outcrop on the north in Bedfordshire.

A general section taken from Chatham to the neighbourhood of Faringdon, leads to the conclusion that, beneath the Cretaceous covering there is a denuded anticline of Jurassic rocks, for the Great Oolite alone has been found under London, and it is followed both eastwards and westwards by higher Jurassic strata.*

The occurrence of Lower Oolites has been notified in the deep boring at Shakespeare Cliff, Dover: beds of Bathonian age being said to be penetrated, and to overlie Coal-measures at a depth of 1,157 feet from the surface: a shaft being sunk 44 feet and a boring carried 1,113 feet, before the older rocks were reached.† As full particulars of the evidence on which the record is based, have not at present been made public, and as Middle and Upper Oolites are also stated to occur at the locality, further remarks will be left for the volume dealing with those higher members of the Jurassic system.

### *Cirencester and Tetbury.*

Attention was first drawn to the occurrence of the Bradford Clay near Cirencester, in 1847, by S. P. Woodward, then Pro-

* H. B. W., Proc. Geol. Assoc., vol. xii. p. 329.

† W. B. Dawkins, Nature, July 31, 1890, p. 320; Contemporary Review, vol. lvii. April 1890, p. 475; Trans. Manchester Geol. Soc., vol. xx. p. 502, and vol. xxi. p. 458. E. Lorieux, Ann. des Mines, ser. 9, vol. ii. p. 227; and F. Brady, Dover Coal Boring, June, 1892 (privately printed, see Nat. Science, vol. ii. p. 230).

fessor of Natural History at the Royal Agricultural College; and many of the specimens he collected are preserved in the College Museum. These were obtained, some from excavations on the College Farm, but most of them from the cutting beneath the Great Western Railway on the high-road (Akeman Street) between Tetbury and Cirencester.*

Similar evidence was obtained in the railway-banks at Kemble; near the Mount, Trewsbury Castle; at Ewen; at Smerrill Quarry, north-east of Kemble; and at Perry Moor, south of Oakley Park.

The section exhibited in the Tetbury road-cutting in 1886, was as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Forest Marble | Rubble and tumbled masses of fissile shelly oolite, with lignite. | | |
| Bradford Clay | Grey clay with thin rubbly beds of oolitic marly limestone - - | 3 | 6 |
| Great Oolite (Kemble Beds). | Pale shelly oolite - - - | 2 | 6 |
| | Brown marly oolite, and hard compact limestone with scattered oolitic grains - - - - - | 3 | 0 |
| | White and brown false-bedded shelly oolite - - - - - | 5 | 0 |

Fossils are fairly abundant in the Bradford Clay, and they indicate the same palæontological horizon as that at Bradford-on-Avon. The following species have been found in the Clay near Cirencester† :—

Ammonites discus.
Avicula costata.
Cardium.
Cypricardia caudata?
—— rostrata.
Myacites.
Ostrea acuminata.
Pecten vagans.
Trigonia costata.
Rhynchonella concinna.
—— spinosa var. bradfordensis.
Rhynchonella varians.
Terebratula coarctata.
—— maxillata.
Waldheimia cardium.
—— digona.
Serpula.
Apiocrinus Parkinsoni.
Cidaris (spines).
Cladophyllia.
Montlivaltia.

Remains of Fishes and Saurians have also been obtained.

The greatest thickness of clay, that in this neighbourhood may be grouped as Bradford Clay, appears to be 8 feet.

There is considerable difficulty near Cirencester and Minchinhampton in fixing a definite boundary between the Great Oolite and Forest Marble. This arises from the fact that the Bradford Clay is not persistent, and when present it is not always fossiliferous, while other clayey and marly beds occur at various horizons in the Great Oolite. We are however prepared for this state of things by the evidence afforded at Corsham; and we must be content with the knowledge that no persistent plane of demarcation

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* See Proc. Cotteswold Club, vol. i. p. 6; and J. Buckman, Quart. Journ. Geol. Soc., vol. xiv. p. 114, vol. xvi. p. 107. The railway-station formerly situated by the high-road was replaced by that at Kemble.

† See also Lycett, Cotteswold Hills, p. 106.

separates the divisions. Here and there we have a good base-line for the Forest Marble, and it may be possible on the 6-inch maps to separate the beds in a more systematic way than has been the case on the present Geological Survey Map. (See p. 271.)

The general section of the Forest Marble beds near Cirencester is as follows:—

| | | Feet. |
|---|---|---|
| Cornbrash. | | |
| Forest Marble | Grey and greenish-grey clay with thin gritty layers (showing curious trails of invertebrata); and occasional beds of sandy, oolitic, and shelly limestone - - - - - | 30 to 40 |
| | Here and there beds of sand and concretionary sandstone are met with - | 10 to 15 |
| | False-bedded shelly and oolitic limestone with clay-galls - - - | 8 to 10 |
| | Grey and blue marly clay and shale with "race," and thin layers and sometimes thicker inconstant beds of hard blue oolitic limestone and gritty limestone: at base, in places, the fossiliferous Bradford Clay - | 30 to 45 |

According to Prof. Hull the thickness of the Forest Marble at Coln Rogers is 40 feet, and at Tetbury about 60 feet; while in the well-boring at the "Cotswold Brewery," Cirencester, it proved to be 108 feet.

A small pit opened to a depth of about 8 feet by the road-side, north-east of Ewen, near Kemble, showed pale marly and racy clays with a band of shelly oolitic limestone, resting on pale shelly oolite (Great Oolite). From the clays I obtained the following species:—

Cypricardia caudata ?
Pecten vagans.
Ostrea.
Terebratula coarctata.
—— maxillata.
Waldheimia cardium.
—— digona.
Rhynchonella concinna.
—— spinosa, var. bradfordensis.
Montlivaltia.

By the Blue House, near the Thames and Severn Canal, north of Furzen Leaze, clay has been worked for repairing the Canal. The section, which I visited under the guidance of Prof. Allen Harker, was as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Forest Marble | Clay with thin layers of gritty limestone - - - - - | 1 | 6 |
| Bradford Clay | Grey racy clay - - - - | 8 | 0 |
| Great Oolite | Grey earthy and oolitic limestone. | | |

Here we do not find many fossils. *Rhynchonella* and spines of Echini may be obtained; and *Ostrea* and *Serpula* have been recorded by Prof. Buckman.* Probably the same clay-bed is exposed in the Trewsbury quarry, although its thickness there is

* Quart. Journ. Geol. Soc., vol. xiv. p. 124.

from 18 inches to 2 ft. 6 in., and, like the beds at Blue House, it yielded during my visit none of the distinctive species of the Bradford Clay.

Again at the old quarry, known as Jarvis's quarry, on the Tetbury road, 2 miles from Cirencester, we have the following section. (See p. 282) :—

| | | Ft. | In. |
|---|---|---|---|
| Forest Marble and Bradford Clay. | Soil and rubbly beds of oolite - - | 1 | 0 |
| | Pale grey marl - - - - | 2 | 0 |
| | Shelly oolite - - - - | 1 | 6 |
| | Grey marl with band of marly limestone - - - - - | 3 | 6 |
| Great Oolite - | Pale shelly current-bedded oolites - | 12 | 0 |

Although the grey marl overlying the Great Oolite does not appear to be fossiliferous, there can be no doubt that it represents the Bradford Clay. At the quarry a short distance to the south-west we find only the Great Oolite to be represented; and the same is the case at the Lime-kiln by the College Farm.

In the immediate neighbourhood of Cirencester, and to the north and north-east, as remarked by Prof. Buckman, indications of the fauna of the Bradford Clay are rare. *Waldheimia digona* has been recorded by F. Bravender, from a quarry on the south side of the town (see p. 283), but elsewhere we find alternations of clays or marls with oolites, exhibiting a passage upwards from the Great Oolite. The clayey beds often yield *Ostrea Sowerbyi* in abundance, but they mark no constant horizon: some beds clearly belonging to the Great Oolite and others to the Forest Marble.

While the lower portions of the Forest Marble are not always to be separated from the Great Oolite, the middle and upper divisions present the characteristic features of the formation, and may be readily identified.

Along the new railway between Kemble and Tetbury, these beds were exposed in cuttings south-east and south-west of Trouble House. The sequence shown was as follows :—

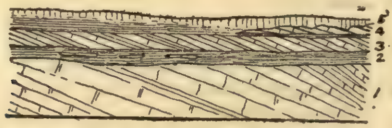
| | | Ft. | In. |
|---|---|---|---|
| Forest Marble - | Brown clay - - - - <br> Thin beds of limestone - - - | 1 | 6 |
| | Grey clay with thin layers of limestone | 6 | 0 |
| | False-bedded shelly and oolitic limestone, with seams of clay and clay-galls - - - - - | 12 | 0 |

At Chavenage, near Tetbury, roofing-tiles have been obtained from the Forest Marble. The beds here, as at Poulton, occur in thin layers, the surfaces of which abound with specimens of *Ostrea, Pecten, Rhynchonella, Lima,* &c. all much compressed and distorted.*

* Lycett, Cotteswold Hills, p. 106.

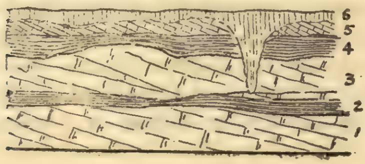
*Sections in the Forest Marble between Norcott and Wiggold, near Cirencester, on the Midland and South-Western Junction Railway.*

FIG. 101.



| | | Ft. | In. |
|---|---|---|---|
| 5. Red clay | - - - - - | 1 | 6 |
| 4. False-bedded limestone and clay | - - - | | |
| 3. False-bedded oolitic limestone | - - - | 1 | 6 |
| 2. Greenish clay with thin bands of limestone | - - | 1 | 4 |
| 1. False-bedded oolitic and shelly limestone | - - | 5 | 0 |

FIG. 102.



| | | Ft. | In. |
|---|---|---|---|
| 6. Red and green clay, filling "pipe" | - - | 1 | 6 |
| 5. False-bedded oolitic limestone | - - - | | |
| 4. Greenish clay | - - - - | 1 0o 1 | 6 |
| 3. False-bedded limestone | - - - | 3 0 to 4 | 6 |
| 2. Clay | - - - - - - | 1 | 0 |
| 1. False-bedded limestone | - - - | 3 0 to 4 | 0 |

FIG. 103

| | | Ft. | In. |
|---|---|---|---|
| 6. Reddish-brown clayey soil | - - - - | 5 | 0 |
| 5. False-bedded limestone | - - - - | | |
| 4. Clay with layers of limestone | - - - | | |
| 3. Curved beds of shelly oolitic limestone | - | 5 0 to 6 | 0 |
| 2. Clay | - - - - - | | |
| 1. False-bedded limestone | - - - | | |

The upper beds of the Forest Marble are shown in quarries at Ampney Crucis and near Driffield Cross. A quarry south of Ampney Park showed the following strata :—

| | | Ft. | In. |
|---|---|---|---|
| Cornbrash | Rubbly beds of marly and shelly limestone | 3 | 0 |
| Forest Marble | Brown and greenish-grey clay, with thin layers of sandy limestone and "race" | 6 | 0 |
| | Hard brown oolitic and shelly limestone | 3 | 0 |
| | Shaly bed (a few inches). | | |
| | False-bedded oolitic limestones. | | |

The above section, noted in 1886, differs considerably from one recorded in 1857 at the same locality by Prof. Buckman.* The evidence, however, afforded by the quarries and railway-cuttings, shows how rapidly the beds change in character.

In the railway-cutting west of the new Cirencester-town station, there was a considerable thickness of clay with thin bands of gritty limestone, beneath the Cornbrash. (See Fig. 131, p. 444.) Towards the east in the Norcott cutting this clay rests on a mass of fissile shelly and oolitic limestones, seen to a depth of about 8 feet. These stone-beds are false-bedded, and they contain lignite, *Lima cardiiformis*, *Ostrea Sowerbyi*, *Pecten annulatus*, *P. lens*, Fish-remains, &c. They rest on clays with beds of shelly oolite developed at inconstant horizons. Quarries south of Ampney Field Barn, west of Norcott, and south of Siddington St. Mary, showed 10 feet of these false-bedded oolitic and shelly limestones, with seams of clay and sandy layers. The stone itself contains marly and ochreous galls. Nodules perforated by boring Mollusca, and encrusted by Serpulæ and Polyzoa, have been noticed in the Forest Marble of this neighbourhood.†

The railway-cuttings to the north-west of Norcott, showed excellent sections of the Forest Marble, in alternations of obliquely bedded oolitic shelly limestone with irregular bands of clay and stone. In one place the shelly and oolitic limestones showed a series of curved beds, no doubt the result of irregular deposition, although presenting the appearance of denuded synclinal and anticlinal structures.‡ The evidence shows the inconstant nature of the stone-beds in the Forest Marble, for the clays swell out at the expense of the limestones in a very abrupt manner.§ The beds here shown belong to the middle and lower part of the Forest Marble. (See Figs. 101–103).

The stone-beds were exposed in a quarry near the 15th milestone, on the high-road east of Daglingworth, and here some of the limestones are more or less gritty in character.

Beds of flaggy calcareous sandstone (usually much ripple-marked), and loamy sands, with concretionary masses of stone, are quarried here and there, near Driffield Cross, Furzen Leaze, &c. They appear to occur generally above the main mass of

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* Quart. Journ. Geol. Soc., vol. xiv. p. 119.

† Morris, Geol. Mag., 1875, p. 267. Morris found 39 per cent. of silica in a specimen of Forest Marble from near Cirencester, p. 268.

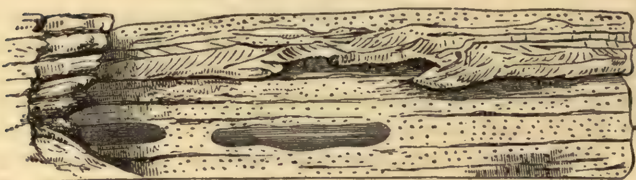
‡ Similar features, on a larger scale, have been noticed in the Frodsham Beds (Lower Keuper Sandstone) by Mr. A. Strahan, Geol. Mag. 1881, p. 396.

§ See also Hull, Geol. Cheltenham, p. 69.

shelly and oolitic limestones, evidence of which is furnished by a section at Pool Road Bridge, near Pool Keynes, south of Kemble, recorded by Prof. Buckman.* No beds of sand or sandstone appear to have been met with in borings through the Forest Marble at Cirencester; but Prof. Hull gives a section near Sandy Lane, south of Cirencester, showing "Slaty false-bedded oolite, with oysters," resting on "Soft yellow sands, with large blocks of chert."† (See Fig. 104.)

FIG. 104.

*Quarry near Sandy Lane, south of Cirencester.*
(Prof. E. Hull.)



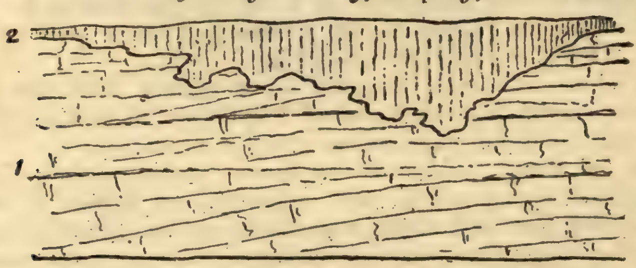

Forest Marble. { a. Slaty, false-bedded oolite, with oysters.
b. Soft yellow sands, with large blocks of hard siliceous limestone or calcareous sandstone.

In a quarry south-west of Long Furlong near Ampney (or Eastington), there were exposed about 10 feet of oolitic shelly and sandy limestones, with occasional layers of fissile micaceous and calcareous sandstone, and a few clay-seams (see Fig. 105). A considerable mass of these beds had been disintegrated and partially dissolved by atmospheric agents, to a depth of 5 feet and over a breadth of 25 feet.

West of Barnsley Church, there was a quarry showing about 3 feet of limestone with clay-bands, resting on 9 ft. 6 in. of false-bedded limestone with here and there horizontal partings of clay. The beds are used for tiling and road-metal.

FIG. 105.

*Section south-west of Long Furlong, Ampney, near Cirencester.*




| | Ft. | In. |
|---|---|---|
| 2. Reddish-brown loam - - - - - - - | 5 | 0 |
| 1. Forest Marble. Oolitic shelly and sandy limestone, with layers of fissile calcareous sandstone, and a few clay-seams - | 10 | 0 |

* Quart. Journ. Geol. Soc., vol. xiv. p. 119.
† Geol. parts Wiltshire (sheet 34), p. 15.

FIG. 106.

*Section through the Forest Marble and Great Oolite, Crickley Barrow, north-east of Coln St. Denis.*
(Prof. E. Hull.)

*a.* Forest Marble. Shelly oolite with oyster-beds.
*b.* Great Oolite. Hard, grey, and white sandy limestone, regularly bedded.

### *Cirencester to Fairford and Burford.*

The false-bedded layers of Forest Marble were well shown in a quarry at Crickley Barrow, north-east of Coln St. Denis, where the beds were seen to rest on the Great Oolite. The section was described by Prof. Hull.* (See Fig. 106.)

At Talland Quarry I noted the following section:—

| | | FT. | IN. |
|---|---|---|---|
| Forest Marble | Flaggy and rubbly stone | 4 | 0 |
| | Clays and thin fissile beds of oolite and gritty limestone | 8 | 0 |

On the thin gritty layers, many trails occur; and among the fossils I obtained *Pecten annulatus*, *P. lens*, *P. vagans*, *Ostrea Sowerbyi*, and *Rhynchonella*.

At Poulton Quarry (see Fig. 107) we find beneath from 2 to 4 feet of brown clay (2), an alternating series, 12 feet thick, of obliquely-bedded bands of oolitic limestone and grey clays (1). The limestone or "blue stone," occurs in thin flags which are largely employed for roofing-purposes, under the name of "Poulton Slates." From these beds I obtained *Rhynchonella obsoleta*, *Lima cardiiformis*, *Pecten lens*, *P. vagans*, and a large *Gryphæa*.

Towards Fairford the Forest Marble appears to diminish in thickness. South of Pilham Lodge, on the road to Quenington, we find a quarry exhibiting the following strata:—

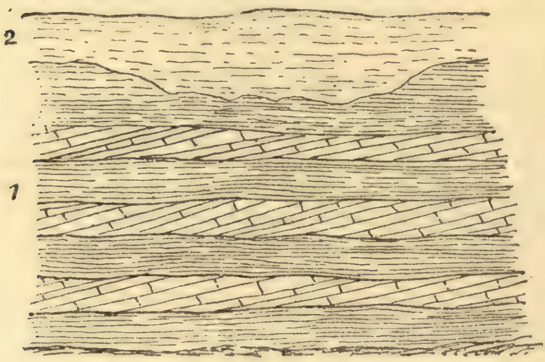
* Geol. Cheltenham, p. 71.

| | | Ft. | In. |
|---|---|---|---|
| | Soil | 1 | 0 |
| Forest Marble | Clays with occasional thin bands of stone | 3 | 0 |
| | Blue-hearted oolitic limestone and greenish clay, of variable thickness | 3 | 6 |
| | False-bedded oolitic limestones, with clay-galls, and seams of clay | 12 | 0 |

The beds are very irregular, the top clays appearing to scoop into the limestones, the result probably of irregular accumulation. Westwards the clays thicken at the expense of the limestone, for we find no conspicuous development of stone-beds in passing across the outcrop of the Forest Marble towards Honeycomb Leaze. In this area the famous Fairford Coral-bed was discovered, and referred by some to the Cornbrash, by others to the base of the Forest Marble (Bradford Clay). It belongs in my opinion to the top of the Great Oolite. (See p. 297.)

Fig. 107.

*Section at Poulton, near Fairford.*




2. Soil.
1. Forest Marble: quarried for "Slates."

Some of the fissile and obliquely-bedded masses of shelly and oolitic limestone are quarried for "slates" and "planking," south of Burford Signett and east of Holwell. The details vary in each opening. The stone-beds alternate with grey racy clays, and are exposed to a depth of from 6 to 12 feet. Some of the limestones are largely composed of spines of Echini, fragments as well as entire specimens of *Ostrea*, and fragments of *Rhynchonella*, together with lignite. From these beds I obtained some Gasteropods, and the following fossils:—

| | |
|---|---|
| Lima cardiiformis. | Pecten lens. |
| Modiola imbricata. | —— vagans. |
| Ostrea Sowerbyi (very abundant). | Rhynchonella. |
| | Serpula. |
| Pecten annulatus. | Acrosalenia? |

Other sections near Aldsworth and Bibury, have been described by Prof. Hull, who notices at the former locality the abundance of

Oyster-shells, which "form lenticular layers, in one instance, two feet in thickness, and extending several yards."*

At Norton Pits, N.W. of Norton Brize, an excellent section of the Cornbrash and Forest Marble has been exposed, indeed the beds have been quarried for many a year, the foreman telling me that in his early days (about 1845) as many as 20 teams of horses had been employed in carting the stone. In this and other cases, the introduction of railways has largely modified the trade, and here the distance from the railway has led to a great decline in the work done. The section was as follows:—

| | | Ft. | In. |
|---|---|---|---|
| | Brown brashy clay - - - | 0 | 8 |
| Cornbrash | Tough rubbly rudely-bedded, pale earthy and shelly limestone: used for road-stone and burnt for lime | 4 | 6 |
| Forest Marble | Irregular marly layer - ; Grey clay with ferruginous seams - - about | 2 | 0 |
| | Grey and buff shelly and oolitic limestone and close-grained gritty rocks:† false-bedded, very hard in places, and of irregular thickness: divided as follows:— Slatt; Strong lime; Planking vein; Soft bed; Freestone; Good weatherstone; Building-stone; Paving (ripple-marked slabs) - 12 0 to | 14 | 0 |

About 6 feet more of rock occurs below, but cannot be worked on account of water. Lignite is met with in the lower beds of the Forest Marble. In the Cornbrash I obtained *Waldheimia obovata*, *Terebratula intermedia*, *Homomya*, and *Avicula echinata*.

I found an indication of the Bradford Clay, in a pit to the south-west of Shilton, where the following section was exposed:—

| | | Ft. | In. |
|---|---|---|---|
| Forest Marble | Brown clay - - 6 in. to about | 3 | 0 |
| | False-bedded, buff and grey, shelly oolitic limestones - - 3 0 to | 4 | 0 |
| Bradford Clay | Pale marly bed (inconstant): *Waldheimia digona* (abundant), *Rhynchonella* - - - - about | 2 | 0 |
| Great Oolite | False-bedded marly, shelly, and oolitic limestone - - - about | 3 | 0 |

To the east of Shilton a quarry showed the Great Oolite, overlaid by a bed of grey clay about 6 feet thick, with sandy layers at its base. It yielded *Ostrea* but no other fossils.

The junction of the Forest Marble with the Cornbrash was shown in the "Quarry ground" west of Rock Farm, south of

* Geol. Cheltenham, pp. 70, 72.

† Among specimens from the Roman village at Silchester, some tesseræ were formed of rock very like the gritty stone of Norton Brize.

Shilton. Here there was no evidence of the hard gritty rocks seen at Norton Brize. The top bed of the Forest Marble consisted of clay, 1 ft. 8 in. thick, and beneath there were exposed about 17 feet of pale grey oolitic limestones and marly clays.

### *Wychwood Forest to Witney and Woodstock.*

In the region of Wychwood Forest, whence the Forest Marble derives its name, we find few open quarries, and none of any magnitude. The beds here occur in outlying masses separated from the main outcrop.

Near White Oak Green to the north-west of Hailey, there are sections showing the lower beds, as follows:—

| | | | Ft. | In. |
|---|---|---|---|---|
| Forest Marble | Grey clays with "race" and beds of flaggy shelly and oolitic limestone: *Ostrea* | 5 0 to | 6 | 0 |
| Great Oolite | Hard brown oolite; False-bedded oolitic and shelly limestones | about | 20 | 0 |

The lower beds were grouped with the Forest Marble by Prof. Hull,* and a similar grouping was adopted in reference to sections near Witney, that were noted by W. S Horton. Horton recorded the occurrence of *Rhynchonella concinna*, *Terebratula maxillata*, *Waldheimia digona*, spines of *Cidaris*, &c.; an assemblage that indicates the Bradford Clay. He states that the clay is divided by a thin band of slaty sandstone, which is capable of being dressed into a rough kind of roofing-tile.†

The record of a well-boring at the Police-station, Witney (1892), communicated to me by Messrs. Le Grand and Sutcliff, gives the following sequence ‡:—

| | | Ft. | In. |
|---|---|---|---|
| | Top soil | 4 | 0 |
| | Cornbrash | 10 | 0 |
| Forest Marble | Blue clay | 8 | 0 |
| | Forest Marble | 23 | 0 |
| | Dark clay and sand | 3 | 6 |
| Great Oolite | Grey earthy limestone | 7 | 6 |
| | Fine oolite | 4 | 0 |
| | | 60 | 0 |

To the north-east of Witney the outcrop of the Forest Marble is confined within comparatively narrow limits, although occasional outliers are found, as in Blenheim Park. Sections have been exposed near Handborough station and at Bladon, and they show that the Forest Marble has undergone great attenuation: this is

* Geol. Woodstock, p. 23.

† Geologist, vol. iii. p. 252.

‡ The record of another boring at Witney, carried through alternations of rock and clay to a depth of 270 feet, has been communicated to me by Mr. J. H. Blake. I leave the publication of this for the volume on the Middle and Upper Oolitic rocks, as the record is difficult to interpret, and it may then be compared with the Wytham boring.

also the case at Islip. A quarry north-east of Bladon showed the following section :—

| | | FT. | IN. |
|---|---|---|---|
| Soil | Brown brashy loam | 2 | 0 |
| Cornbrash | Hard brown and grey rubbly limestones, with *Terebratula intermedia*, &c. | 4 | 0 |
| Forest Marble | Blue and brown clay | 0 | 4 |
| | Fissile oolitic limestone | 0 | 8 |
| | Blue and brown laminated clay | 1 | 0 |
| | Clay with thin bands of shelly and oolitic limestone | 1 | 6 |
| | False-bedded brown oolitic limestones with *Rhynchonella* | 2 | 0 |
| | Blue clay (of irregular thickness), with lignite and compressed shells | 0 | 8 |
| | Blue and grey marly oolitic limestone (of irregular thickness) | 0 | 10 |
| | Dark blue and grey clay | 1 | 6 |
| | Buff and blue false-bedded oolite. Bottom beds used for building | 3 | 6 |
| | Thin clay (impersistent). | | |
| Great Oolite | Buff and blue oolitic and shelly limestones without clay-partings. (Building-stone.) Fish-remains - about | 10 | 0 |
| | ["Soft limestone, not worked."] | | |

The above grouping corresponds with that adopted by Prof. Hull.*

The lower beds here appear to be identical with the stone-beds worked in the quarry north-east of Handborough railway-station (see p. 319), and like them they contain palatal teeth of fishes.

The entire thickness of the Forest Marble was well shown in the cuttings of the branch-railway to Woodstock. (See Fig. 108.) The details are as follow :—

| | | FT. | IN. |
|---|---|---|---|
| Cornbrash (see p. 447). | | | |
| Forest Marble | Blue and greenish-grey clay with nodules of limestone | 6 | 0 |
| | Shelly oolitic and marly limestone, false-bedded - 1 0 to | 2 | 6 |
| | Blue and grey shaly clay and marly oolitic beds, with irregular layers of blue flaggy and false-bedded oolitic limestone | 11 | 0 |
| Great Oolite (see p. 320). | | | |

The Forest Marble is thus reduced to about 18 feet thick, and is in the main a clayey formation.

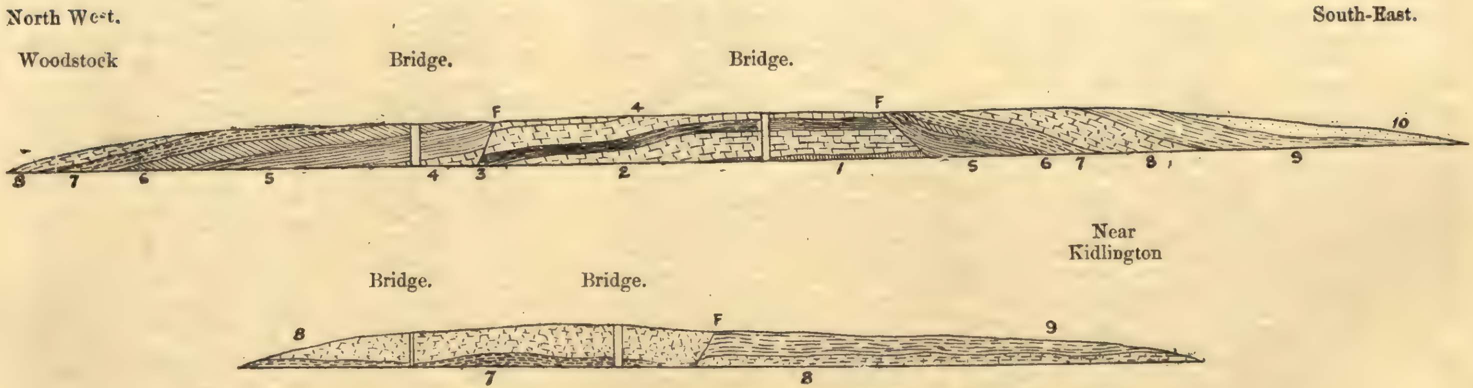
The beds have again been well exposed at the famous quarries near Bletchington railway-station. (See p. 321). On the eastern side of the railway, south-east of the station, the lower beds of the Cornbrash, and the whole of the Forest Marble were exposed, as follows :—

* Geol. Woodstock, p. 23.

FIG. 108.

*Sections along the Woodstock Branch Railway, Oxfordshire.*

(Distance within two miles. Vertical scale, 80 feet to one inch.)




10. Sands } Kellaways Beds.
9. Clay. }
8. Cornbrash.
7. Greenish-grey clay - - - - } Forest Marble.
6. Shelly oolitic and marly limestone - - }
5. Blue and grey shaly clay with occasional bands of oolitic limestone - - }

4. Oolitic and earthy limestones - - - } Great Oolite.
3. Black and green racy clay with lignite - - }
2. False-bedded oolite and shelly limestones - }
1. Marly limestone, Fossil-bed, with *Terebratula maxillata* - - - - }

| | | Ft. | In. |
|---|---|---|---|
| Cornbrash (see p. 447). | | | |
| Forest Marble | Dark clay and rubbly marl (tapering away to the north) - - - | 3 | 0 |
| | Oolitic calcareous sandstone and shelly oolite; resting on false-bedded shelly and oolitic limestones, with calcareous sandy layers, abundant ripple-marks, clay-galls, lignite, &c., and impersistent clay-beds - - - | 13 | 0 |
| Great Oolite | Hard grey oolite, the lower part iron-stained - - - - | 4 | 0 |

Here the Forest Marble is reduced to about 16 feet in thickness. There is a specimen of *Apiocrinus* from Kirtlington, in the collection of Mr. James Parker, of Oxford: the occurrence of this fossil is interesting, as no other record of it has been noted in the neighbourhood, not even at Islip where fossils indicating the horizon of the Bradford Clay have been found.

Towards Tackley, according to Prof. Hull, the Forest Marble becomes very thin, while in the direction of Middleton Stoney it is represented by clays overlying 5 or 6 feet of shelly oolite, with bands of clay.*

### *Chipping Norton to Epwell.*

Further to the north-west we find occasional outlying patches of Forest Marble.

In the cutting at Pest House, south-east of Great Rollright, on the railway from Chipping Norton to Banbury, the Cornbrash and Forest Marble have been exposed, attention being drawn to the sections by Mr. T. Beesley, Prof. Morris, and Mr. Hudleston.† The beds which I noted, were as follows :—

| | | Ft. | In. |
|---|---|---|---|
| Cornnbrash | Tough grey limestones (see p. 446) - | 6 | 0 |
| Forest Marble | Band of hard calcareous sandstone, and sandy shale - - - - | 1 | 0 |
| | Irregular false-bedded series of bluish shales, with thin beds of sandy limestone, and inconstant beds of oolitic limestone and calcareous sandstone; with much lignite - - - | 15 | 6 |
| | Blue shelly oolitic limestones with lignite - - - - - | 3 | 0 |
| | Yellowish marly clays with harder lumps of marl: *Ostrea Sowerbyi, Gervillia*, &c. - - - - | 2 | 6 |

A number of fossils were collected by Mr. Beesley, including Fish-remains, *Cyprina loweana, Ostrea Sowerbyi, Pecten annulatus, P. vagans*, &c., and I obtained *Gervillia crassicosta, Unicardium impressum*, and *U. varicosum*?

Another outlier of Forest Marble has been observed on the east of Tadmarton near Banbury. (See p. 335)

* See Hull, Geol. Woodstock, pp. 20 and 24.
† Proc. Geol. Assoc., vol. v. p. 177.

The most northerly outlier of the Forest Marble in this neighbourhood is situated south-east of Broomhill Farm, and N.W. of Epwell. The section was as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Drift soil | Brown clay, and irregular capping of loam with pebbles of quartz, quartzite, flint, and ironstone 1 6 to | 6 | 0 |
| Cornbrash | Rubble of grey shelly limestone, with *Terebratula intermedia*, &c. | 3 | 0 |
| Forest Marble | Grey marly clay, with thin films of sandy limestone | 6 | 0 |
| | Very shelly blue limestones with grey marly patches, and lignite | 0 | 8 |
| | Hard blue and grey limestones, obscurely oolitic | 1 | 0 |
| | Tough blue shelly limestone, with lignite<br>Irregular hard blue shelly limestone, slightly oolitic | 6 | 0 |
| | Blue shaly beds | 0 | 6 |
| | Hard blue limestone. (Water.) | | |

An adjoining quarry to the south of the above pit, showed the following beds:—

| | | Ft. | In. |
|---|---|---|---|
| | Brown clayey soil | 3 | 0 |
| Forest Marble | Impure gritty and obscurely oolitic limestones, flaggy and irregular | 1 | 8 |
| | Shaly beds | 0 | 8 |
| | Blue shelly limestones, false-bedded | 1 | 10 |

These quarries are opened in beds that present the general characters of the Forest Marble, but we do not clearly see the relations between the beds in the two quarries.

### *Islip, Bicester, and Buckingham.*

In the neighbourhood of Islip we have further evidence of the attenuation of the Forest Marble, which is shown beneath the Cornbrash in a quarry south-west of the church. The section was as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Cornbrash | Rubbly limestone with *Waldheimia obovata*, *Homomya*, &c. | 5 | 0 |
| Forest Marble and Bradford Clay | Grey clay with thin bands of limestone (impersistent) | 1 | 2 |
| | Fissile layers of brown sandy and false-bedded limestone, ripple-marked; with clay-bands | 1 | 0 |
| | Blue and grey laminated clay | 1 | 7 |
| | Hard grey marl with dark oolitic grains and many fossils: (impersistent) | 0 | 6 |
| | Grey marly clay | 0 | 6 |
| Great Oolite | Blue and yellow oolitic limestone, much false-bedded | 5 | 0 |

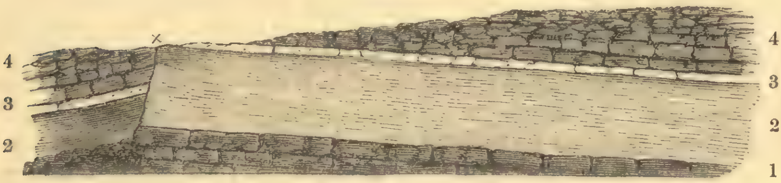
The fossil-bed yielded much lignite, and I obtained *Lima cardiiformis*, *Ostrea Sowerbyi*, *Pecten lens*, *P. vagans*, *Waldheimia cardium*, *W. digona*, *Rhynchonella concinna*, *Serpula*, Polyzoa, and spines of Echini.

Numerous fossils were collected many years ago by Mr. J. F. Whiteaves, from the Forest Marble at Islip and Kidlington.* Many of the specimens are now in the Oxford Museum: they include, from Islip, *Avicula costata, Corbula islipensis, Modiola imbricata, Terebratula maxillata, Terebellaria ramosissima*, and *Cidaris bradfordensis*, forms altogether indicative of the Bradford Clay, as suggested by Lycett.

The limestone at the base is probably the same as that exposed near the Handborough railway-station. Another section north of Islip, showing about 5 feet of Forest Marble was noted by Mr. W. Whitaker.†

FIG. 109.

*Section at the Brickyard, Blackthorn Hill, south-east of Bicester.* (Prof. A. H. Green.)




| | | Ft. | In. |
|---|---|---|---|
| | 4. Cornbrash - - - - | 4 | 0 |
| Forest Marble. | 3. Nodular white marly limestone - - | 0 | 9 |
| | 2. Light-blue laminated clay - - | 7 | 0 |
| | 1. Blue flaggy Forest Marble - - | 4 | 0 |
| | × Fault. | | |

Other sections of Forest Marble have been exposed in the low ridges of Oddington and Charlton, north-east of Islip, where the thickness of the beds is from 3 to 7 feet.‡

Occasionally we find a bed of flaggy oolitic limestone, as at Oddington, at the top of the Forest Marble: but near Bicester the upper beds comprise pale greenish-grey clays, that may be compared with the Great Oolite Clay of districts to the north-east.

Excavations at the Brickyard on Blackthorn Hill, south-east of Bicester, exposed some good sections of the Forest Marble; and these are described in the Chapter dealing with the Cornbrash (p. 448). It is interesting to note that fossils suggestive of the Bradford Clay occur here, as at Islip.

A boring (at Mr. W. Baker's) at Bicester, made in 1889 by Messrs. Le Grand and Sutcliff, commenced at the bottom of an old dug well, 21 feet deep (Cornbrash and Forest Marble), and passed

* Rep. Brit. Assoc. for 1860, p. 106; Green, Geology of Banbury, p. 29; Lycett, Supp. to Great Oolite Mollusca, p. 64; and Phillips, Geol. Oxford, p. 153.

† Green, Geology of Banbury, p. 35; and Hull, Explan. of Hor. Sections, Sheets 71 and 72 (Geol. Survey), p. 3.

‡ Green, Geology of Banbury, p. 36.

through 4 feet of green clay, and 19 feet of hard rock (Great Oolite).

The Forest Marble has been traced as far as Bucknell, near which a small outlier, described by Prof. Green, consists of "coarse, reddish brown, flaggy limestone, very much false-bedded." He adds that "Beyond this point the Forest Marble seems to thin rapidly away, and traces of it have been found only in a few places. It nowhere reaches a thickness of more than three or four [15] feet, and as it would have been impossible to trace so thin a bed over a drift-covered country, it has been left out on the map, except at those spots where sections prove it to be present."*

Sandy and marly clays and hard blue fissile limestones, with *Ostrea*, spines of Echini, &c. were seen in the valley east of Tingewick. These were grouped somewhat doubtfully with the Forest Marble by Prof. Green: but there can be little question that they form the commencement of the group which to the north-east is denominated "Great Oolite Clay." This group is practically equivalent to the Forest Marble. The section given by Prof. Green of the (now disused) clay-pit on the Bourton road, near Buckingham, showed beneath the Cornbrash, a thickness of about 15 feet, of blue clays with bands of sandy and marly limestone, that should be grouped with the Forest Marble.

The beds were more clearly shown at Lillingston Lovell, where the following strata were exposed in a quarry:—

| | | Ft. | In. |
|---|---|---|---|
| | Dark brown clayey soil. | | |
| Forest Marble | Rubble and white marl - - - | | |
| | Clay - - - - - - | | |
| | Current-bedded calcareous sandstone - | 3 | 0 |
| | Thin shale with gritty laminæ - - | | |
| | Blue shelly and oolitic limestones, rotten in places - - - | 6 | 0 |
| Great Oolite | Pale compact and shelly limestone, oolitic in places, with *Cyprina*, *Gervillia*, *Terebratula*, &c. - - | 1 | 7 |
| | Greenish-grey clay - - - | 0 | 4 |
| | Brown oolite. | | |

The top bed of the Great Oolite here resembled the upper bed in a quarry near Akeley Brickyard, and that in the Woodstock railway-cutting. The beds of Forest Marble are variable in character, and do not exceed 10 or 15 feet in thickness.

At Thornton to the south-west of Stony Stratford, the following section was noted by Prof. Green†:—

| | | Ft. | In. |
|---|---|---|---|
| Cornbrash - | | | |
| Forest Marble | Alternations of white, bluish, and brown clay, white beds of smooth, evenly jointed white marl - - | 10 | 0 |
| Great Oolite - | White shelly limestone. | | |

* Geol. Banbury, pp. 28, 29, 31.
† *Ibid.*, p. 28.

These beds are evidently the same as those exposed in the valley near Tingewick, and in the old clay-pit on the Bourton road near Buckingham.

In the Museum of Practical Geology there is a polished specimen of Marble from Buckinghamshire (see p. 481); and also some curious flat calcareous concretions (of the nature of "race") from the Forest Marble Clay at Graves' Brickyard, near Buckingham.

The blue shelly and oolitic limestones, that form the characteristic portion of the Forest Marble are now lost sight of, and beds resembling them are only occasionally seen further north, between Stony Stratford and Newport Pagnell, at Stowe-nine-churches, and elsewhere in Northamptonshire. These beds will be noticed under the heading of Great Oolite Clay; but other beds resembling the Forest Marble occur in the Great Oolite Limestone, as at Alwalton, south-west of Peterborough.*

* See also Judd, Geol. Rutland, p. 216. Some references to the Forest Marble and Cornbrash, near Gayhurst, are made in a paper by J. H. Macalister (Geologist, vol. iv. p. 215); he however has not distinguished between the Great and Inferior Oolite of the district. In a later paper (*Ibid.* p. 481), he has given lists of fossils from the Great Oolite Series of North Bucks, &c., but the horizons are not clearly separated.

# CHAPTER XIII.

## GREAT OOLITE SERIES.

### 2. Northamptonshire to Lincolnshire.

### General Account of the Strata.

In the area extending from Northamptonshire and Buckinghamshire, through Bedfordshire into Lincolnshire, the strata between the Inferior Oolite Series and the Cornbrash are divided as follows:—

Great Oolite Clay (Blisworth Clay).
Great Oolite Limestone.
Upper Estuarine Series.

In total thickness they vary from about 30 to a little over 100 feet.

A general description of each division will first be given; and the local details of the strata of the three divisions, may then most conveniently be described together. It may here be observed that for our particular knowledge of the strata in this area, we are indebted to Prof. Judd, whose observations were made during the course of the Geological Survey; to Samuel Sharp; and to the officers of the Survey who subsequently carried on the work in Lincolnshire.

It will be obvious that in this conformable and variable series, it is not possible to correlate exactly each portion of the strata with the divisions found in the area to the west and south-west. Even the above divisions are not likely to correspond more than approximately in the planes of division locally taken to separate them.

### Upper Estuarine Series.

The occurrence of fluvio-marine beds yielding plant-remains, *Cyrena*, &c., above the limestones of Ketton and Casterton (Lincolnshire Limestone), was pointed out by John Morris, in 1853, although the age of the underlying limestones was not at that time rightly interpreted, and the strata in question were regarded as the equivalents of the Forest Marble.*

To these strata Prof. Judd, in 1867, applied the name Upper Estuarine Series, and he then stated that they "appear to represent the Stonesfield Slate or Lower Zone of the Great Oolite of the South of England."†

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* Morris, Geol. Mag., 1869, p. 102.
† Geol. Rutland, pp. 90, 189.

The strata consist of blue, purple, white, and variegated clays of a more or less sandy character, with pyrites, selenite, lignite and occasional and irregular layers of limestone. In many of their characters, therefore, they resemble the Lower Estuarine Series, and when the two series come together it is difficult to distinguish them.

Prof. Judd remarks that "Interstratified with the clays are bands of sandy stone, with vertical plant-markings and layers of shells, sometimes marine, as *Pholadomya*, *Modiola*, *Ostrea*, *Neæra*, &c., at other times fresh-water, as *Cyrena*, *Unio*, [*Paludina*], &c. Beds full of small calcareous concretions and bands of "beef" or fibrous carbonate of lime, also frequently occur, and the sections sometimes closely resemble those of the Purbeck series. In its lower part this series consists usually, but not always, of white clays passing into sands." At the base of these clays there is usually found a thin band of nodular ironstone, seldom much more than one foot in thickness; this "ironstone junction-band" is generally conspicuous, and marks the limit between the Great and Inferior Oolite Series in the district. "There is very decided evidence of a break, accompanied by slight unconformity, between these two series in the Midland area. All the characters presented by the beds of the Upper Estuarine Series point to the conclusion that they were accumulated under an alternation of marine and fresh-water conditions, such as takes place in the estuaries of rivers." (See Figs. 48, 51, and 53, pp. 169, 188, and 191.)

The break to which Prof. Judd refers, is undoubtedly a well-marked one; but the unconformity is sometimes intensified by local dissolution of underlying calcareous beds. The ferruginous nodules, though generally found at the base, are not confined to that position; they are probably of much later date than the accumulations in which they occur.

The beds vary from 15 to a little over 30 feet in thickness. Near Northampton the thickness is 15 feet; near Bedford, 27 feet; at Aunby, near Essendine, 33 feet; at Heighington, south-east of Lincoln, it is 35 feet; and further north the beds diminish in thickness.

Prof. Judd remarks that, lying, as they do, upon a great mass of limestones (the Lincolnshire Oolite), the sandy clays of the Upper Estuarine Series are often found in "pipes," in consequence of the removal of the calcareous rock by subterranean waters, usually along lines of jointing. "Thus, patches of these strata are sometimes seen at considerable distances from their proper lines of outcrop; but such "outliers," are of course, on too small a scale to be represented upon the map." This mode of occurrence is similar to that noticed in the "Rift Bed" of the area near Chipping Norton. (See pp. 149, 325.) In that area the basement beds of the Great Oolite (Stonesfield Series), that are intimately linked with the Fuller's Earth, comprise marls and marly limestones, and yield, among other fossils, *Modiola imbricata*, *Ostrea acuminata*, *O. subrugulosa*, and *Rhynchonella concinna*.

Prof. Judd remarks that, "The marine shells of the series appear to be identical with those of the Great Oolite Limestones above, into which formation the beds we are describing insensibly merge."

The freshwater fossils are for the most part too badly preserved for specific determination; but much useful work might be done by geologists living in the district, in collecting and studying additional specimens. The only fresh-water species identified, is *Cyrena Cunninghami.* None of the plant-remains, so far as I am aware, have been determined. The "rootlets" occur at different horizons, and do not in themselves mark any important break.

The following list will show the character of the fauna of the Upper Estuarine Series; it is given mainly on the authority of Samuel Sharp.*

LIST OF FOSSILS FROM THE UPPER ESTUARINE BEDS.

| | |
|---|---|
| Teleosaurus. | Modiola imbricata. |
| Cerithium. | —— Lonsdalei. |
| Natica pyramidata. | Neæra Ibbetsoni. |
| Paludina. | Ostrea Sowerbyi. |
| Arca rugosa. | Pecten. |
| Astarte. | Pinna. |
| Avicula. | Pholadomya acuticosta. |
| Cardium Stricklandi. | Tancredia angulata. |
| —— subtrigonum. | —— axiniformis. |
| Cucullæa concinna. | —— planata. |
| Cypricardia bathonica. | Thracia. |
| —— caudata. | Unicardium gibbosum. |
| Cyprina loweana. | —— impressum. |
| Cyrena Cunninghami. | Unio. |
| Gresslya. | Rhynchonella concinna. |
| Lima. | Eryma (allied to) elegans. |
| Modiola gibbosa. | Acrosalenia. |

GREAT OOLITE LIMESTONE.

This division, which was so named by Prof. Judd to distinguish it from other local members of the Great Oolite Series, consists of grey, white, and sometimes pinkish limestone, with bands of marl, yielding *Ostrea Sowerbyi,* and *O. subrugulosa.*

Prof. Judd remarks that, "Sometimes the limestones consist of comminuted shells and then split up into thin flags like the Forest Marble of the South of England, for which they have been mistaken. Beds of this character are seen at Castor, Alwalton, &c. More usually the limestones are soft, white, and marly, abounding in casts of shells, those of the *Myadæ* being especially abundant."

Layers of rock that resemble the Forest Marble occur also at a higher horizon in the Great Oolite Clay.

"The limestones at the bottom of the series sometimes attain to a considerable thickness, and very occasionally, as near Brigstock and Stanion, exhibit traces of oolitic grains; but, as a general

* Quart. Journ. Geol. Soc., vol. xxix. p. 263.

rule, the Great Oolite of this district is everywhere distinguished from the Inferior by the total absence of oolitic structure. When dug under a considerable thickness of clay, all the beds are blue and of great hardness. Occasionally these beds become somewhat ferruginous, and are then, in their general aspect, scarcely distinguishable from the Cornbrash." This is more especially the case in some parts of Lincolnshire.

The thickness of the Great Oolite Limestone is from 25 to 30 feet near Bedford, about 25 feet at Northampton, and from 12 to 20 feet in Lincolnshire.

"There are many local variations in the character of its beds and in the general assemblage and facies of its fossils, which seem to indicate numerous changes in the depth and other conditions of the seas in which the beds were deposited. The graduation of the strata of the Great Oolite Limestone Series downwards into the Upper Estuarine Series, and upwards into the Great Oolite Clays is most perfect."*

Prof. Judd comments on the general similarity between the organic remains of the Great Oolite Limestone and those of the Cornbrash. The more abundant fossils of the Great Oolite Limestone, some of which are locally preserved, are *Nautilus Baberi, Cyprina loweana, Homomya gibbosa, Isocardia minima, Modiola gibbosa, M. imbricata, Ostrea Sowerbyi, O. subrugulosa, Pholadomya deltoidea, P. Heraulti*, and *Clypeus Mülleri.*

Remains of *Cetiosaurus* have been found at Blisworth, and elsewhere, and other remains of Saurians and Fish-remains are to be found.

## List of Fossils from the Great Oolite Limestone.

Cetiosaurus.
Hybodus.
Mesodon (Pycnodus).
Strophodus magnus.
Nautilus Baberi.
—— subtruncatus.
Natica globosa
—— pyramidata.
Nerinæa Voltzi.
Anatina siliqua.
Arca Pratti.
Astarte angulata.
Cardium subtrigonum.
Ceromya concentrica.
—— Symondsi.
Corbicella bathonica.
Cucullæa concinna.
Cypricardia bathonica.
—— rostrata.
Cyprina loweana.
Gervillia crassicosta.
Hinnites abjectus.
Homomya gibbosa.
—— Vezelayi.
Isocardia minima.
Lima cardiiformis.
Lima duplicata.
Lucina bellona.
Macrodon hirsonensis.
Modiola gibbosa.
—— imbricata.
—— Lonsdalei.
Myacites calceiformis.
—— securiformis.
Myacites tumidus.
Mytilus sublævis.
Nucula Menkei.
Ostrea acuminata.
—— Sowerbyi.
—— subrugulosa.
Pecten annulatus.
—— demissus.

* Judd, Geol. Rutland, pp. 202, 203; see also Aveline and Trench, Geol. part of Northamptonshire, p. 13; Morris, Geol. Mag., 1869, p. 101; Sharp, Quart. Journ. Geol. Soc., xxvi. p. 382, vol. xxix. p. 287.

Pecten lens.
Perna rugosa.
—— —— var. quadrata.
Pholadomya deltoidea.
—— Heraulti.
—— lyrata.
—— socialis.
Pinna ampla.
Pteroperna costatula.
—— plana.
Quenstedtia lævigata.
Tancredia axiniformis.
Thracia curtansata.
Trigonia costata.
—— Moretoni.
Unicardium varicosum.
Rhynchonella concinna.
—— varians.
Terebratula maxillata.
Acrosalenia hemicidaroides.
Clypeus Mülleri.
Echinobrissus Griesbachi.
—— Woodwardi.
Isastræa.
Thamnastræa.

## GREAT OOLITE CLAY (BLISWORTH CLAY).

These beds, so named by Prof. Judd,* present many characters similar to those of the Upper Estuarine Series. They comprise variegated, blue, green, yellow, purplish, and black clays, with irregular sandy, ferruginous, and shelly bands. Layers of "beef" occur, also crystals of selenite; and lignite, nodules of "race" and also of ironstone are met with. Very often there is a layer of ironstone-nodules at the base, but ferruginous bands occur also higher up. The beds are from 5 to about 40 feet thick—but usually a thickness of about 20 feet may be expected.

The term Blisworth Clay was introduced for the strata in 1870, by Samuel Sharp: at the same time he employed the name Great Oolite Clay for the beds known as the Upper Estuarine Series.† Later on he used the term Great Oolite Clay instead of Blisworth Clay. If, however, a distinctive local term be used, that of Blisworth Clay should be adopted.

Fossils, as a rule, are rarely to be obtained, but all those recorded are marine forms. Nevertheless, as remarked by Prof. Judd, it is not improbable that the strata are, in part at least, of estuarine character. The coloured clays which charaterize the strata, are suggestive of fluvio-marine conditions.

Oyster-beds with *Ostrea subrugulosa* occur; and it is noticeable that *Placunopsis socialis*, which is locally abundant, is elsewhere common in the Stonesfield Series. The beds are intimately linked with the Great Oolite Limestone below, and the division between them is mainly a lithological one that is not likely to be taken on a constant horizon.

The beds may be regarded as generally equivalent to the Forest Marble. They are, however, of little economic value, and sections are consequently scarce.

Allusion has been made to the attenuation of the strata in parts of Oxfordshire; and Prof. Judd remarks that, further to the north and north-east, in South Northamptonshire, &c., "it was found impracticable by the Geological Survey to map them separately, and hence they are in those districts grouped with the Great Oolite. As we go northwards into North Northampton-

* Geol. Rutland, pp. 9, 32, 186, 214.
† Quart. Journ. Geol. Soc., vol. xxvi. pp. 359, 380; and vol. xxix. p. 228.

shire and Lincolnshire, these beds of clay again thicken, and become of greater importance." Here and there, as at Stowe-nine-Churches, there are bands of limestone that present the characters of Forest Marble. Nevertheless in several areas, as near Oundle, the Great Oolite Clay was too thin and insignificant in its outcrop, to be separately shown on the Geological Survey Map.

### List of Fossils from the Great Oolite Clay.

Cetiosaurus.
Fish-remains.
Gervillia.
Modiola.
Ostrea gregaria.
—— Sowerbyi.
—— subrugulosa.
Placunopsis socialis.
Perna.
Trigonia.
Rhynchonella concinna.
Terebratula.
Serpula.
Foraminifera.

Fig. 110.

Ostrea subrugulosa, *Mor. and Lyc.*, × 1½.

### Local Details.

*Aynho to Brackley and Buckingham.*

In the country from Aynho to Towcester it is difficult to make any satisfactory divisions in the Great Oolite, for I know of no continuous section of the strata ; the Upper Estuarine Series and the Great Oolite Clay are not often exposed, and the Great Oolite Limestone is shown only in shallow quarries.

Here and there we may recognize at the base of the formation fissile and sandy beds, suggestive of the Stonesfield Slate (I.), but no definite correlation can be made ; and these beds rest on blue clay, that may be equivalent to the Fullonian Clay seen near Chipping Norton, but is (in the area to be described) more conveniently grouped with the Upper Estuarine Series.

Broadly speaking the beds may be divided as follows :—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite Clay. | Clay. | | |
| Great Oolite Limestone. | II. White limestones and occasional oolitic and shelly limestones, sandy beds, and layers of marl and greenish and dark clay ; with *Nerinæa*, *Ostrea*, *Trigonia*, *Pholadomya*, and Corals 12 0 to | 25 | 0 |
| | I. Fissile and false-bedded oolite and layers of marl ; *Clypeus Mülleri* - - | 10 | 0 |
| Upper Estuarine Series. | Dark blue clay - - - 1 6 to | 5 | 0 |

These strata rest on the Northampton Beds, in which term the Lower Estuarine Series and Northampton Sand may be included.

The divisions I. and II. will be noted in some of the sections to be described: they may to a certain extent correspond with the Upper and Lower Divisions of the Great Oolite elsewhere noticed.

In the neighbourhood of Aynho we meet with very fossiliferous beds of the Great Oolite. The white limestones have been quarried in Aynho Park, at Souldern, and Croughton. To the north-east of Aynho, the following section was noted* :—

| | | Ft. | In. |
|---|---|---|---|
| | Brown Clay - - - - | 2 | 0 |
| Great Oolite Limestone. | II. Rubby oolite - - - | 1 | 0 |
| | Whitish marl, in places crowded with fossils. *Cardium subtrigonum*, *Isocardia minima*, *Modiola imbricata*, *Myacites*, *Ostrea acuminata*, *O. Sowerbyi*, and *Rhynchonella concinna* - - | 4 | 0 |
| | I. Brown fissile and false-bedded shelly oolite, with clayey galls; spines of Echini - - - - | 1 | 2 |
| | Grey marl, with indurated and shelly bands - - - - - | 4 | 3 |
| | Brown shelly oolites, current-bedded, with spines of Echini and comminuted shells - - - - | 4 | 4 |

Many other fossils from Aynho have been obtained by Mr. Beesley. The beds may be compared with those noted at Tadmarton, and again at Kirtlington.

South-west of Hinton-in-the-Hedges the upper beds of the Great Oolite Limestone are worked for road-metal, in a shallow quarry which showed the following section :—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite Limestone. | II. White limestone (like White Lias) resting on hard grey shelly limestone, compact and oolitic, with *Trigonia*, *Myacites*, and *Pholadomya* - - - - | 2 | 0 |

North-west of Plowmans Furze the beds have been better exposed, and the following section was shown :—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite Limestone. | II. Rubbly white oolite - about | 3 | 0 |
| | White limestone, imperfectly oolitic: *Nerinœa*, Corals, and Spongiform bodies - - | 2 | 0 |
| | Grey marl - - - 0 10 to | 1 | 0 |
| | I. Brown shelly oolitic limestone - | 0 | 4 |

At Hethe the following section was recorded by Prof. Green :—†

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* See also section by T. R. Polwhele, in Green's Geol. Banbury, p. 18.

† Geol. Banbury, p. 18.

| | | Ft. | In. |
|---|---|---|---|
| | Surface soil with fragments of Cornbrash | 3 | 0 |
| [Great Oolite Clay.] | Laminated, dirty-blue clay, full of oysters - - - - | 4 | 0 |
| | White rubbly marl - - - | 2 | 0 |
| [Great Oolite Limestone.] | II. Hard, solid white limestone - | 3 | 0 |
| | Rubbly limestone and clay about | 3 | 3 |
| | Hard, solid, white limestone - | 5 | 0 |

Quarries near Evenly and Mixbury showed alternations of white limestone and clay, and pale sandy limestone and sandstone, from 8 to 12 feet thick. These sandy beds occur likewise in the area between Brackley and Buckingham.

A section on the railway at Gretworth (or Greatworth) beyond Farthingho, on the Banbury and Northampton line, was recorded as follows by Mr. Beesley* :—

| | Ft. | In. |
|---|---|---|
| Great Oolite (white limestones and marls). | | |
| Northampton Sand (pure sand) - - - - | 12 | 0 |
| Upper Lias. | | |

At the base of the white limestones and marls, beds of dark blue clay (Upper Estuarine Series) were observed at Souldern, Newbottle, and again between Brackley and Helmedon.†

In the section north-east of Newbottle Spinney, the clay was overlaid by flaggy beds of gritty and oolitic limestone. Similar beds were shown to the north-east of Newbottle church. They yield *Cardium subtrigonum, Modiola imbricata, Ostrea Sowerbyi* (and acuminate form), *Rhynchonella concinna, Terebratula maxillata,* and *Clypeus Mülleri.* (See Fig. 49, p. 176).

A number of sections between Brackley and Buckingham have been described by Prof. Green. Large quarries, between Westbury and Shalstone, showed the intercalation of sandy strata among the white limestones; and shallow quarries in the white limestones, showing shelly and oolitic beds, were to be seen south of Turweston and south-east of Fulwell near Westbury. Other sections were to be seen on the borders of Stowe Park and Whittlewood Forest.

The junction with the Forest Marble or Great Oolite Clay is difficult enough to determine, but we may confidently assign to that division the beds so indicated in the section at Thornborough, by Prof. Green. We may also group the similar beds, 8 feet thick, seen by Prof. Green, near Hogholes Farm west of Stowe; and the 3 or 4 feet of dark-blue clay seen on top of the Great Oolite at Buffler's Holt to the south of Stowe Park, at Radcliff west of Buckingham, and on the road to Gawcott, near Buckingham.‡

The following sections will be of service in showing the characters of the strata.

* Proc. Warwickshire Field Club, 1872, p. 37.
† Green, Geol. Banbury, p. 16.
‡ Geol. Banbury, pp. 20, 21, 32.

A section in a clay-pit (now abandoned), on the Bourton road, near Buckingham, showed, below the Cornbrash, the following strata, which were noted by Prof. Green * :—

| | | Ft. | In. |
|---|---|---|---|
| [Great Oolite Clay.] | Dark blue laminated clay | 0 | 4 |
| | White marly chalk-like limestone | 1 | 0 |
| | Hard yellowish sandy limestone | 1 | 0 |
| | Stiff blue clay, with broken shells, lignite, and pyrites | 5 | 6 |
| | Very stiff dark blue clay | 4 | 0 |
| | Blue and yellow mottled clay | 3 | 0 |
| [Great Oolite Limestone]. | White Limestone. | | |

These beds were regarded by Mr. T. R. Polwhele as about the horizon of the Forest Marble.

*Buckingham to Silverstone, Stony Stratford, and Newport Pagnell.*

At the Lime-kiln north of Boycot, the following section was shown † :—

| | | Ft. | In. |
|---|---|---|---|
| | Stony Drift Clay. | | |
| Great Oolite Limestone. | Rubbly stone | 1 | 0 |
| | Greenish clay, White Marl } Ostrea-bed | 1 | 6 |
| | Bands of marl and rotten marly oolitic stone, with occasional hard beds: *Nerinœa* abundant in top stone | 15 | 0 |

This section may be compared with that at Kirtlington, and with the beds 25, &c., in the railway-cutting near Hook Norton p. 330).

At the Lime-kiln, east of Silverstone, the strata shown were as follows :—

| | | Ft. | In. |
|---|---|---|---|
| Drift. | Gravel | 5 | 0 |
| | Stony clay, with Boulders (in part re-arranged Great Oolite Clay) | 8 | 0 |
| Great Oolite Limestone. | Rubbly stone and marl, with *Ostrea Sowerbyi*, and other Bivalves | 1 | 0 |
| | Rubbly oolitic stone | 3 | 0 |
| | Yellow oolitic limestone, rather a crumbly stone; otherwise in character like the Bedford Great Oolite | 9 | 0 |

*Ostrea acuminata* occurs in the top (Drift) clay.

In the valley south-west of Thornborough the following section was noted by Prof. Green‡ :—

* Green, Geol. Banbury, p. 31.
† See also Green, Geol. Banbury, p. 20
‡ Geol. Banbury, p. 21.

| | | Ft. | In. |
|---|---|---|---|
| Cornbrash. | Rubble | 2 | 0 |
| [Great Oolite Clay.] | White marly limestone | 0 | 6 |
| | Brown clay | 2 | 6 |
| | White marl | 3 | 0 |
| | Stiff blue clay | 4 | 0 |
| Great Oolite Limestone. | Hard grey evenly-bedded limestones, separated by bed of clay | 4 | 6 |
| | Rubbly marl, fossiliferous | 2 | 0 |
| | Hard whitish limestone | 3 | 6 |
| | White sand and sandstone | 2 | 9 |
| | Sandy clay | 0 | 9 |
| | Hard, brown limestone | 0 | 6 |
| | Clay | 0 | 9 |
| | Hard cream-coloured limestone | 2 | 0 |
| | Rubbly marl, *Lima cardiiformis* | 4 | 0 |

A small quarry by the Barn, N.E. of Akeley Brickyard, showed the following section. (See also Fig. 133, p. 450):—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite Clay. | Rubbly beds, and greenish clay, with *Ostrea*. | | |
| Great Oolite Limestone. | Compact shelly limestone (as at Woodstock and Lillingston Lovell) | 9 | 0 |
| | Marl | | |
| | Pale marly stone: Coral-bed, with Corals and *Lima cardiiformis* | | |
| | Marl | | |
| | Pale marly stone with scattered oolite grains | | |
| | Marl | | |
| | Oolite limestone | 3 | 0 |
| | Marl | | |

By the mill south-east of Maids Moreton the following beds were noted by Prof. Green:—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite Limestone. | Rubble and brown sandy oolite | 6 | 0 |
| | Soft white rubbly limestones and clays | 5 | 0 |
| | Brown sandy oolite, false-bedded | 8 | 0 |

These beds appear to belong to the upper part of the Great Oolite, for the Cornbrash was noted not far above. Sandy beds are also associated with the white limestones at South End, south of Leckhampstead; and probably the beds of "Cornbrash" with corals, noted by Prof. Green on the Stony Stratford road near Buckingham, should be included with the Great Oolite.* The beds seem to agree with those at Akeley.

In Long Copse, N.N.W. of Wicken, the beds are rich in fossils (as noted by Prof. Green); and *Modiola imbricata*, *Ostrea Sowerbyi*, *Trigonia*, and *Unicardium* may be found.† There are faulted remnants, I believe, of Oxford Clay, hereabouts, to which reference will be made in the volume on the Middle and Upper Oolites.

Sections showing the junction with beds that present the aspect of Forest Marble, have been shown at Lillingston Lovell and

* Geol. Banbury, p. 32.
† *Ibid.*, p. 22.

Thornton. (See p. 378.) Hard white and shelly limestones form the top portion of the Great Oolite, while lower down there are alternations of brown limestone and sandstone, the observed thickness at Thornton being a little over 12 feet.*

The occurrence in this area of thin layers of sandstone alternating with the limestones is of interest. Such sandy beds, as a rule, characterize the Lower Division of the Great Oolite, and more especially the Stonesfield Series in Gloucestershire and Oxfordshire. Prof. Green observed "beds of flaggy sandstone, plentifully marked by the tracks and sandy excrement of worms," in the quarries at Cosgrove.†

A quarry west of Deanshanger showed the following section:—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite Limestone. | Fissile oolitic limestone and rubble - ; Marly bed and greenish clay, with *Ostrea* - - - - - ; White fossiliferous marly beds, the top layer more or less oolitic - - | 6 | 0 |
| | Current-bedded gritty limestone 0 8 to | 1 | 0 |
| | Fissile marly beds - - - | 2 | 6 |
| | Oolitic limestones - - - | 3 | 6 |

These beds may be compared with those of Akeley Barn and Lillingston Lovell; and they occur in the upper part of the Great Oolite Limestone.

More important sections were shown in the quarries and brickyard at Deanshanger, where I noted the following sequence of beds:—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite Limestone. | Rubbly beds. | | |
| | Impure and oolitic limestones and seams of blue clay: the former worked for building-stone - - 8 0 to | 10 | 0 |
| | * * * * | | |
| | Shelly bed, with Echinoderms (*Clypeus Mülleri*) and Gasteropods - - | 1 | 6 |
| | Rotten marly and earthy beds - - | 2 | 8 |
| | Clayey bed - - - - | 0 | 6 |
| | Whitish marly stone - - - | 3 | 6 |
| Upper Estuarine Series. | Blue clay, with *Ostrea* and thin calcareous stone - - - - | 3 | 0 |
| | Grey marly bed - - - - | 0 | 6 |
| | Stiff blue, black, and greenish clay, with lignite (and bones, according to workmen) 3 ft. 6 in. seen. Said to be 18 feet altogether - - - | 18 | 0 |
| Lower Estuarine Series. | White Sand (yielding water). | | |

The clay is said to get white and sandy towards the base. The dark clays burn to a white brick, and the greenish clay burns to a red brick.

Clay for the old potteries of Potterspury, was obtained in Cosgrove Field; but the works have long been closed.‡

* Geol. Banbury, p. 28.

† These and subsequent notes by Prof. Green on the country near Stony Stratford and Newport Pagnell, are from his MSS., prepared for the Explanation of Sheet 46 N.W. of the Geological Survey Map.

‡ Morton, Nat. Hist. Northants, 1712, p. 72.

Here we have a passage from the Upper Estuarine Series into the Great Oolite Limestone, with intermediate beds that may be said to represent the Stonesfield Series.*

Prof. Green (MS.) mentions, that "An old brick-pit in Thornton, just opposite the turn to Beachampton, showed rubbly Cornbrash, resting on pale-blue sandy clay; the clay was said to be 15 or 20 feet thick." It would belong to the Great Oolite Clay.

A boring for the Waterworks at Stony Stratford (town) furnished the following section, of which the details were communicated by Messrs. Le Grand and Sutcliff (see p. 511):—

| | | Ft. | In. |
|---|---|---|---|
| | Soil and gravel | 9 | 0 |
| Great Oolite Limestone. | Clay | 1 | 0 |
| | Rock | 7 | 0 |
| | Sandy clay | 1 | 0 |
| | Limestone | 6 | 0 |
| Upper Estuarine Series. | Clay | 16 | 0 |
| Northampton Beds? | Rock | 0 | 10 |
| Upper Lias. | Clay with stone | 51 | 2 |
| | Stone | 1 | 0 |
| | Black clay | 2 | 0 |
| | Stone | 2 | 0 |
| | Clay | 0 | 6 |
| Middle Lias? | Stone | 6 | 0 |
| | Clay | 3 | 3 |
| | Clay and stones | 4 | 0 |
| | Black clay | 9 | 3 |
| | | 120 | 0 |

At Old Stratford borings have been made to depths of 109 and 115 feet, mainly through blue clay, sand, and silt (Drift, etc.) reaching "rock" at depths of 109 and 113 feet respectively.

A well-section at Brick-kiln Farm, S.E. of Stony Stratford, proved the following strata, the details of which were communicated by Mr. W. H. Dalton:—

| | | Ft. | In. |
|---|---|---|---|
| Drift<br>Kellaways Beds | | 76 | 6 |
| Cornbrash | | 5 | 6 |
| Great Oolite Clay: | Clay and stone | 15 | 9 |
| Great Oolite Limestone. | Stone with thin band of clay | 15 | 0 |
| Upper Estuarine Series<br>Upper Lias, &c. | Clay | 88 | 3 |
| Middle Lias? | Rock, yielding scanty supply of brackish water | 5 | 6 |
| | Hard clay, with occasional rock | 18 | 6 |
| | | 225 | 0 |

I have inserted the Upper Estuarine Series, as it is no doubt represented, judging by the evidence obtained at Deanshanger.

* H. B. W., Explanation of Horizontal Section, Sheet 140, p. 5.

In parts of this area the Series appears to rest directly on the Upper Lias Clay, and where two clays come together, the well-sinkers are not likely to make a distinction.

Prof. Green (MS.) has noted that, "between Calverton and Stony Stratford, thick-bedded white limestones, which must be very near the top of the series, occur in great force, and have been largely quarried."

The Great Oolite at Linford Station, consists of fissile beds of earthy and oolitic limestone (5 feet seen), resting on an alternating series of grey, earthy, and more or less oolitic limestone and marly beds. These strata all vary a good deal in character, the softer marly beds becoming indurated into stone at short distances.

A quarry N.W. of Great Linford Church showed the following beds:—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite Clay, &c. | Brown clay - - - - - | 2 | 0 |
| | Pale grey clay and rubbly stone - | 1 | 0 |
| Great Oolite. | Grey earthy limestone, more or less oolitic, and very shelly, rubbly on top and hard below; with shells weathered out on faces, chiefly Lamellibranchs, *Gervillia*, *Astarte*, &c. and some Gasteropods - - | 2 | 6 |
| | Marl, with *Ostrea* - - 0 10 to | 1 | 0 |
| | Fissile pale, earthy, and oolitic banded limestone - - - - | 1 | 0 |
| | Marly layer, a few inches. | | |
| | Hard more or less banded bed of tough fissile limestone, oolitic and shelly in places - - - - 1 7 to | 1 | 10 |
| | Pale rubbly and earthy limestone, oolitic here and there, and clay 1 6 to | 2 | 0 |
| | Current-bedded shelly and oolitic limestone, pale, hard and earthy in places - - - - - - | 3 | 0 |
| | Pale earthy limestone - - - | 1 | 6 |
| | Yellowish earthy limestone - - | 1 | 2 |

These are no doubt portions of the same beds as those seen in the large quarry to the west. They are also exposed in a bank further east, and in the railway-cutting west of Linford station.

The stone makes a good strong lime for mortar, and a useful lime for the land, if put on in small quantities. As a building-material, it is poor, although it has been used.

A pit, and the adjoining railway-cutting at Bradwell, near Newport Pagnell, showed the following section:—

| | | Ft. | In. |
|---|---|---|---|
| Cornbrash - | Brown clay, and rubble of earthy limestone, with *Terebratula intermedia* - - 1 0 to | 2 | 6 |
| Great Oolite Clay. | Rubbly (in places reconstructed) bed of white and grey marly limestone, crowded with *Ostrea* - - 1 6 to | 1 | 8 |
| | Hard marly clay, with *Ostrea* - | 1 | 3 |
| | Brown, blue, and greenish clays and marl - - - - - - | 2 | 6 |
| | Sand - - - - - - | 0 | 6 |

| | | Ft. | In. |
|---|---|---|---|
| | Bluish-grey clay with "race" and decomposed pyrites, and much ferruginous matter at base - - | 6 | 0 |
| | Irregular earthy band, with *Ostrea* - | 1 | 6 |
| Great Oolite Limestone. | Massive bed of banded earthy limestone - - - - - | 5 | 0 |
| | Layer of selenite. | | |
| | Marly limestones with *Ostrea Sowerbyi* and *Modiola gibbosa*; much selenite | 3 | 0 |
| | Seam of selenite. | | |
| | Pale earthy oolitic limestone - - | 1 | 2 |
| | Layer of selenite. | | |
| | Pale earthy oolitic and shelly limestone - - - - - | 1 | 0 |
| | Seam of clay. | | |
| | Marly bed crowded with *Ostrea* - | 2 | 0 |
| | False-bedded shelly oolitic limestone, with veins of selenite; seen to depth of - - - - - | 4 | 0 |

This section may be compared with that seen at Stow-nine-Churches (p. 398). The occurrence of so much selenite is a remarkable feature; it is, however, local, and the layers are but an inch or two thick. On the whole it seems most probable that the selenite has arisen from decomposition of pyritic layers in the beds above, and the consequent formation of sulphate of lime which was deposited along the open planes of bedding and in crevices of the fractured rock.

### *Newport Pagnell to Olney and Bedford.*

The Great Oolite limestone is quarried to the north of Gayhurst.* The beds that have been worked, comprise nearly 12 feet of limestones separated by marls. The stone-layers are much jointed and fissured, and the walls of the fissures are seen to be water-worn. The layers are slightly wedge-bedded in places, and some are seen to be current-bedded on a small scale. There are hard bands of bluish-grey oolitic limestone, resembling beds of Forest Marble, and there are softer layers of marly limestone. The former are employed for walling, and the latter for ordinary building-purposes. The stone, according to the quarryman, requires to "lie out" about 12 months before it is used; it must at any rate be well seasoned, otherwise it shatters with the frost. Some of the hard layers of oolitic limestone contain marly patches and small pebbles of marl, that are suggestive of contemporaneous erosion. The fissured and shattered nature of the stone-beds, shows that the strata might hold a good deal of water under favourable circumstances.

Further northwards of Stoke Goldington, a brickyard has been excavated in dark grey and purplish clays. In company with Mr. Cameron, I visited this pit and also a number of exposures in the clay (formerly mapped as Upper Lias) along the borders of the Ouse valley by Weston Underwood to Olney. We found

* See foot-note, p. 379.

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no evidence of Upper Lias. On the contrary, the clay is of a variegated character, having in places greenish, purplish, and reddish tints; it contains marly bands and fragments of *Ostrea*. At Stoke Goldington the clay, which was exposed to a depth of 5 or 6 feet, contains, at a lower level, irregular concretionary slabs of pyrites, nodules of earthy limestone, and seams of fibrous carbonate of lime like "beef," but exhibiting well-marked "cone-in-cone" structure. This structure, under the name of nail-head spar, is frequently found in the Upper Lias Clay; but layers of beef are not uncommon in the Upper Estuarine Clays, as in some portions of the Purbeck Beds, with which they have been compared in general characters. It is not unlikely that deeper excavations at Stoke Goldington would expose the Upper Lias.

Mr. Cameron informs me that at the disused brickyard, south of Olney, the beds worked were yellow and blue clay, with a sand-bed 1 foot thick, at the depth of 8 feet from the surface, and thus beneath the level of the Alluvium. This sand-bed may perhaps be a representative of the Northampton Beds.

A well sinking (1891) one-half mile north of Olney railway-station, showed the following section, of which the details were communicated by Mr. Cameron:—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite Limestone. | Limestone, with *Modiola imbricata* and *Rhynchonella concinna* - - | 18 | 0 |
| Upper Estuarine Series. | Grey clay - - - - - | 10 | 0 |
| | Limestone - - - - - | 2 | 0 |
| | Black clay - - - - - | 10 | 0 |
| | Black shelly and carbonaceous clay: with lignite on top - - - | 5 | 2 |
| | | 45 | 2 |

The character of all the clays here is more like that of the Upper Estuarine Series than the Upper Lias.

At Olney Court, according to Mr. Cameron, 20 feet of Limestone (Great Oolite) was proved, and beneath that 100 feet of clay. This clay would represent both Upper Estuarine Series and Upper Lias. Wells on the flats between the market-place at Olney and the river, are from 60 to 80 feet deep. It is to be presumed that the Marlstone must be reached; in this case the Upper Lias clay would be of irregular thickness, being unconformably overlaid by the Upper Estuarine Series. (See also p. 391.)

At Bedford County-school, a well was sunk in 1886, in the following strata, which are noted on the authority of Mr. Cameron:—

| | | Ft. | In. |
|---|---|---|---|
| | Gravel - - - - - | 8 | 0 |
| Kellaways Beds. | Loamy sand and stone-lumps - - | 17 | 0 |
| | Black clay - - - - | 8 | 0 |
| Cornbrash - | Limestone - - - - | 1 | 0 |
| | Clay - - - - - | 0 | 3 |
| | Limestone - - - - | 1 | 3 |
| Great Oolite Clay. | Clay - - - - - | 2 | 8 |

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite Limestone. | Limestone - - - - | 10 | 0 |
| | Clay - - - - - | 0 | 6 |
| | Limestone - - - - | 10 | 0 |
| | Clay - - - - - | 3 | 4 |
| | Limestone - - - - | 8 | 0 |
| Upper Estuarine Series. | Greenish sandy clay - - - | 1 | 0 |
| | Limestone - - - - | 1 | 2 |
| | Greyish-blue sand - - - | 0 | 9 |
| | White sand - - - - | 1 | 0 |
| | Hard and soft stone - - - | 3 | 0 |
| | | 76 | 11 |

Mr. Cameron informs me that the thickness assigned to the Kellaways Beds may be too great, as the Gravel and underlying strata were somewhat mixed at the junction.

It is difficult to fix any definite division between Great Oolite Clay and Limestone; in some places near Bedford Mr. Cameron has noted 10 feet of purple and black clays that represent the Great Oolite Clay. At Franklin's Pit, Bedford, this Clay comprised mottled red, green, yellow, grey, and purplish clay with selenite, resting on dark carbonaceous clay, with a concretionary ferruginous bed. (See p. 451.)

At Cox's quarry, Bedford, I noted the accompanying section in company with Mr. Topley and Mr. Cameron:—

| | | Ft. | In. |
|---|---|---|---|
| | Loamy soil (resting irregularly on bed below). | | |
| Valley Gravel. | Sandy and calcareous loam and gravel—contorted. | | |
| Great Oolite Limestone. | Pale grey nodular marl, with nodules of compact grey limestone (burnt for lime); passing down into pale grey earthy limestone; *Ostrea Sowerbyi* - - - | 2 | 6 |
| | Clay parting. | | |
| | Dark blue limestone (1 ft.) passing into thin flaggy, false-bedded and blue-hearted limestone (like Forest Marble) of irregular thickness - - 2 0 to | 3 | 0 |
| | Dark blue clay, crowded with specimens of *Ostrea Sowerbyi* - - - - | 1 | 0 |
| | Blue and bluish-grey limestones and shaly clays with *Ostrea Sowerbyi*; the beds are slightly oolitic in places, more especially those near the bottom of the quarry. There are also layers of denser limestone with streaks of marly limestone. The beds generally are variable in thickness and false-bedded to some extent. The full thickness is about 12 feet down to clay: seen to depth of - - - | 7 | 0 |

The limestones are quarried chiefly for lime-burning. Among the fossils there may be found *Nautilus Baberi*, *Modiola imbricata*, *M. sowerbyana*, *Myacites calceiformis*, *Ostrea Sowerbyi*, *Pinna ampla*, *Trigonia*, &c.

The full thickness of the Great Oolite Limestone is from 25 to 30 feet.

The Great Oolite Limestone has been worked in several places, near Kempston, and between Bromham and Stagsden. At the Stagsden quarry I noted the following section, also in company with Mr. Topley and Mr. Cameron:—

| | | Ft. | In. |
|---|---|---|---|
| Kellaways Beds. | Clay. | | |
| Cornbrash | Tough grey limestone, in impersistent masses: *Ostrea flabelloides*, &c. | | |
| Great Oolite Clay. | Brown, blue, and greenish clays, calcareous in places, and with nodular ironstone-band near base | 4 | 0 |
| Great Oolite Limestone. | Pale marly and rubbly bed (like top-bed at Cox's pit) | 2 | 6 |
| | Pale earthy and shelly limestones, false-bedded | 1 | 3 |
| | Irregular band of earthy limestone, current-bedded: crowded with specimens of *Ostrea Sowerbyi* | 0 | 9 |
| | Earthy and marly clay | 0 | 10 |
| | Pale oolitic limestone. *O. Sowerbyi* | 0 | 10 |
| | Clayey marl, greenish-grey and mottled. | | |

The Great Oolite limestone is quarried for lime-burning and for building-stone. Where, thickly covered by clayey beds, it is blue hearted and less divided than at the northern end of the quarry, where it comes to the surface.

At the brickyard three-quarters of a mile N.N.W. of West End, Stevington, the Cornbrash rests on bluish oolitic limestone, with apparently no Great Oolite Clay.

North of Olney, the workings at the Warrington stone-pit and lime-kiln, showed the following section:—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite Clay. | Brown clay | 1 0 to 2 | 0 |
| | Marly clay | 1 | 0 |
| Great Oolite Limestone. | Pale fissile limestones | 1 | 0 |
| | Pale rubbly and earthy limestone and clay | 5 | 0 |
| | Banded marly limestone | | |
| | Fissile beds: dense limestone with scattered oolite grains | 5 | 0 |
| | Hard oolitic limestone, with marly galls | | |
| | False-bedded oolitic and shelly beds | 4 6 to 5 | 0 |
| | Calcareous sandy beds | 2 | 0 |
| | Hard limestone | 1 | 0 |
| | Calcareous sandstone | 1 | 0 |
| | Poor stone (not seen) | 3 | 0 |
| | Water (? Upper Estuarine clay). | | |

Building-blocks are obtained from the lower beds of stone.

The beds on the whole are irregular and more or less oolitic, and sandy towards the base. Among the fossils collected by Mr. Cameron and myself, were *Ostrea*, *Pecten annulatus*, *Lima cardiiformis*, *Modiola*, *Terebratula maxillata*, and *Echinobrissus*.

A great many fossils, including *Pecten wollastonensis*, were obtained by the Rev. A. W. Griesbach, from the Great Oolite of Wollaston; and it is noteworthy that *Waldheimia digona* was there found in some abundance:* a fossil suggestive of the Bradfordian horizon.

* See Morris, Geol. Mag. 1869, p. 102.

*Towcester to Stowe-nine-Churches.*

Referring to the country around Towcester, Mr. Aveline has remarked on the unconformity between the Great Oolite and the Northampton Sand, observing that "the superior formation lies indifferently on higher or lower beds of the inferior formation, indeed sometimes the Northampton Sand is entirely overlapped by the Great Oolite, the latter resting on the Upper Lias Clay."* There is no doubt that the Northampton Sand becomes very thin in that neighbourhood and along the borders of the Tove Valley and Castlethorpe, but we have evidence at Deanshanger, near Stony Stratford, that Upper Estuarine Clays as well as Northampton Sand intervene between the base of the Great Oolite and the Upper Lias. The same is probably the case, so far as regards the Upper Estuarine Series, in those areas of the Tove and Nene valleys, where the Great Oolite is shown, on the Geological Survey Map, to rest directly on Upper Lias Clay. I am informed (1892) by Mr. Beeby Thompson, that Upper Lias Clay has been opened up in the brickyard at Grafton Regis; that it is "capped by some whitish sand with much argillaceous matter, which represents, no doubt, the Northampton Sand of this district."

Quarries have been opened in various places to obtain material for lime-burning, and for local building-purposes or road-metal; but a number of those marked on the Geological Survey Map are now closed. Among the openings, there are those west of Sulgrave, near Culworth, east of Weedon Lois, and south-east of Maidford. At the Maidford lime-kiln the following section was to be seen (Fig. 111):—

| | | Ft. | In. |
|---|---|---|---|
| Glacial Drift. | 3. Boulder clay, gravel and loamy sand, with disturbed and contorted masses of Great Oolite Clay and rubble - - - 6 0 to | 8 | 0 |
| Great Oolite Limestone. | 2. Greenish rubbly stone, with *Ostrea* 1. Pale limestones with scattered grains of oolite, and with bands of marl and clay - - - - | 12 | 0 |

A deeper section, showing 16 feet of the beds, was recorded by Mr. Aveline, who notes the occurrence of *Nerinæa*, *Pholadomya Heraulti*, *Trigonia*, and a band with Corals.

On Grimscot Hill, north of Grimscot, and north-east of Cold Higham, a small area of "Forest Marble," observed by R. Trench, was marked on the Geological Survey Map.† This outlier is of interest in connection with the section near Stowe-nine-Churches. A specimen of *Nautilus obesus*? is recorded from Litchborough, probably from the Great Oolite Series.‡

* Aveline and Trench, Geol. part of Northamptonshire, p. 11; see also Judd, Geol. Rutland, p. 31.
† Aveline and Trench, Geol. part of Northamptonshire, p. 13.
‡ Foord, Cat. Fossil Cephalopoda, Brit. Mus., Part 2, p. 218.

FIG. 111.

*Section at Maidford, north-west of Towcester.*

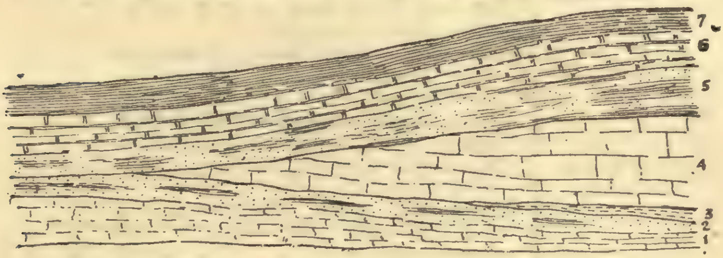

An important section at Stowe-nine-Churches, shows the sequence of beds from the bottom Oxford Clay, or Kellaways Clay, down to the Northampton Sand. My attention was directed to the quarry by Mr. Beeby Thompson, who has since described the beds in detail, and in whose company the following record was made:—

| | | FT. | IN. |
|---|---|---|---|
| Kellaways Clay. | Stiff grey and brown clay and purplish clay with ochreous veins: filling hollows or "pipes" in the beds below - - - 3 0 to | 5 | 0 |
| Cornbrash. | Grey, shelly, and ferruginous limestones, with bands of white earthy limestone at base - - - | 4 | 6 |
| Great Oolite Clay. | Grey clay - - - - - | 0 | 6 |
| | Hard fissile grey and blue limestones | 1 | 4 |
| | Greenish clay, with plant-remains - | 1 | 3 |
| | Hard and fissile grey shelly limestone; occurs in irregular masses - - | 1 | 2 |
| | Dark, purplish, carbonaceous clay, with selenite and rusty band at base - - - - - 9 0 to | 10 | 0 |
| | Brown marly clay with veins of fibrous gypsum, and pebbles of white limestone - - - - - - | 3 | 0 |
| | Impersistent layer of greenish shelly clay, with lignite - - - | 1 | 0 |
| Great Oolite Limestone. | Oolitic shelly limestone; Gasteropods, numerous Lamellibranchs, *Terebratula maxillata*, *Clypeus* - - | 2 | 0 |
| | Pale marly beds, more or less indurated, shelly and oolitic: *Pholadomya Heraulti* - - - - - | 6 | 6 |
| | Oolitic and shelly limestones (base of quarry); *Trigonia costata* - - | 10 | 0 |
| | [Other beds of limestone, noted by Mr. Thompson, about 14 feet.] | | |
| Upper Estuarine Beds. | Dark clay, &c. | | |

Some of the layers in the Great Oolite Clay strongly resemble beds of Forest Marble, and Mr. Thompson has used the name in describing the upper portions of this subdivision.* The pebbles of white limestone are probably due to some local erosion of the upper beds of the Great Oolite. Lists of fossils from the several formations have been published by Mr. Thompson.

Fig. 112.

*Diagram-section to show the relations between the Great and Inferior Oolite Series from Northamptonshire to Lincolnshire.*




7. Great Oolite Clay.
6. Great Oolite Limestone.
5. Upper Estuarine Series.
4. Lincolnshire Limestone.
3. Collyweston Slate.
2. Lower Estuarine Series.
1. Northampton Sand.

### *Roade and Blisworth to Northampton.*

Cuttings on the new Towcester (Midland) Railway, south-west of Roade, showed the following section:—

| | | Ft. | In. |
|---|---|---|---|
| Glacial Drift. | Boulder Clay (shown in cutting east of bridge over railway) - 10 0 to | 12 | 0 |
| Great Oolite Limestone. | Pale fissile and earthy limestone, *Ostrea* abundant in earthy layer at base: *O. Sowerbyi* and *O. lingulata*? 3 0 or | 4 | 0 |
| | Thicker beds of pale earthy limestone 2 0 or 3 0; Shelly and oolitic limestones, false-bedded - - - - | 15 | 0 |
| | Rubbly marl with indurated bands, *Ostrea*, &c. sparingly; and at base, marl with *Rhynchonella*, *Ostrea*, *Modiola*, *Lima*, &c. - - - | 7 | 0 |
| | Rotten marly limestones, with *Rhynchonella*, &c. - - - - | 2 | 0 |
| | Rubbly marl, with *Pholadomya* (in position), *Ostrea Sowerbyi*, *Rhynchonella*; very shelly in places 5 0 to | 6 | 0 |
| Upper Estuarine | Greenish grey and brown clay, with many specimens of *Ostrea* - - | 4 | 0+ |
| (Beds not seen) | * * * | | |
| Upper Lias. | Stiff blue clay, shown in foundations for bridge over stream, by junction with L. & N.W. Railway. | | |

* See Journ. Northamptonshire Nat. Hist. Soc., vol. vi. 1891, p. 294.

A quarry opened to the south-east of Roade, for ballast on the railway, showed 8 feet of pale, flaggy, and shelly false-bedded oolite, yielding no fossils, and with a crumbly marl on top. The same beds were exposed at the base of the cutting on the south, capped by 6 or 7 feet of rubbly beds, with broken-up marly stone on top, with *Ostrea*, &c. These are evidently the same as the higher beds of the section above recorded.

The Great Oolite has been well exposed in the cuttings of the L. & N.W. Railway at Roade, and also in quarries to the south-east. The general section is as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite Limestone. | Clay and fissile beds of grey oolite, with *Ostrea Sowerbyi*. | | |
| | Fossil Bed: Grey marly limestone, with calcitic Corals, *Terebratula maxillata*, *Rhynchonella varians*, *Trigonia*, *Myacites tumidus*, *Pecten annulatus*, *Lima cardiiformis*, *Ceromya Symondsi*, *Modiola imbricata*, Gasteropods and *Nautilus* - 1 0 to | 3 | 6 |
| | False-bedded oolite, shelly in places, and with thin marly beds (8 feet seen in quarry) - - about | 15 | 0 |
| | Pale earthy and oolitic limestone, passing down into dense grey oolite, with white marly kernels; full thickness about - - - - | 3 | 6+ |
| Upper Estuarine.—Green clays, &c. | | | |
| Northampton Sand. | | | |
| Upper Lias Clay. | | | |

We have in the Great Oolite Limestone, a false-bedded series overlaid and underlaid by even beds of limestone: these are well shown in the cutting north of Roade Station. The fossil-bed, where at the surface of the ground (as shown in one of the quarries), weathers to a rubbly marl, which is piped.

At Blisworth, a quarry in the Great Oolite showed the following section:—

| | | Ft. | In. |
|---|---|---|---|
| Glacial Drift. | - Boulder Clay, &c. | | |
| Great Oolite Clay. | Green and bluish grey clay with *Ostrea subrugulosa*, and lignite - - | 2 | 0 |
| Great Oolite Limestone. | Flaggy limestone (Pendle), with *Acrosalenia*, &c. - - - - - | 5 | 0 |
| | Grey earthy and oolitic limestone: *Pholadomya* - - - - | 2 | 0 |
| | Banded earthy limestone, flaggy in places and minutely current-bedded 2 0 to | 3 | 0 |
| | Hard shelly oolite - - 0 5 to | 0 | 8 |
| | Clay with *Ostrea* - - - | 0 | 3 |
| | Fossil-bed: *Lima*, *Terebratula maxillata* - - - - - ; Pale marly beds, with scattered oolitic grains - - - - | 3 | 0 |
| | Oolitic limestone ("Blocks") with *Nautilus Baberi*, *N. subtruncatus*, *Clypeus Mülleri* (stone used for window sills, &c.) - - - | 2 | 9 |
| | Alternations of hard blue-hearted stone and clay - - - about | 4 | 0 |

The Banded bed is similar to a layer seen at Deanshanger and Newport Pagnell. The details below the fossil-bed and the names of fossils are given from the account published by S. Sharp.* He records from the "Blocks," a specimen of *Ammonites gracilis*, 16 in. in diameter.

Many Saurian-remains, including bones of *Cetiosaurus*, were obtained during the construction of the railway at Blisworth.†

At the Ironstone-pit, about a quarter of a mile N.W. of the Limestone-quarry at Blisworth, the following section was recorded by Sharp‡:—

| | | Ft. | In. |
|---|---|---|---|
| | Surface soil | 1 | 0 |
| Great Oolite Limestone. | Soft calcareous marl | 1 | 6 |
| | Hard limestone | 1 | 3 |
| | Soft marly bed, with *Ostrea Sowerbyi* | 1 | 0 |
| | Compact marly limestone | 2 | 3 |
| | Soft marly limestone, with *O. Sowerbyi*, *Trigonia*, *Modiola* | 1 | 3 |
| Upper Estuarine Series. | Dark grey clay, with *O. Sowerbyi* | 1 | 6 |
| | Ironstone-band, with *O. Sowerbyi*, *Modiola imbricata*, *Pteroperna plana*, *Perna rugosa*, var. *quadrata*, *Natica pyramidata* | 1 | 0 |
| Lower Estuarine Series. | Variable sandy clay, with vertical plant-markings. | | |

*Goniomya hemicostata* has also been recorded.

Among the fossils from the Great Oolite of Duston, I obtained the following species:—

Lepidotus.
Strophodus magnus.
Nautilus Baberi.
Natica formosa?
—— Verneuili?
Cardium.
Cyprina loweana.
Gresslya? (cast).
Isocardia? (cast).
Modiola bipartita.
—— imbricata.
Ostrea Sowerbyi.
Pecten annulatus.
Perna rugosa.
Pholadomya deltoidea.
—— socialis (a gregarious form).
—— Heraulti.
Trigonia undulata.
Terebratula maxillata.
Clypeus Ploti.

The Great Oolite has been well exposed in several sections near Duston, to the west of Northampton. West of Duston Lodge, near Hopping Mill, a deep trench showed the following beds, beneath a covering of Boulder Drift:—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite Clay. | Dark greenish-grey clay | 2 | 0 |
| | Pale marly bed | 3 | 0 |
| | Grey clay, &c., with *Ostrea* | 1 | 0 |
| Great Oolite Limestone. | Hard grey more or less oolitic shelly limestone, with Gasteropoda: *Ostrea* on upper surfaces of stone | 2 | 2 |
| | Seam of grey clay, with *Ostrea*. | | |
| | Fossiliferous marly beds in harder and softer bands, blue and shaly in places, and occasionally oolitic | 9 | 0 |
| | Flaggy and shelly oolite 3 0 or | 4 | 0 |

* Quart. Journ. Geol. Soc., vol. xxvi. p. 378.
† Owen, Proc. Geol. Soc., vol. iii. p. 460.
‡ Quart. Journ. Geol. Soc., vol. xxvi. p. 379.

These beds seem to be continued in the Lime-kiln quarry at Bunker's Hill, where, beneath a foot of marl and rubble, we find the following series:—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite Limestone. | Pale flaggy oolitic limestone - - | 2 | 0 |
| | Fossil-bed: oolitic and shelly limestone, with *Ostrea, Modiola,* and Echinoderms - - - - | 2 | 2 |
| | Grey earthy and oolitic limestones, large *Pholadomya* - - - | 1 | 4 |
| | Brown clay, with "race" and *Ostrea* - | 1 | 8 |
| | Fossil-bed: shelly and oolitic marly bed, more or less oolitic, with Echinoderms - - - - | 4 | 0 |
| | Pale (blue-hearted) earthy limestone, with *Modiola, Ostrea, Rhynchonella,* spines of Echini - - - | 0 | 6 |
| | Blue clay resting on hard pale marl - | 2 | 0 |
| | Hard blue-hearted calcareous sandstone (like beds at Olney). | | |

* * *

In an adjoining brickyard, N.W. of Dallington, still lower beds were exposed, and between them and those above there may be an interval of 20 feet.

| | | Ft. | In. |
|---|---|---|---|
| Upper Estuarine Series. | Brown and grey clay (with stony soil) | 2 | 0 |
| | Pale grey clay with "race," and a band of dark ferruginous clay. This clay is too calcareous for brick-making - - - - - | 7 | 0 |
| | Ferruginous shelly layer - - | 0 | 2 |
| | Shaly and marly clay, with *Ostrea* - | 1 | 6 |
| | Hard stone almost made up of shell-fragments, *Ostrea,* &c.; with pale marly seams in places, and much jointed - - - - - | 4 | 0 |
| | Brown clayey sand, with *Ostrea* - | 2 | 0 |
| | Bluish-grey shelly clay - - | 0 | 8 |
| | Purplish and grey clay with carbonaceous matter and ochreous bands and veins—thickening from east to west. This clay is used for the manufacture of red bricks, tiles, and drain-pipes - - 8 0 to | 12 | 0 |

The lowest bed of clay is said to become sandy at the base and to rest on "rough stone," probably indurated sand. Still lower beds of loam resting on sand, were proved to a depth of 12 feet in an adjoining field: they may belong to the Lower Estuarine Series; and beneath comes the Duston Stone (Northampton Sand).

A well by the Lime-kiln quarry was sunk to a depth of 119 feet, and water was obtained from the stone-beds of the Northampton Sand.*

The sequence of the beds at Duston Lodge and those at the Lime-kiln, is corroborated by the following section at Wooton Hall, south of Northampton† :—

| | | Ft. | In. |
|---|---|---|---|
| Base of Great Oolite Clay. | Brown clay (piped). | | |
| | Rubbly marl and oolitic limestone, with *Lima cardiiformis, Terebratula maxillata, Waldheimia digona,* &c. - | 5 | 0 |

* See also Sharp, Quart. Journ. Geol. Soc., vol. xxvi. p. 369.
† See also Proc. Geol. Assoc., vol. xii. p. 177.

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite. | Marl and thin layers of hard earthy limestone | 2 | 0 |
| | Clayey band, with *Ostrea*. | | |
| | Pale indurated earthy marls with bands of clay; oolitic in places *Ostrea*, &c. | 7 | 0 |
| | Bands of shelly and oolitic limestone, with marly partings: *Isocardia minima*, *Myacites securiformis*, *M. tumidus*, *Modiola gibbosa*, *Ostrea*, *Pholadomya*, *Terebratula*, *Echinobrissus Griesbachi* | 4 | 6 |

The occurrence of *Waldheimia digona* is of interest, as it is not often found in this region, the only other locality noted, being that of Wollaston, further east. It would seem that in this country, as near Oxford and Cirencester, we have occasional evidence of beds that represent the Bradford Clay.

### *Northampton to Rockingham Forest.*

There are several quarries at Moulton Park, near Kingsthorpe: that at the lime-kiln on the east side of the road is as follows:—

| | | | Ft. | In. |
|---|---|---|---|---|
| | | Boulder clay and soil | 3 | 0 |
| Great Oolite Limestone. | Bastard Beds. | Rubbly fossiliferous marl, with *Strophodus*, &c. | 1 | 2 |
| | | Pale earthy and slightly oolitic limestone | 0 | 5 |
| | | Marly clay, with *Ostrea* | 1 | 2 |
| | | Earthy and shelly limestone, *Trigonia* | 0 | 8 |
| | | Pendle. Earthy and marly limestone, with plant-remains | 1 | 6 |
| | | Laminated earthy clay with, *Ostrea* | 0 | 4 |
| | | Pavingstone. Shelly earthy and oolitic limestones, with Gasteropods | 4 | 0 |
| | | Jubs. Marly and oolitic limestone, with veins of clay or marl (as near Towcester). Fossil nuts, *Pandanocarpum ooliticum* | 6 | 6 |
| Upper Estuarine Series. | | Blue and greenish marly clay, with *Ostrea* and *Modiola*. | | |

The Jubs beds make the strongest lime, but the Pavingstone yields the best lime for agricultural purposes. The Pavingstone-bed was formerly sawn up and used for hearthstones, flues, flooring, window-sills, chimney-pieces, &c.*

Morris noted the occurrence of *Pholadomya* in these beds in the position of life†; as I have noted also near Roade. The fossils from the Great Oolite include *Strophodus, Nautilus, Trigonia, Cypricardia, Modiola imbricata, Perna, Pholadomya, Pinna, Rhynchonella concinna, Clypeus* and Crustacea.

One of the best sections of the Great Oolite and Inferior Oolite Series has been exposed at the Ironstone-workings at Finedon.

* See also Sharp. Quart. Journ. Geol. Soc., vol. xxvi. p. 360; and Carruthers, Geol. Mag., 1868, p. 155.

† Geol. Mag. 1868, p. 102.

The beds are faulted in places, but the sequence can be traced as follows:—

| | | | Ft. | In. |
|---|---|---|---|---|
| Great Oolite Clay. | Brown clay - - - | about | 6 | 0 |
| | Black clay with ironstone-nodules - - - | | | |
| | Grey clay - - - | | | |
| Great Oolite Limestone. | Fissile earthy and marly beds, with *Ostrea* - - - - | | 1 | 0 |
| | Hard flaggy, and shelly calcareous sandstone - - - - | | 1 | 0 |
| | Fossil-bed: Marly and oolitic layer, full of *Ostrea*, *Modiola*, *Myacites*, and *Pholadomya* - - - - | | 1 | 3 |
| | Oolitic shelly and marly limestone - | | 1 | 0 |
| | Oolitic marly bed: *Ostrea*, *Trigonia* | | 1 | 2 |
| | False-bedded shelly and marly oolite | | 6 | 0 |
| | Fossil-bed: Brown earthy clay and impure limestone, with *Modiola*, *Ostrea* - - - - | | 1 | 7 |
| | Pale earthy and occasionally shelly limestones, with earthy partings: *Ostrea*, *Rhynchonella* - - - | | 7 | 10 |
| Upper Estuarine Series. | Blue clay (full thickness not seen) - - - - - about | | 1 | 6 |
| | Marl, with *Ostrea* and *Rhynchonella* - | | 0 | 9 |
| | Flaggy and sandy limestone: *Ostrea* - | | 0 | 9 |
| | Pale marly bed - - 0 10 to | | 2 | 0 |
| | Clay, with *Ostrea* and crushed *Rhynchonella* - - 0 6 to | | 1 | 0 |
| | Shelly and earthy limestone and marl, with fossils as above - 1 6 to | | 2 | 0 |
| | Clays with *Ostrea Sowerbyi* - - | | 1 | 2 |
| | Calcareous sandstone, with *Rhynchonella* and *Ostrea*, resting on irregular surface of bed below 0 8 to | | 2 | 6 |
| Lower Estuarine Series. | Grey and brown shelly sand, clayey in places and passing into white sand - - - 2 0 to | | 3 | 0 |
| | Clay - - - - - - | | 0 | 8 |
| Northampton Sand. | Brown ironstone - - | about | 15 | 0 |
| | Brown and green ironstone | | | |
| | Nodular bed - - | | | |
| | Sandy clay with ironstone-nodules - | | 0 | 8 |
| Upper Lias. | Blue micaceous clay. | | | |

The junction of the Ironstone and Upper Lias Clay is rather irregular, and it appears that the base of the ironstone is nodular (or conglomeratic ?) where it rests in the hollows of the clay beneath.

From the Great Oolite Limestone I obtained *Gervillia crassicosta*, *Modiola imbricata*, *Ostrea Sowerbyi*, *O. subrugulosa*, *Perna rugosa*, *Trigonia elongata*, and *Thamnastræa*.

At Cinque-foil Lodge, south-east of Warkton, near Kettering, a trial-boring (made by Mr. T Hennell) was carried to a depth of 77 feet in "Limestone Rock," and below that into brown clay to a further depth of 19 feet. The Limestone Rock probably includes not only Great Oolite, but the underlying Inferior Oolite Series, down to the top of the Upper Lias Clay.

The Upper Estuarine Series in this neighbourhood, between Geddington and Grafton-under-Wood, is thus described by Prof. Judd*:—

| | | Ft. | In. |
|---|---|---|---|
| | Soil - - - - - | 1 | 0 |
| Upper Estuarine Series. | Pale bluish-white clay, with carbonaceous markings - - 2 0 to | 3 | 0 |
| | Indurated, variegated, sandy clay (bright yellow, pale blue, ash-coloured, pink, crimson, and greenish), occasionally traversed by ironstone laminæ - - - | 1 | 0 |
| | Irregular ferruginous band - - | 0 | 2 |
| | Ash-coloured sands, with irregular clay seams - - - - - | 0 | 5 |
| | Fine white clay, with carbonaceous markings - - - 3 0 to | 0 | 6 |
| | Band of ironstone-nodules (ferruginous junction-band) - - - | 0 | 6 |

We now enter an area that has been fully described by Prof. Judd, and it will be necessary to record only a few of the principal sections, to show the characters of the strata.

Prof. Judd states that at Great Oakley the beds of the Upper Estuarine Series are dug for brick-making, but, at the time the district was surveyed, there was not, unfortunately, any clear exposure of the strata. The succession of beds here was as follows:—

| | |
|---|---|
| Great Oolite. Limestone. | Alternations of fœtid limestone, with *Ostrea* and other marine shells, and bands of clay also full of oysters. |
| Upper Estuarine Series. | Light-blue, sandy clays, with thin bands of laminated, highly pyritous sandstone of a grey colour, exhibiting plant-markings and shells of *Cyrena*. These clays also contain carbonaceous and shelly bands. |

At the excavations at the brick-yard and lime-kiln at Brigstock Mill, between Stanion and Brigstock ("Lord Lyveden's pits"), he noted the following section:—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite Limestone (base). | Soil. | | |
| | Oyster-beds (*O. Sowerbyi*, &c.) - - | 1 | 0 |
| Upper Estuarine Series. | Blue clay - - - - | 6 | 0 |
| | Ferruginous band - - - | 0 | 6 |
| | White and mottled, sandy clay - | 2 | 0 |
| | Sandy clays, whitish above and greenish below, full of compressed shells (*Modiola*) - - - - | 3 | 6 |
| | Dark mottled clays full of carbonaceous markings and plant-remains more than | 5 | 0 |
| | Whitish, mottled, sandy clay - - | 4 | 6 |
| | Line of concentric, ferruginous nodules | 0 | 6 |
| Lincolnshire Limestone and Collyweston Slate. | Irregularly bedded, sandy limestone - | 2 | 0? |
| | Hard marly limestone (Coralline facies of the Lincolnshire Oolite) - - | 6 | 0 |
| | Sandy limestone passing downwards into calcareous sand - 12 0 to | 14 | 0 |

* Geol. Rutland, p. 146.

| | | Ft. | In. |
|---|---|---|---|
| Lower Estuarine Series. | Clay - - - - - - | 1 | 6 |
| Northampton Sand. | Ironstone rock. | | |

The beds below the sandy limestone, that no doubt represents the Collyweston Slate, were proved in a well.

In Brigstock Park a similar sequence of beds was observed, the details varying to some extent in thickness.*

At the northern end of Geddington Chase, and not far from the village of Stanion, the following section in the Great Oolite was noted by Prof. Judd:—

| | | Ft. | In. |
|---|---|---|---|
| | Soil - - - - - - | 0 | 6 |
| Glacial Drift. | Boulder Clay, containing boulders of quartzite, Coal-measure sandstone, a few flints, but little or no chalk. Near its base traces of a gravel composed of Northampton Sand detritus were seen - - - | 3 | 0 |
| Great Oolite Clay. | Variegated (greenish, bluish, and purplish) clay, in some places quite denuded away - - - | 1 | 0 |
| | Pale greenish-white marl, full of irregular, concretionary, hard, sub-crystalline, calcareous nodules, also of a pale greenish-white colour (weathering white; comparable with bed at Ailsworth) - - - | 0 | 6 |
| | Green and variegated clay, with carbonaceous markings - - - | 0 | 6 |
| | Grey, fœtid, somewhat sandy, limestone - - - | 0 | 4 |
| | Laminated, marly parting - - | 0 | 2 |
| | Extremely hard, sub-crystalline, drab limestone - - - - | 1 | 6 |
| | Marly parting - - - - - | 0 | 2 |
| | Marly bed, abounding in "Beef" - | 0 | 6 |
| | Variegated, dark, carbonaceous clays, finely stratified - - - | 2 | 0 |
| | Fine laminated marl, with "Beef" - | 0 | 3 |
| | Hard, white, shelly limestone, with many shells and an oyster-bed at the bottom, with *O. subrugulosa* - - | 0 | 6 |
| | Marly bed, crowded with *O. Sowerbyi* - | 0 | 2 |
| | Dark carbonaceous clay - - | 1 | 0 |
| Great Oolite Limestone. | Beds of hard limestone, with few traces of marly partings. The limestone is sometimes compact and full of oysters, or made up of comminuted shells; and it becomes in places very oolitic, thus simulating the characters of the Inferior Oolite. Near the bottom there are traces apparently of pebbles of compact oolite (like those seen at Benefield). This limestone contains lignite, *Ostrea Sowerbyi*, *Echinobrissus clunicularis*, &c. (the bottom not seen) - - | 6 | 0 |

* Judd, Geol. Rutland, pp. 190, 191, 197.

Here there is evidence of a passage between the Great Oolite Limestone, and overlying Clay; and it is unlikely that the same plane of division would be taken in different localities.

Prof. Judd states that about Brigstock and Stanion, both the limestones and oyster-beds of the Great Oolite are exposed at many points. Westward, about Great and Little Oakley and at Pipwell, they are also seen, but do not furnish any very good sections. The best is that afforded by the Great Oakley brick-yard, where we have 6 feet of Great Oolite Limestone, consisting of alternate courses, each about 1 foot thick, of Forest Marble-like stone, and marly oyster bands, containing *Ostrea subrugulosa* and *O. Sowerbyi*. Under the rock there occur black, carbonaceous clays, and, still lower, light, variegated clays; both belonging to the Upper Estuarine Series.

He also observes, that by the roadside, half a mile east of Sudborough Church, a pit in the Great Oolite Limestone exhibits a thick bed of rock, somewhat oolitic (as in the pit at Geddington Chase), and covered by an oyster-bed, with the usual characters, about 1 foot thick. Above the oyster-bed there is a considerable thickness of variegated clays with stony bands, representing the Great Oolite Clay.

Some of the beds of limestone in this neighbourhood are flaggy, and shelly, like the Forest Marble of the south of England, having diffused through their masses a few oolitic grains.*

### *Northampton to Thrapston, Oundle, and King's Cliffe.*

Reference has been made to the attenuation and even absence of the Northampton Beds (as well as the Lincolnshire Limestone), in the country between Northampton and Newport Pagnell. There is thus evidence of much unconformity between the members of the Great Oolite Series and underlying strata. Over much of this area the Upper Estuarine Beds have not at present been mapped, although they have been traced here and there along the outcrop, on the southern side of the Nene valley, at Castle Ashby and Wollaston. The beds are not very thick, and there is much Drift, so that the apparently impersistent nature of the outcrop is due probably to the fact that no evidence of these Upper Estuarine Beds has been obtained, in places, as at Bozeat. Wherever sections have been opened, the beds have been seen to occur at the base of the Great Oolite Limestone.

The unconformity between the Upper Estuarine Series and beds below, is of a more marked character in some areas than in others, as near Draughton; while at Stanwick and Irthlingborough, the Northampton Beds are so reduced in thickness, as not to have been marked on the Geological Survey Map, and the Upper Estuarine Beds are shown to rest directly on Upper Lias.

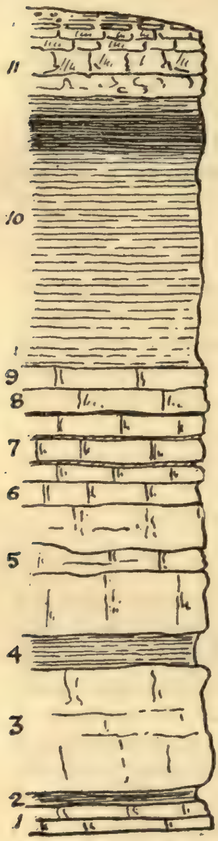
The following series of beds was noted by me in a quarry and cutting on the Midland Railway south of Thrapston† (Fig. 113):—

* Judd, Geol. Rutland, pp. 212, 213.

† See also Sharp, (who records fossils from this locality), Quart. Journ. Geol. Soc., vol. xxix. p. 281.

FIG. 113.

*Section of the strata south of Thrapston.*




| | | Ft. | In. |
|---|---|---|---|
| | Soil, with Drift pebbles - | 1 | 0 |
| Cornbrash. | 11. Rubbly limestone and marl, with *Goniomya, Isocardia, Myacites, Ostrea, Pholadomya, Waldheimia lagenalis, W. obovata, Terebratula intermedia* (at base), *Serpula*, &c. - | 3 | 0 |
| Great Oolite Clay. | 10. Brown shelly clay with "race," passing down into dark blue clay, and thence into greenish-grey carbonaceous clay, dark shaly clay, and greenish-yellow and blue clay - | 12 | 0 |
| Great Oolite Limestone. | 9. Calcareous gritty rock and clay, with *Ostrea* - - | 1 | 0 |
| | 8. Yellow marly limestone, with fragments of *Ostrea*: layer of *Ostrea Sowerbyi* at base - - - | 1 | 0 |
| | 7. Marly and occasionally oolitic limestones (3 layers), with *Ostrea, Modiola*, &c.: parted by thin bands of selenite (as at Newport Pagnell) - | 2 | 7 |
| | 6. Soft brown rock made up of comminuted shells and oolite grains - - | 0 | 10 |
| | 5. Hard and soft marly, shelly, and oolitic limestones - | 5 | 0 |
| | 4. Brown shaly clay, with *Ostrea* - - - | 1 | 5 |
| | 3. Brown and yellow (blue-hearted) marly limestone, with shell-fragments and unbroken Mollusca - | 5 | 0 |
| | 2. Blue and brown shelly clay | 0 | 5 |
| | 1. Grey earthy marl and limestone - - - | 1 | 4 |

The beds undulate a little, and the upper portions of the Great Oolite Clay and Cornbrash are nipped up here and there, as if by Glacial action, like the Lower Lias strata noted in the Memoir on the Lias (p. 146). The limestone is quarried for use in the furnaces at the Ironworks.

Prof. Judd has stated that in the Tichmarsh cutting of the Northampton and Peterborough Railway, the base of the Upper Estuarine Series, consisting of a mass of clays about 5 or 6 feet thick, is seen resting directly upon the sandy, and here non-ferruginous, beds of the Northampton Sand. South of the village of Wadenhoe, there was a pit in which he noted the following section:—

| | | Ft. | In. |
|---|---|---|---|
| | Soil and rubble of Great Oolite. | | |
| Upper and ? Lower Estuarine Series. | White clay | 1 | 0 |
| | Yellow, sandy clay | 1 | 0 |
| | Dark, laminated, carbonaceous clay | 1 | 6 |
| | White clay with vertical plant-markings | 0 | 9 |
| | Dark, carbonaceous clay | 0 | 6 |
| | White clays, with vertical carbonaceous markings and ferruginous stains | 2 | 0 |
| Northampton Sand. | Ironstone-beds to the bottom | 8 | 0 |

A little below the level of this pit, the Upper Lias Clay was dug; while the Great Oolite and Cornbrash were seen in the high ground above the pit. Prof. Judd was disposed to include all the beds above the Ironstone, with the Upper Estuarine Series, and in any case the formation has become greatly attenuated and is not more than 8 feet in thickness. He says, "The Northampton Sand also is evidently very poorly represented, and we have thus an illustration of the fact, that all the members of the Jurassic series partake in a greater or less degree of that easternly attenuation, which, in the case of the Lincolnshire Oolite, is so marked in degree and so productive of complexity in the relations of the beds."

He describes a section lower down the Nene valley, in the "wood-pit" at Stibbington, and this showed the Upper Estuarine clays and sands, and shelly oolite (Lincolnshire Limestone) which was quarried beneath them. "Here the upper surface of the Oolitic limestone displays great irregularity, but this appearance is, in part at least, due to the percolation of surface waters, which have dissolved the upper surface of the limestone, and let down the superjacent clays into holes and 'pockets.' Under the sandy, whitish and bluish clays, with irregular plant-beds, we find the 'junction-band,' a layer of nodules of more or less compact or earthy brown ironstone. This is underlaid in many places by a bed of white marl probably the product of the decomposition of the limestone, and containing apparently waterworn fragments of *compact* limestone, the beds below being *highly oolitic.* This would seem to indicate that a considerable amount of denudation of the Inferior Oolite limestone preceded, at this point, the deposition of the earliest beds of the Great Oolite series."

"The strata of the Upper Estuarine Series were well exposed in making the Sibson tunnel on the Northampton and Peterborough Railway, and sections of them may still be traced at either end of it in the deep cuttings. At the western end of the tunnel, near Wansford station, the whole series of beds, from the Great Oolite Limestone (here underlaid by a considerable thickness of freshwater sands and clays, with the ferruginous nodular junction band at their base), down to the thin representative of the Lincolnshire Limestone and Northampton Sand, may be seen."*

* Judd Geol. Rutland, pp. 174, 193, 194.

At the Water Newton brickyard, Prof. Judd notes the occurrence of both Upper and Lower Estuarine Series, separated by 4 feet of fine-grained oolitic limestone (Lincolnshire Limestone). In a quarry, west of Lilford Lodge, south of Oundle, he observed the following section:—

| | | Ft. | In. |
|---|---|---|---|
| | Soil - - - - - | 1 | 0 |
| Great Oolite Clay. | Bluish-green and mottled clay - | 2 | 0 |
| | Clayey band, crowded with oysters - | 1 | 0 |
| Great Oolite Limestone. | Stony band, almost made up of oysters, thickness irregular - from 9 in. to | 1 | 3 |
| | Bed of compact stone, very hard, and made up of comminuted shells. (This bed greatly resembles the Forest Marble of Dorsetshire) - | 1 | 6 |
| | Soft, white, slightly oolitic rock, becoming marly at its base, and crowded with oysters - - | 2 | 0 |
| | Stone, entirely composed of comminuted shells, very irregularly bedded, and with little or no clay in its partings - - | 6 | 0 |
| | Somewhat softer, marly bed, full of oysters, &c., irregular in thickness, but averaging - - - | 1 | 0 |
| | Beds of hard stone, base not seen—to bottom of pit - - - | 6 | 0 |

Prof. Judd states that this pit was formerly dug somewhat lower, but no good stone was found under the lowest bed, which rests on a marly band with oysters. "It is uncertain whether the clays and sands of the Upper Estuarine Series were reached. The Great Oolite Limestone in this area is probably about 20 feet in thickness." It "is exposed at several points near Stoke Doyle, and its junction with the clays below is marked by the occurrence of powerful springs."

South of Oundle, the beds of the Great Oolite Limestone were exposed in a number of cuttings on the Northampton and Peterborough Railway. Near Barnwell Prof. Judd observed the following section*:—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite Clay. | Blue and mottled clays, with a thin band of ferruginous nodules at the base - - - - - - | 5 | 9 |
| | Bed of laminated, sandy limestone, with bands of white marl and thin layers of "beef" (fibrous carbonate of lime). There are but few fossils in this bed, except the ubiquitous *Modiola imbricata* and *Ostrea subrugulosa* - - - - - | 1 | 8 |
| | Beds of hard ("Forest-Marble"-like) limestone, entirely composed of comminuted shells, with a few specimens of *Ostrea subrugulosa* - - | 2 | 0 |

* Geol. Rutland, pp. 203, 204, 216.

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite Limestone. | White, marly limestone, full of shells, *Modiola imbricata*, *Ostrea subrugulosa*, *Pholadomya deltoidea*, *Pteroperna plana*, *Myacites decurtatus*, *Cardium* - - - - | 1 | 6 |
| | Beds of hard ("Forest-Marble-like") stone, composed of comminuted shells, in two courses, with a clay-band between them. In other places this clay-band increases to a thick bed of white marl, full of oysters and other shells - - - | 7 | 0 |
| | Bed of white marl, becoming, in places, hard and nodular, and containing shells - - - | 3 | 0 |

Prof. Judd remarks that the Great Oolite Clay includes beds of more or less sandy clay, and in some places the strata are "crowded with carbonaceous markings."

The following section at Oundle was recorded by S. Sharp* :—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite Limestone. | "Lime Earth": cream-coloured argillaceous bed, sometimes used for mortar, without burning - - | 2 | 0 |
| | "Pendle": Hard flaggy stone, with *Modiola imbricata* - - - | 0 | 6 |
| | Blue clay - - - - | 1 | 0 |
| | Marl with *Ostrea Sowerbyi*: burnt for lime - - - - - - | 1 | 3 |
| | Hard shelly limestones - - | 0 | 9 |
| | Best Building Stone: Hard blue-hearted limestone, full of comminuted shells; stone worked into lintels and window-sills, &c. - - | 3 | 0 |
| | Marly limestone, full of shells - | 3 | 0 |
| | Hard blue-hearted limestone, full of comminuted shells, *Pteroperna*, &c.: stone used for road-metal - - | 2 | 6 |
| | Upper Estuarine Series. | | |

From these beds the Star-fish, *Ophiurella Griesbachi* was obtained; and Sharp notes also the occurrence of *Belemnites* (small specimens), fossils which are exceedingly rare, as a rule, in the Great Oolite. Many other species have been obtained at Oundle, at Wadenhoe, and other localities.

Prof. Judd estimated the thickness of the Great Oolite Limestone at 15 feet, and the Great Oolite Clay at 6 feet, near Wadenhoe and Pilton.† Near Oundle the thickness of the Clay is about 15 feet.

He mentions that in the valleys west of Oundle, the oyster-beds and underlying ragstone of the Great Oolite Limestone are exposed in a number of pits. The former beds are known locally as "hurr," and are often dug for constructing artificial rock-work. Where covered by ferruginous gravel (derived from the Northampton Sand), these beds have often acquired,

* Quart. Journ., Geol. Soc., vol. xxix. p. 280.
† Geol. Rutland, p. 216.

by the percolation of chalybeate waters, a deep brown colour and great induration. He remarks that one of the most interesting pits in which these characters are displayed, lies to the north-east of Benefield, where we find the following succession of beds :—

| | | Ft. | In. |
|---|---|---|---|
| Drift, &c. | Sandy gravel, containing small, irregular pebbles of brown oxide of iron, derived from the Northampton Sand. | | |
| | Breccia of argillaceous limestone and clay, full of Great Oolite fossils. | | |
| Great Oolite Limestone. | "Hurr," beds almost wholly made up of small oyster shells, and in their upper part indurated and stained of a dark brown colour by oxide of iron* - - - - about | 2 | 0 |
| | Blue clay - - - - | 1 | 0 |
| | Beds of good stone to bottom: quarried in places to depth of - - | 9 | 0 |

"Another peculiarity of the Great Oolite Limestone, as seen in the neighbourhood of Oundle, is well displayed in a pit between Upper and Lower Benefield. Here the bottom-beds of the series, which can be raised in very large slabs and blocks, exhibit much false-bedding and are crowded with shells; they also contain fragments, usually subangular, of a compact limestone possibly derived from the Lincolnshire Limestone, and indicating the denudation which those beds suffered prior to, and during, the deposition of the Great Oolite." The stone-beds of the Great Oolite here present the aspect of Forest Marble. The Great Oolite Clay is little more than 3 feet thick; and therefore, as Prof. Judd remarks, no attempt was made to separate it from the Limestone on the Geological Survey Map, in this part of the district.

"The 'town-pit' of Apethorpe is opened in the lowest hard bed of the white limestone. It is here about 16 inches thick, and is overlaid by hard, cemented, limestone rubble. It is underlaid by a bed of marl, and that in turn rests on a bed of stone 4 inches in thickness. Below this we find a great mass of light-blue clay belonging to the Upper Estuarine Series. Along the line of the valley by King's Cliffe, Apethorpe, and Wood Newton to Fotheringhay, a number of small pits occur by means of which the general succession of the Great Oolite beds may be traced."†

Below Calvey Wood, on the Walk of Morehay, south of King's Cliffe, the Great Oolite Clays "are seen below the Cornbrash, and are found to contain numerous branch-like concretions of brown oxide of iron, like those of the equivalent beds at New England, near Peterborough."

"On the Bedford Purlieus the beds of Great Oolite Limestone are exposed in some small openings, and are also reached in two of the wells dug on parts of the old forest-land which, at the time

* There is a specimen of this Oyster Bed in the Museum of Practical Geology.

† Judd, Geol. Rutland, pp. 205, 207, 216, 217; see also Sharp, Quart. Journ. Geol. Soc., vol. xxix. p. 280.

of the survey of the district, were being cleared and laid out in farms in this old forest tract. The same beds were passed through in a well at Cross Leas in the same district." The Great Oolite Clays have been worked for brick-making.

"About Elton there are several exposures of the Great Oolite strata, and between that village and Holborn Lodge, a well 72 feet deep yielded the following succession of beds":—

| | | Ft. | In. |
|---|---|---|---|
| Cornbrash | | 3 | 0 seen. |
| Great Oolite Clay | | 14 0 to 15 | 0 |
| Great Oolite Limestone. | Shaly rock (oyster bands) | 5 | 0 |
| | Hard rock (limestones) | 4 0 to 5 | 0 |
| Upper Estuarine Series. | Indurated sand and clay | 30 0 to 40 | 0 |
| Lincolnshire Limestone. | | | |

"In the last bed water was obtained. What is most remarkable in this section, is the thinness of the Great Oolite Limestone, another example of the tendency of its beds to south-easternly attenuation. A somewhat similar section was found in a well nearer to Elton."

Prof. Judd remarks that the Upper Estuarine Series and Great Oolite Limestone, that extend in outliers, from Weldon to Wakerley, are largely concealed by Drift, and present no sections of value till we reach the Great Wood south of the latter village. "Here the lowest beds of the series, consisting of white fire-clay, have been rather extensively dug and conveyed to Stamford for the purposes of being made into muffles and also for the manufacture, in admixture with other clays, of terra-cotta."

"The Wakerley clays are dug immediately below the peaty soil of the wood, to the depth of 6 feet, being found to rest directly on the oolitic rocks of the Lincolnshire Limestone; and they appear to be here of tolerably uniform character throughout. A pit at a slightly lower level showed only 4 feet of white fire-clay lying upon the limestone."*

### *Ketton to Peterborough and Stamford.*

The Upper Estuarine beds form the subsoil of Ketton Heath, and sections were exposed on the west side of Ketton Stones, and again in the Deeps, further south. The details vary in both sections: those which I noted at Ketton Stones were as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Upper Estuarine Series. | Grey and brown clay | 3 | 0 |
| | Grey banded clay with "race"; and with ferruginous nodules and calciferous gritty layers, *Ostrea Sowerbyi* | 10 | 0 |
| | Blue carbonaceous clay with selenite | 6 | 0 |
| | White sand and grey clay with rootlets | 7 | 0 |
| | Layer of ironstone-nodules | | |
| Lincolnshire Limestone. | | | |

* Geol. Rutland, p. 198.

Sharp, who has also noted the section at this locality, has recorded from the Upper Estuarine Beds, *Neæra Ibbetsoni Cyrena,* and *Modiola imbricata.**

An interesting section, recorded by Prof. Judd, was to be seen at the lime-kiln near the corner of Collyweston and Hornstock Woods.† (Fig. 114.)

FIG. 114.

*Section at the corner of Collyweston and Hornstock Woods, north of King's Cliffe.* (Prof. J. W. Judd.)


The section seen here is as follows:—

| | | FT. | IN. |
|---|---|---|---|
| | *a.* Soil - - - - - | 2 | 0 |
| Upper Estuarine Series. | *b.* Marly clays, white, light-blue, and mottled, somewhat laminated and "dicey" about | 4 | 6 |
| | *c.* Nodular, ferruginous, sandy bed - <br> *d.* White marl - - - - <br> *e.* Nodular, ferruginous, sandy bed - | 1 | 6 |
| Lincolnshire Limestone. | *f.* Laminated, sandy beds, passing down into sandy, oolitic limestone at the bottom of the pit. | | |

* Quart. Journ. Geol. Soc. vol. xxix. p. 241.
† Geol. Rutland, p. 192.

Prof. Judd remarks that "There are several points of some interest in connexion with this section. In the first place the 'ironstone junction-band' at the base is double, this being however merely a local variation. And, secondly, the character of the lower, white, sandy, and argillaceous beds of the Upper Estuarine Series, is such as to forcibly suggest that they may have originated in the denudation of limestone beds like those on which they repose; the soluble calcareous constituents having apparently been removed, and the remaining fine-grained materials sorted in moving water. A similar origin has been assigned to other fire-clays of analogous character."

The occurrence of sandy beds graduating down into the Lincolnshire Limestone is a noteworthy and unusual feature. No fossils are recorded by Prof. Judd, but it is possible (having regard to the unconformity with the beds above), that we have here somewhat higher portions of the Lincolnshire Limestone than are elsewhere shown.

Prof. Judd mentions that at Castor the oyster-beds of the Great Oolite Limestone are seen, and on Castor Heath the Limestone assumes the form known as Alwalton Marble, greatly resembling some of the flaggy beds of the Forest Marble of the south of England. The beds "which are seen at several points about Water Newton, can be traced between that point and Alwalton, at which latter place they are well exposed in the railway-cuttings and old marble-pits. The steep escarpment of the Alwalton Lynch is formed by the limestones and oyster-beds of the Great Oolite, overlying the variegated sandy clays of the Upper Estuarine Series. The beds are well seen in the road leading from the village down to the Nene. The Alwalton Marble was formerly dug all along the Alwalton Lynch, but the whole of the pits are now closed. The hard, blue, shelly limestone was found to take an excellent polish, but does not appear to have been very durable."

"About Milton Park a number of wells showed the beds of the Great Oolite Limestone to vary from 10 to 20 feet in thickness. There is a small pit in the oyster-beds in Thorpe Park."

"At Orton (or Overton), near Peterborough, a well gave the following succession of beds":—

| | |
|---|---|
| Cornbrash. | |
| Great Oolite Clay - - - - - | 13 to 14 feet. |
| Great Oolite Limestone - - - - | 17 feet. |
| Upper and Lower Estuarine Series - - | 39 feet. |
| Ironstone-rock (Northampton Sand). | |

"In the admirable exposures of the Great Oolite in the railway-cuttings at Bottlebridge, near Orton, the late Dr. Porter collected large numbers of very interesting fossils."* Many specimens were also obtained by Prof. Judd from Ailsworth, near Castor. Lists of fossils from the Great Oolite of this neighbourhood have been published by Sharp.†

* Judd, Geol. Rutland, pp. 207–209; and Porter, Geology of Peterborough, 1861.
† Quart. Journ. Geol. Soc., vol. xxix. p. 279.

Referring again to Prof. Judd, we learn that at Ufford, a well was sunk through the hard limestone of the Great Oolite (which required blasting) into the green clays with *Cyrena* (Upper Estuarine Series) below it.

"At Helpstone, a number of large pits have been opened in the Great Oolite Limestone, the stone being extensively quarried for road-metal, which is sent to considerable distances in the Fenland. In a large stone-pit, containing a lime-kiln, above Helpstone, we have the following section":—

| | | Ft. | In. |
|---|---|---|---|
| | Soil, &c. - - - - - | 2 | 0 |
| Great Oolite Clay. | Oyster-beds, with bands of clay between them - - - - - | 3 | 0 |
| Great Oolite Limestone. | Thick mass of very hard, dark-blue limestone, with many shells to bottom of pit. | | |

"A well here, commencing at the top of the oyster-beds, and dug to the depth of 12 feet, just reached the top of the clays of the Upper Estuarine Series." Another well, noted by Prof. Judd, sunk at the western end of Helpstone, passed through Cornbrash and Great Oolite Clay (13 feet), into ferruginous rock that yielded an abundance of water, but this, however, was unfit for drinking purposes. Around Milton Park the Great Oolite Clay is from 15 to 30 feet in thickness, and is very variable in character.

"At the railway-cutting near Overton Longville, at a place called Bottlebridge (St. Botolph's Bridge), the clays of the Great Oolite were exposed between the Cornbrash and Great Oolite Limestones. At this place the late Marquis of Huntly commenced digging the ironstone-balls, which form four bands in the midst of the dark-blue clays. The ironstone in the upper bands was soft and of a dark-brown colour, owing to weathering action, but the lower bands were of a greenish-white colour, and unoxidized, and every gradation between these two varieties occurred. The ironstone is said to have been of good quality, and between 100 and 200 tons of it were sent to Wellingborough to be smelted. Its exploitation was soon abandoned, owing to the quantity of material which had to be removed to obtain the nodules of ironstone."* In an excavation for the New England Gasworks, near Peterborough, the clays of the Great Oolite were found to have a thickness of 22 feet. At this locality a brickyard has been opened in the beds. (See p. 203.)

In the brickyard at Stamford Field (Torkington's pit) Prof. Judd observed, in 1869, the following section†:—

| | | Ft. | In |
|---|---|---|---|
| | Soil - - - - - | 1 | 6 |
| Great Oolite Limestone. | Oyster-beds - - - - | 3 | 0 |
| | Dark-coloured, nearly black, carbonaceous and ferruginous clay - - | 3 | 6 |
| | Green clays, with shells - - | 3 | 0 |
| | Clays of a tea-green colour, sometimes passing to a bright green, and crowded with shells - - - | 5 | 6 |

* Judd. Geol. Rutland, p. 217.

† Judd, Geol. Rutland, p. 199.

| | | Ft. | In. |
|---|---|---|---|
| Upper Estuarine Series. | Black, carbonaceous bed - | 1 to 2 | 0 |
| | Grey clay with masses of jet - - | 2 | 0 |
| | "Skerry," a hard gritty clay used for making fire-bricks. It resembles in texture the "root-beds," but has no vertical plant remains - - | 0 | 8 |
| | Grey clay, blackish in places (but makes fine white bricks and is estimated the best clay in the pit) - - - | 4 | 0 |
| | White clays, very sandy in places - | 5 | 0 |
| | Light reddish-brown clay, full of wood | 1 | 0 |
| | Ironstone junction-band - - | 1 | 0 |
| Lincolnshire Limestone - - - - - | | 74 | 0 |
| Northampton Beds. | Sands and ironstone. | | |

In the "skerry" and the clays below it, iron-pyrites abounds. The total thickness of the Upper Estuarine Series here is 27 feet.

The upper clays burn into a red brick, the "skerry" into a fire-brick, and the grey clays below into a fine white brick.

S. Sharp, who also described this section in somewhat different detail, records the following fossils from the Upper Estuarine Beds:—

Cyrena.
Modiola imbricata.
—— Lonsdalei.
Neæra Ibbetsoni.
Ostrea Sowerbyi.
Pholadomya acuticosta.
Tancredia angulata.

From the same beds at Belmesthorpe he obtained remains of *Teleosaurus*, *Hybodus*, &c.* He also notes the occurrence of *Ammonites gracilis*, *Nautilus Baberi*, and other fossils from the Great Oolite Limestone north of Stamford.

The accompanying section (Fig. 115) was noted by myself, with the exception of the upper beds (Nos. 8 and 9).

### *Stamford to Castle Bytham.*

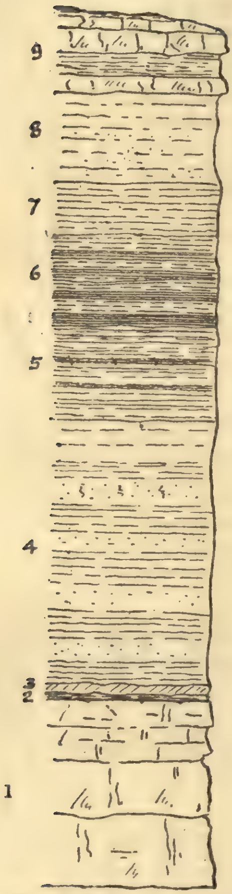
The Upper Estuarine Beds were well exposed in the railway-cuttings on the Great Northern Railway between Essendine and Careby. The strata were described in detail by Prof. Morris,† and as the cuttings are now for the most part obscured, his descriptions have been reproduced in the Survey Memoirs. The principal cutting, known as that of Danes' Hill, is situated west of Carlby, other sections were seen near Aunby and Careby. The beds were shown to a thickness of from 22 to 32 feet, and comprise grey and white, and black and green, shelly and sandy and bituminous clays, with beds of sandy and marly rock, containing vertical plant-markings and lignite. An oyster-bed was shown at the top, and the usual ferruginous band at the base. Many fossils are recorded by Sharp. (See Fig. 116, p. 421.)

* Quart. Journ. Geol. Soc., vol. xxix. pp. 249, 258.

† Morris, Quart. Geol. Soc., vol. ix. pp. 328–331; and Geol. Mag. 1869, p. 102; Judd, Geol. Rutland, pp. 199, 209, 210; Sharp, Quart. Journ. Geol. Soc., vol. xxix. pp. 257, 258, 261–264.

FIG 115.

*Section north-west of Stamford.*




| | | Ft. | In. |
|---|---|---|---|
| | 9. Great Oolite Limestone | 3 | 6 |
| Upper Estuarine Series. | 8. Sandy and ferruginous clay - - - | 4 | 0 |
| | 7. Blue and brown clay - | 2 | 0 |
| | 6. Banded green and grey shelly clay - - | 4 | 0 |
| | 5. Purplish, green, and grey clay - - | 4 | 0 |
| | 4. White and grey, purplish carbonaceous clays, with selenite, and sandy layers with rootlets - - | 11 | 0 |
| | 3. Dark red ironstone - | 0 | 5 |
| | 2. Ferruginous clay - | 0 | 3 |
| | 1. Lincolnshire Limestone. | | |

Prof. Judd states that: "At Little Bytham, at the adamantine clinker works beside the Great Northern Railway, the clays of the Upper Estuarine Series are extensively dug for the purpose of making bricks of peculiarly excellent quality, which, from the ringing sound which they give when struck together, are known as 'clinker bricks.' We have here a very interesting section exposed":—

*Section at the "Clinker Works" and Railway-cutting, Little Bytham.*

| | Ft. | In. |
|---|---|---|
| Soil - - - - - - | 0 | 6 |
| Tea-green clays - - - - - | 1 | 2 |
| Brown, sandy clay - - - | 1 | 0 |
| Greenish clay, full of soft, white, carbonate of lime ["race"] - - | 1 | 0 |
| Variegated blue and brown, sandy clay | 1 | 6 |
| Blue clay - - - - - | | 6 |
| Blue and brown, sandy clay - - | 1 | 6 |
| Bed of indurated sand with fossils - | 0 | 6 |

| | | Ft. | In. |
|---|---|---|---|
| Upper Estuarine Series. | Blue clay, slightly mottled - - | 0 | 4 |
| | Brown and blue mottled, stiff clay, with lumps of soft carbonate of lime | 0 | 4 |
| | Tea-green clay, ferruginous at the bottom - - - - | 1 | 0 |
| | Dull tea-green clays - - - | 1 | 0 |
| | Lighter-coloured tea-green clays, with seams of comminuted shells and carbonaceous markings - - | 2 | 0 |
| | Brown sand, full of shells, and containing carbonaceous markings - | 0 | 1 |
| | Black clay - - - - | 1 | 3 |
| | Lighter-coloured and more compact clay - - - - - | 0 | 7 |
| | Greenish, compact clay, with ferruginous markings - - - | 1 | 2 |
| | Tea-green clays with ferruginous markings - - - - | 0 | 3 |
| | Dark-blue, compact clay with ferruginous markings - - - | 1 | 6 |
| | Dark-blue, compact clay, becoming ferruginous at the bottom, with vertical plant-markings - - - | 5 | 2 |
| | Brown, ferruginous clay (representative of junction-bed) - - - | 1 | 6 |
| Lincolnshire Limestone. | Rubbly limestone (Inferior Oolite) - | 1 | 0 |
| | *The following were seen in the Railway-cutting :—* | | |
| | False-bedded oolitic limestone - - | 4 | 0 |
| | Sandy bed, full of oolitic grains - | 0 | 3 |
| | Compact, blue-hearted, oolitic limestone, slightly false-bedded - - | 5 | 6 |

In the railway-cuttings near Counthorpe, Swayfield, and Corby, the Upper Estuarine Beds were at one time well exposed. These sections were described by Prof. Morris, who noted the following general sequence :—

| | | Ft. | In. |
|---|---|---|---|
| [Great Oolite Limestone.] | Soft brown marly rock, with layers of *Ostrea*, and with *Lima*, *Modiola*, *Perna quadrata*, *Serpula*, &c. - | 6 | 0 |
| [Upper Estuarine Series.] | Mottled clay with bands of oysters - | 3 | 0 |
| | Dark bituminous clay - - - | 1 | 0 |
| | Compact sandy and soft shelly rock, with vertical remains of plants; *Natica*, *Modiola*, *Trigonia* - - | 3 | 0 |
| | Dark green and brown shelly clays - | 4 | 0 |
| | Dark shelly clays, with *Avicula*, *Cyrena*? *Lima*, *Ostrea*, *Pecten*, &c. - - | 4 | 0 |
| | Mottled and dark clays, and bituminous band (at base) - - - - | 6 | 6 |
| | Brown and grey clays, with numerous vertical plant-markings - - | 7 | 0 |
| | White and yellow clays with ferruginous band at base - - - | 4 | 0 |
| Lincolnshire Limestone. | Fine grained and pinkish oolite. | | |

Here two layers with vertical plant-remains occur; the upper one was included in the Great Oolite Limestone in the Geological Survey Memoir.*

* Geol. S.W. Lincolnshire, p. 65.

Prof. Judd remarks that the cutting on the Great Northern branch railway at Belmesthorpe, between Stamford and Essendine, "not only furnishes an excellent section of the beds of the Great Oolite Limestone, but enabled the former collector of the Survey, Mr. Richard Gibbs, to obtain an interesting series of its characteristic fossils. North of Essendine, about which place there are numerous exposures of the limestones and oyster-beds, we find rocks exposed in this formation which yield a greater variety of fossils than is usually found in the beds of this age. At this point large masses of coral (*Isastræa*) are very abundant in the Great Oolite Limestones."

At Belmesthorpe large specimens of *Nautilus Baberi* occurred in abundance; a fact of interest when we remember that this form is so conspicuous at Bedford. Lamellibranchs were also obtained in great variety, including *Macrodon hirsonensis*.

In the Dane's Hill cutting further to the north-west, Prof. Judd noticed that "the lowest bed of the Great Oolite Limestone presents some interesting characters, which are worthy of remark. It constitutes a mass of about 3 feet thick, the upper layer of which contains many long cylindrical spines of echinoderms, especially of *Acrosalenia*."*

The Great Oolite Clay was shown in the railway-cutting at Banthorpe, south of Essendine, and from it Sharp obtained a fine vertebra of *Cetiosaurus*. Immense bones of the same Saurian, were also obtained in the Essendine cutting, probably from the equivalent strata.† The horizon may be compared with that at Kirtlington and other localities near Oxford, where similar remains have been found. (See p. 323.)

In the neighbourhood of Witham-on-the-Hill there are many pits exhibiting the beds of the Great Oolite Series, among which Prof. Judd records the following section between that village and Manthorpe‡:—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite Clay and Limestone | Soil | 0 | 9 |
| | Oyster-bed | 0 | 9 |
| | Dark coloured, stiff clay | 2 | 0 |
| | Oyster-bed with layers of "Beef" | 0 | 9 |
| | Marly parting. | | |
| | Oyster-bed with layers of "Beef" | 1 | 0 |
| | Marly parting. | | |
| | Oyster-bed with "Beef" | 1 | 6 |
| | Oyster-beds | 1 | 3 |
| | Marly parting. | | |
| | Bed of hard, solid, blue-hearted limestone, crowded with shells, etc., including— | | |

Strophodus (tooth). Perna rugosa.
Lima duplicata. Pteroperna plana.
Modiola imbricata. Trigonia costata.
Ostrea subrugulosa.

The limestone was quarried for road-metal.

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* See Judd, Geol. Rutland, pp. 209, 210, 211.

† Sharp, Quart. Journ. Geol. Soc., vol. xxix. pp. 261, 262; Morris, *Ibid.*, vol. ix., p. 332.

‡ Judd, Geol. Rutland, p. 212.

Fig. 116.

*Section in the Danes' Hill Cutting, west of Carlby, Lincolnshire, on the Great Northern Railway.*
(Prof. J. Morris.)

(Length 22 chains. Vertical Scale, 120 feet to 1 inch.)


*e.* Cornbrash.
*d.* Great Oolite Clay.
*c.* Great Oolite Limestone.
*b.* Upper Estuarine Series.
† Plant Bed.
} Great Oolite Series.

*a.* Lincolnshire Limestone. Inferior Oolite.

(This figure is inserted by permission of the Council of the Geological Society.)

The cuttings on the new (Midland) railway, between Bourn and Saxby, opened up a number of interesting sections in the Great Oolite Series, and these I had the opportunity of examining in the spring of 1892.

To the north-west of Lound, north of Elderwood Farm, the railway traverses the ground at a comparatively high level; but on the western side of the valley the Great Oolite Limestone was exposed in trial-pits. The formation consists of hard earthy and shelly limestone, with (on top) a band crowded with *Ostrea subrugulosa*. Above, there was to be seen the Great Oolite Clay, comprising brown, grey, green, and purplish racy clay, with an included band of hard marl full of oysters, chiefly *Ostrea subrugulosa*. Overlying the Great Oolite Clay, came the Cornbrash, with *Ostrea flabelloides*, *Gresslya peregrina*, &c.; and this formation was overlaid by clays and sandy strata belonging to the Kellaway's Beds.

Further west there was a cutting in Great Oolite Clay and Cornbrash, the position of which indicates the presence of a fault (of no great magnitude), which traverses the ground in a direction a little west of north, and about 300 yards west of Elderwood Farm.* The section of the beds, in descending order from west to east, was as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Oxford Clay. | Kellaways Beds, seen south of Home Bottom Farm. | | |
| Cornbrash. | Rubbly and flaggy limestone. | | |
| Great Oolite Clay. | Nodular compact and shelly limestone, in brown racy clay.<br>Clay with "race": *Ostrea subrugulosa* and *O. Sowerbyi*. | 1 | 6 |
| | Stiff grey clay - - - -<br>Purple clay - - - -<br>*Ostrea*-band - - - -<br>Green clay - - - -<br>Traces of red ironstone nodules - - | 6 | 0 |

The Great Oolite Limestone, which must come on below, was not here exposed.

Shallow cuttings in chalky Boulder Clay extend from the south of Pells and Dobbin Woods to a little west of the disused Little Bytham and Edenham Railway. Along portions of this tract large blocks of fossiliferous Great Oolite Limestone were brought from the cutting on the west, to be broken up for ballast. On either side of the disused railway the Boulder Clay was seen resting on Great Oolite Clay. The Boulder Clay here, as in other exposures along this Midland railway, contains numerous glaciated Chalk-stones, together with flint and a good deal of Jurassic material. It is, however, noteworthy that Oxfordian fossils (*Gryphæa dilatata*) occur here amid the Chalk detritus, while further west Lower Oolitic material is noteworthy, and still further west I found many Lower Lias fossils. In the cutting to which attention is now directed, and which is to the north-east of Little Bytham station (on the Great Northern Railway), the Great Oolite Clay presents its usual characters of grey and green clay and loamy clays, with *Ostrea*-bands, and with nodules of red

* This little fault was not shown on the Geological Survey Map, and consequently the beds above the Great Oolite Limestone to the east of it, were not represented in the little spur on which Elderwood Farm stands. In other respects the new railway confirmed the mapping of the strata, by Prof. Judd, with the exception of the fact noted further on p. 423.

and purplish ironstone at the base. The top-bed of the Great Oolite Limestone comprises slabs of *Ostrea*-limestone (six to eight inches thick) with *O. subrugulosa.* Below are compact grey earthy and shelly limestones, evenly bedded and divided by bands of clay. The more prominent bed is near the base, and it is a hard blue-hearted limestone (2 to 3 feet thick), full of fossils; but many of them, both Corals and Mollusca, are replaced by calcite. Some Gasteropods occur, together with *Lima, Modiola, Perna, Pteroperna, Trigonia,* &c. Specimens of *Ostrea Sowerbyi,* and *O. subrugulosa,* as might be expected, are well preserved. Some of the blocks of limestone show fucoidal markings. The rock resembles the Great Oolite Limestone of Bedford, and consists of dark and light grey material. The joint-faces weather white. The total thickness of the Great Oolite Limestone is about 10 feet. The thick bed at the base was shivered in places, but I was informed that many large blocks had lain out all the winter and had withstood the frost. It is not likely however to prove a very serviceable building-stone.

Below it there occurs a layer of fissile earthy limestone with *Ostrea* (about 1 foot thick), and it rests on the Upper Estuarine Series. This Series comprises brown and green clays (like those of the Great Oolite Clay), with a band of earthy limestone with plant-markings. A thin gravel rests on the Upper Estuarine Series, in the cutting west of the road that leads to Bytham Park.

At Potter's Hill, to the west of Castle Bytham, there was a cutting through the oolitic freestone (Lincolnshire Limestone), which was shown at the east end, and the rock was capped by Upper Estuarine Beds and again by Boulder Clay (see also p. 208). Further west the Boulder Clay has cut more deeply into the strata down to the level of the railway; but it rises again and a fine section of Upper Estuarine Beds was exposed. Like the Great Oolite Clay, these beds contain a marly oyster-bed, and this appeared as a white band in a variable series of clays, the tints of which (in descending order) were brown, dark blue, green, grey, white, green, and dark blue. Altogether these Upper Estuarine Beds are from 15 to 18 feet thick. At the eastern end of the cutting the nodular ironstone-bed was shown above the Lincolnshire Limestone. The western end of the cutting was not completed at the time of my visit. The Boulder Clay contained a large nest of sand, and a block of Great Oolite Limestone, measuring 7 feet × 4 feet × 18 inches.*

### *Castle Bytham to Sleaford.*

In Lincolnshire there is little difficulty in separating the Upper Estuarine Series from the Lincolnshire Limestone on which it reposes; but it is by no means so clearly to be distinguished from the Great Oolite Limestone above. The lower portions of that formation comprise limestones, marls, and clays with oyster-beds,

* There was no indication of Great Oolite Limestone in the cutting, nor of the fault shown on the Geological Survey Map.

some of which are evidently very closely linked with the Upper Estuarine Series.

Thus in a section in Grimsthorpe Park, noted by W. H. Holloway, some of these oyster-beds have been included in the Upper Estuarine Series, but the section was much obscured by talus, so that it is not clear that the classification there adopted is correct; and it may be best to group with the Great Oolite Limestone, the beds of shelly limestone (6 to 10 feet thick) and the overlying marly oyster-beds, that there rest on the green and purplish clays of the Upper Estuarine Series.* Well-sections at Horbling, Billingborough, Dunsby, and Pinchbeck North Fen, indicate that the Upper Estuarine Series varies in thickness from 26 to 35 feet.†

In the cutting near Rauceby station, Mr. W. H. Dalton noted a thickness of over 18 feet of shelly marls, and green, grey and purple clays, with layers of white and yellow sand at the base; and from these beds *Ostrea* was obtained. A well at Leasingham, N.W. of Sleaford indicates 66 feet of dicey clay beneath the Great Oolite; but this unusual thickness for the Upper Estuarine Series requires confirmation.‡

The Upper Estuarine Beds have been well shown in the Haydor and Wilsford quarries, above the Ancaster stone (Lincolnshire Limestone). There grey shale and ferruginous layers occur at the base, and higher up we find purple and greenish shales and clays with thin bands of marly limestone.

Above the Upper Estuarine Clays near the Windmill, at Ancaster, there are bands of grey marly, shelly, and sandy limestone, and flaggy calcareous sandstone, with *Ostrea* and *Modiola*, belonging to the base of the Great Oolite Limestone.

Quarries in the Great Oolite Limestone were noted by W. H. Holloway near Ingoldsby, Walcot, and Pickworth. There we find 3 or 4 feet of marls, and shelly bands crowded with *Ostrea Sowerbyi* and *O. subrugulosa*, and with occasionally a band of dark blue and greenish clay, overlying 3 or 4 feet of hard marly and shelly limestone with oolitic grains; the stone is dug for road-metal. Near Sleaford the Great Oolite Limestone forms no conspicuous feature in the land. (See Fig. 117.)

Well-sections at Horbling, Billingborough, Dunsby, Pinchbeck North Fen and Bourn, indicate the thickness of the Great Oolite Limestone to vary from 12 to 33 feet. At Swarby, S.W. of Sleaford, it is 24 feet, at Osbournby 14 feet, and at Leasingham to the N.W. of Sleaford from 21 to 33 feet.§

At Great Humby, information (derived from a well-section) shows that the Great Oolite Clay attains a thickness of 29 feet: it consists of blue and grey clays with thin rock-beds. Eastwards, judging by well-sections, the thickness of this division varies from 22 to 29 feet at Horbling, Billingborough, and Pinchbeck North Fen, but it increases to 33 and 46 feet at Dunsby, and it is 35 feet at Bourn. At Swarby, south-west of Sleaford the thickness is stated to be 30 feet.||

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* Jukes-Browne, Geol. S.W. Lincolnshire, pp. 63, 64.

† *Ibid.*, pp. 140, 142, 146, 152.

‡ *Ibid.* p. 147.

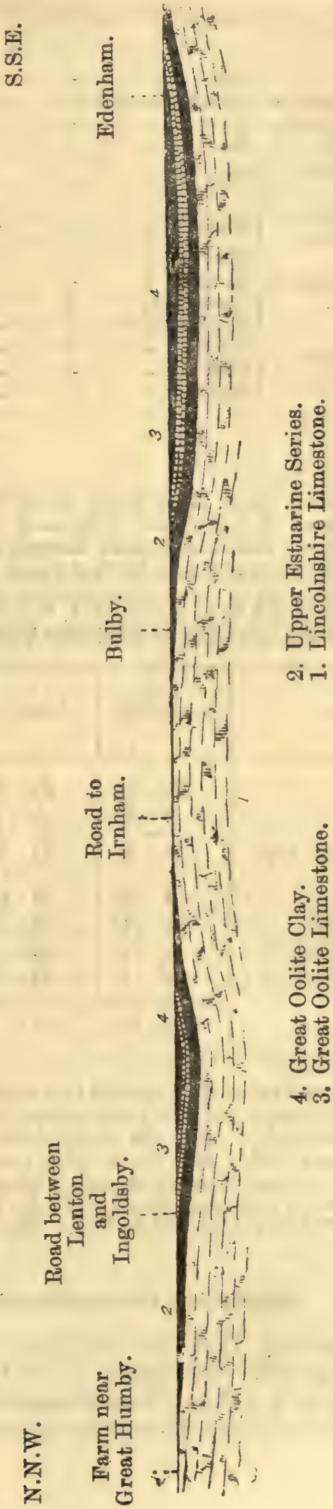
§ *Ibid.*, p. 64.

|| *Ibid.*, pp. 140, 142, 147. The section recorded (*Ibid.* p. 67) by W. H. Holloway, in a brickyard at Little Humby, seems from the account of the strata to refer to the Upper Estuarine Series.

FIG. 117.

*Diagram-section along the Valley from Great Humby to Edenham, Lincolnshire.* (A. J. Jukes-Browne.)

(Horizontal Scale about one inch to a mile.)



A well-boring made at Sleaford, for Messrs. Bass and Co., proved the following strata:—

| | | Ft. | In. |
|---|---|---|---|
| | Soil - - - - - | 1 | 6 |
| Valley Gravel - | Gravel and sand - - - | 12 | 0 |
| Kellaways Clay - | Clay - - - - - | 1 | 0 |
| Cornbrash - | Rock - - - - - | 10 | 0 |
| Great Oolite Clay. | Clay - - - - - | 24 | 0 |
| Great Oolite Limestone. | Rock - - - - - | 12 | 0 |
| Lower Estuarine Series. | Clay - - - - - | 7 | 0 |
| | Rock - - - - - | 2 | 6 |
| | Green clay - - - - | 1 | 0 |
| | Dark clay - - - - | 4 | 0 |
| Lincolnshire Limestone. | Rock - - - - - | 15 | 0 |
| | Clay - - - - - | 2 | 9 |
| | Rock - - - - - | 85 | 0 |
| | | 177 | 9 |

Another well at Cross Keys Yard, Sleaford, showed 36 feet of clays with a rock-band (2 feet thick) that must be grouped with the Lower Estuarine Series. The Lincolnshire Limestone was reached at a depth of 70 feet, and penetrated to a further depth of only 11 ft. 6 in.

Other well-borings in the neighbourhood proved the following strata, the details of which I have interpreted, though not always with absolute certainty as to the grouping of particular bands of clay or rock:—

| Strata. | Osbournby. | | Swaton. | | Heckington. | | Silk Willoughby. | |
|---|---|---|---|---|---|---|---|---|
| | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. |
| Soil - - - | 1 | 6 | 1 | 0 | 10 | 0 | 8 | 0 |
| Drift - - - | — | | 41 | 0 | — | | — | |
| Oxford Clay and Kellaways Beds. | 17 | 6 | 58 | 0 | 245 | 0 | — | |
| Cornbrash - - | 9 | 2 | 14 | 10 | 7 | 0 | 3 | 0 |
| Great Oolite Clay - | 21 | 0 | 28 | 6 | 22 | 0 | 20 | 0 |
| Great Oolite Limestone - | 13 | 10 | 21 | 4 | 17 | 0 | 17 | 0 |
| Upper Estuarine Series - | 29 | 6 | 27 | 0 | 22 | 0 | 26 | 0 |
| Lincolnshire Limestone - | 58 | 4 | 59 | 0 | 77 | 0 | 104 | 0 |
| | 150 | 10 | 250 | 8 | 400 | 0 | 178 | 0 |

At Aswarby a boring was carried to a depth of 131 feet (into the Lincolnshire Limestone), and the beds passed through were practically the same as at Osbournby. For the above details I am chiefly indebted to Messrs. Thomas Tilley and Sons. The record of the Silk Willoughby boring was communicated by Messrs. Wadsley and Son; and this boring was continued to a further depth of 37 ft. 9 in., in "Lias" 20 feet, and "Blue Rock" [? Marlstone] 17 ft. 9 in. (See p. 505.)

### *Sleaford to Greetwell and Winterton.*

Near Blankney Hall the thickness of the Upper Estuarine Series was proved to a depth of 25 feet. Mr. W. H. Dalton remarks that in a well at Potter Hanworth Station, the lower part of the Series was found to consist of blue and green clay, with masses of jet and bands of pyritous sandstone, in which occur remains of Fishes, Ostracoda, and *Paludina*.

Mr. Dalton also notes that the Upper Estuarine Series was admirably exposed, to nearly its full thickness, in the railway-cutting at Heighington. The beds lie in a slight synclinal, and to the eastward abut against a faulted face of the Inferior Oolite. Their natural junction with that rock is marked by a feature crossing the line at the Station, and below the level of the rails. The cutting shows the following sequence* :—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite Limestone. | Limestone | 11 | 0 |
| | Shales with three hard sandy bands, 6 to 12 inches thick, full of *Ostrea* | 7 | 7 |
| Upper Estuarine Series. | Tea-green shales | 3 | 5 |
| | Ochry shale | 3 | 6 |
| | Green shale | 4 | 6 |
| | Ochry shale | 2 | 6 |
| | Grey shale | 6 | 3 |
| | White sand, about 14 feet, but seen to depth of | 8 | 0 |

The hard sandy or calcareous gritty bands, which I have grouped with the Great Oolite Limestone, contain *Ostrea Sowerbyi*, *O. subrugulosa*, and *Rhynchonella*. At Metheringham the Great Oolite Limestone comprises beds of shelly ragstone, with clay-bands yielding *Ostrea*.

Near Greetwell the following appears to be the sequence of the several beds, as observed by Mr. Dalton in the railway-cutting :—

| | | Ft. | In. |
|---|---|---|---|
| Great Oolite Limestone, &c. | Limestone passing down into greyish-blue clay, *Rhynchonella*, *Ostrea*, &c. | 14 | 0 |
| Upper Estuarine Series. | Hard sand of a pale mauve tint | 1 | 6 |
| | Blue clay weathering yellow and brown | 6 | 0 |
| | Hard sand, pale mauve, with carbonaceous plant-markings | 9 | 0 |
| | Line of nodular limonite with veins of fibrous gypsum. | | |
| Lincolnshire Limestone. | | | |

In the Sudbrook Holme well-section, the following beds, referable to the Upper Estuarine Series, were proved :—

| | Ft. | In. |
|---|---|---|
| Green Clay | 3 | 8 |
| Stone | 5 | 4 |
| Clay | 15 | 0 |

The full thickness of the Great Oolite Limestone in this neighbourhood, is about 20 feet; the beds comprise ragstones and marls, and they yield remains of Fishes, Mollusca, Echinoderms and Corals.

Further north, as remarked by Mr. Ussher, the Upper Estuarine Series appears to be largely composed of sand, irregu-

* Ussher, Geol. Lincoln, pp. 62–65.

larly associated with grey and greenish clay, either of the constituents locally prevailing. In the area north of Ancholme Head, the thickness is from 15 to 20 feet.

West of Waddingham Mr. Ussher obtained *Modiola imbricata*, *Ostrea Sowerbyi*, and *Rhynchonella*, from beds of blue clay and loam under the Great Oolite Limestone. These are like the beds at Greetwell. Beds of white and buff sand belonging to the Upper Estuarine Series occur in this neighbourhood and also to the east of Redbourne. The thickness of the Series is little more than 10 feet. The most northerly exposure occurs near Hibaldstow, where rubbly shale, dark grey and greenish clay and sand, were exposed beneath shaly Great Oolite Limestone; but it is probable, as noted by Mr. Ussher, that the beds were penetrated in a deep boring at Brigg (see p. 430).*

In 1875 Prof. Judd remarked that: "As we pass northwards in the county of Lincoln, the Upper Estuarine Series, like the other members of the Great Oolite, becomes gradually reduced in thickness, and by the thinning out of the Upper Zone of the Great Oolite, the two argillaceous series, representing the Forest Marble and the Stonesfield Slate respectively, are brought together, thus the only vestige of the Great Oolite formation below the Cornbrash in North Lincolnshire is a thin series of clays of more or less estuarine character."†

Mr. Ussher states that: "West of Saxby, Owmby, and Normanby, the Great Oolite Limestone forms a rock of some economic importance, furnishing tolerably thick beds, suitable for building-purposes; but the general tendency of the rock to split along lateral joints, or what might be called irregular incipient bedding-planes, is apparent even in parts of the best stone-beds. As we proceed northward the Great Oolite Limestone becomes more brashy, and there are beds in it so like Cornbrash, that a very detailed investigation was necessary to prove that the Cornbrash was absolutely nowhere in contact with the Great Oolite Limestone." Referring to the strata near Bishop's Norton, he remarks: "We have here the type so frequently exhibited by the Great Oolite from Snitterby northward, namely, the irregular association of tolerably hard irregular shaly limestones with softer beds of decomposed fossiliferous limestone, or of broken shells in a loamy or clayey matrix."‡

The Great Oolite Limestone in North Lincolnshire consists of shaly limestone, somewhat arenaceous in character and grey siliceous limestone, having the rubbly aspect of Cornbrash. Clayey beds are intercalated with the lower strata north of Waddingham and Redbourne, furnishing evidence of a passage into the underlying Upper Estuarine Beds. From the beds exposed in this district Mr. Ussher has obtained the following fossils:—

* Ussher, Geol. North Lincolnshire, pp. 81, 82.
† Geol. Rutland, pp. 11, 186.
‡ Ussher, Geol. Lincoln, pp. 65, 68.

Corbicella.
Lima rigida.
Modiola furcata.
—— imbricata.
Myacites calceiformis.
Ostrea Sowerbyi.
Pteroperna plana.
Trigonia costata.
—— flecta.
—— striata.
Rhynchonella concinna.

Mr. Ussher remarks that from Hibaldstow northward there is no surface-indication of the extension of the Great Oolite Limestone, though it may be represented by 11 feet 7 inches of rock and shale in the boring at Brigg. Thus the Great Oolite Limestone dies away, apparently interdigitating with clays, and finally permitting of the direct superposition of beds having the character of the Great Oolite Clay upon the Upper Estuarine Series.*

Near Lincoln the Great Oolite Clay is from 20 to 26 feet thick. It consists of dark bluish-grey clay often mottled with green, and contains numerous shells of *Ostrea Sowerbyi*, *O. gregaria*, and also *Rhynchonella concinna*, which appear to be most abundant in the upper part, at the junction with the Cornbrash.† The clay was formerly dug for brickmaking near Metheringham station, but now there are very few sections worthy of note along the outcrop that extends towards Brigg.

Mr. Ussher has stated that the thickness of the Great Oolite Clay may be from 20 to 30 feet near Gander Hill, south-east of Hibaldstow. He notes that from Low Bank to Brigg the clay is concealed by Alluvium. It is proved at Brigg; but from Brigg northwards it is concealed by Alluvium and Sand for a distance of nearly 3 miles. The thickness of the Clay would appear to be 24 feet 4 inches in the Brigg Boring, and it was encountered at a depth of 105 feet from the surface. On the east of Thornholme Priory and near Broughton Carr Side, green and blue clay, with *Ostrea*, was visible.

Referring generally to the clays between the Lincolnshire Limestone and Cornbrash in North Lincolnshire, the Rev. J. E. Cross estimated their thickness at 40 feet; and he gave the following list of fossils from the beds:—

Fish-remains.
Gervillia crassicosta.
Modiola ungulata.
Ostrea Sowerbyi.
Ostrea subrugulosa.
Perna rugosa, var. quadrata.
Trigonia flecta.

Mr. Ussher states that Cornbrash forms the surface for about a quarter of a mile west of Appleby Station; its junction with the Great Oolite Clay was shown in a pit on the south side of the Railway.‡

The divisions of Upper Estuarine Series, Great Oolite Limestone, and Great Oolite Clay appear to be continuous as far as Hibaldstow. At Thornholme Priory and Mickle Holme, north of Appleby, clay alone occupies the interval between the Inferior Oolite and the Cornbrash. Mr. Ussher states that this clayey series "is about the same thickness as the Great Oolite Clay,

* Geol. N. Lincolnshire, pp. 82–84.
† Geol. Lincoln, p. 68; Geol. N. Lincolnshire, p. 85.
‡ Geol. N. Lincoln, pp. 85, 86; Cross, Quart. Journ. Geol. Soc., vol. xxxi. p. 125.

which it resembles in character. We are therefore obliged to conclude that the Great Oolite Limestone disappears altogether north of Brigg, and that the Great Oolite and Upper Estuarine Clays are brought together, and, being indistinguishable, constitute one group ; or that the Upper Estuarine Clay also thins out northward. The alternative is mentioned by Mr. Fox-Strangways in his notes on the Hibaldstow Beds, but I am indisposed to admit that the absence of the Great Oolite Limestone and Upper Estuarine Clay is due to the unconformable overlap of the Great Oolite Clay upon the Lincolnshire Limestone, not being in a position to prove that the Upper Estuarine Series is really unrepresented in this district, and not regarding the disappearance of the thin series of brashy Great Oolite Limestones as evidence of unconformity."

Mr. Ussher further observes "that it is possible to put such a construction upon the record of the bore-hole made on the south side of Bridge Street, Brigg, by Mr. Joseph Parker, 1864–5 (at a spot 70 yards west of the River Ancholme) as to give a considerable thickness to the Great Oolite Series, and to make an Upper Estuarine Series composed as follows" :—

| | | Ft. | In. | Ft. | In. |
|---|---|---|---|---|---|
| Drift, &c. | | | | 40 | 0 |
| Oxford Clay and Kellaways Beds | | | | 62 | 0 |
| Cornbrash | | | | 3 | 0 |
| Great Oolite Clay | Blue shale | | | 24 | 4 |
| ? Great Oolite Limestone | Sandstone rock | 0 | 9 | 11 | 7 |
| | Grey shale | 1 | 6 | | |
| | Hard rock or boulder | 0 | 6 | | |
| | Grey shale | 0 | 11 | | |
| | Rock | 1 | 1 | | |
| | Unformed rock | 6 | 10 | | |
| Upper Estuarine Series | Grey shale | 2 | 10 | 24 | 2 |
| | Sandy shale | 10 | 5 | | |
| | Sand | 10 | 11 | | |
| Lincolnshire Limestone | | | | 44 | 7 |
| Upper Lias, &c. | | | | | |

"If this be reliable the attenuation of the Upper Estuarine Series and dying-out of the Great Oolite Limestone must take place between Brigg and Appleby Station."* The last traces of the Great Oolite Series that are represented on the Geological Survey Map, are at Winterton Holme, but the beds are entirely concealed by Boulder Clay.

On the whole the evidence favours the view that in the northern part of Lincolnshire, we have but one stratigraphical division, that represents the Upper Estuarine Series, the Great Oolite Limestone, and the Great Oolite Clay.

On the northern side of the Humber there is a series of clays and sands, from 20 to 30 feet thick, that lie between the Cave Oolite (Inferior Oolite) and the Kellaways Beds; and these strata are said by Mr. Strangways to "occupy a similar position to the Upper Estuarine Series of the Yorkshire basin."†

* Ussher, Geol. N. Lincolnshire, pp. 81, 211.

† Jurassic Rocks of Yorkshire, vol. i. p. 259.

# CHAPTER XIV.

## GREAT OOLITE SERIES.

### CORNBRASH.

### GENERAL ACCOUNT OF THE STRATA.

CORNBRASH is an old agricultural term, applied in Wiltshire to certain stony or brashy soils that are well suited to the growth of corn. These soils are derived from the strata that lie between the Forest Marble and Oxford Clay; and the name Cornbrash, adopted in 1812 by William Smith as a geological term for these strata, was published by Townsend in 1813.

The Cornbrash, where exposed in quarries, usually presents a very rubbly appearance; and the broken stone is often coated with tufaceous material. It consists of tough irregular layers of earthy and shelly limestone, alternating with softer beds of pasty limestone, and with partings and bands of marly or sandy clay: occasionally the limestone is sandy. The beds are usually of a buff or pale-grey colour, but the lower layers are frequently blue-hearted; and where the strata are protected from the weather by a covering of clay, the stone is for the most part of a bluish-grey colour, and it occurs in beds sufficiently solid to be employed locally for building-purposes. The rock hardly ever exhibits any traces of oolitic structure; and no indications of false-bedding have been observed. Occasionally we find sandy and gritty layers.

The formation is usually from 10 to 25 feet thick; sometimes even less, and in places near Bedford it is represented by a single layer of rock. Nevertheless in lithological characters, and in the fossils which usually are to be found in abundance, the formation is remarkably uniform in its development throughout the country.

In most cases it is clearly separated from the clays and flaggy limestones of the Forest Marble on which it rests in the south of England; and further north where resting on the Great Oolite Clays, the junction as a rule is equally marked. In north Lincolnshire however the Great Oolite Limestone presents characters resembling those of the Cornbrash and care is needed to distinguish them. In this region and in Yorkshire, the Cornbrash is overlaid by clays that yield *Avicula echinata*, and these have been termed the Cornbrash Clays.* Whether they represent in time a portion of the Cornbrash of the south of England, or a portion of the Kellaways Clay, is a subject on which no definite opinion can be expressed. As will be seen, there is no palæontological break in the south of England nor elsewhere, between the Cornbrash and the Oxfordian series, for in the Kellaways Rock we find more or less abundantly some of the characteristic fossils of the Cornbrash. Hence we are nowhere justified in fixing time-limits by

* Fox-Strangways, Jurassic Rocks of Yorkshire, vol. i. p. 263.

the evidence of general lithological divisions. It is however both convenient and necessary to abide by the stratigraphical divisions in our descriptions of the several formations.

### *Organic Remains.*

Although fossils, as a rule, are plentiful in the Cornbrash, there is no great variety in the remains preserved. Saurians and Fishes are rare. Cephalopoda are represented by few species: and of these Belemnites are exceedingly rare. Of other Mollusca, not many Gasteropods are to be found, but the Lamellibranchs, and especially species of *Avicula, Gresslya, Homomya, Isocardia, Modiola, Myacites, Ostrea, Pecten,* and *Pholadomya* are abundant, though the shelly matter is in most cases but poorly preserved, and the specimens are often in the form of casts. Brachiopoda are exceedingly common, and Echinodermata are abundant. Other forms such as Polyzoa, Crustacea, and Corals are rare. No species of Plants are recorded, although lignite is found here and there.

CORNBRASH FOSSILS.

FIG. 118.

FIG. 119.

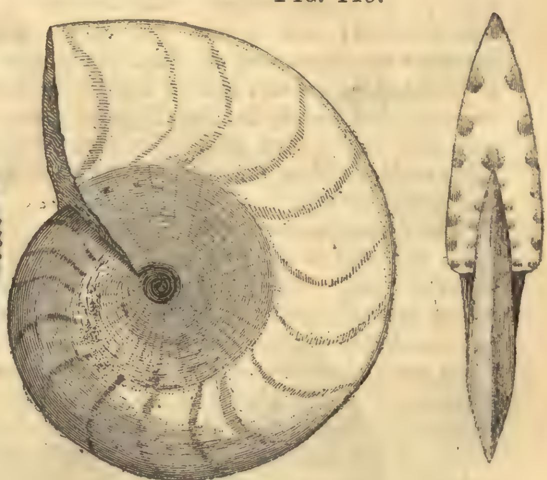


FIG. 120.

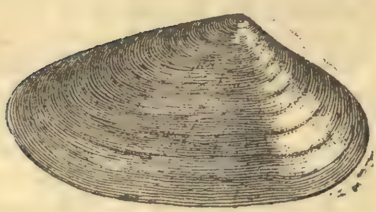


FIG. 121.

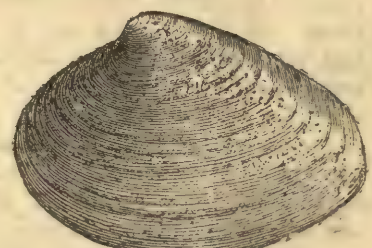


FIG. 118. Ammonites macrocephalus, *Schloth.* ½.
,, 119. Ammonites discus, *Sow.* ½.
,, 120. Myacites securiformis, *Phil.* ⅔.
,, 121. Gresslya peregrina, *Phil.* ⅔.

FIG. 123.

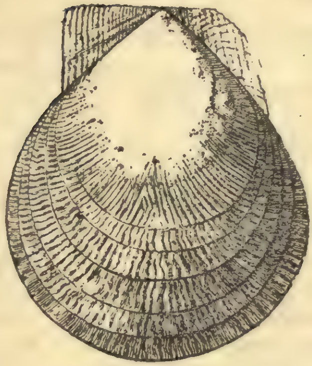


FIG. 122.

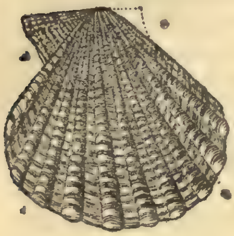


FIG. 124.

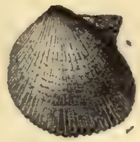


FIG. 125.

FIG. 126.

FIG. 127.

FIG. 128.

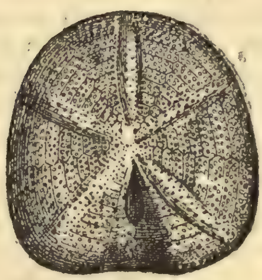


FIG. 122. Pecten vagans, *Sow.* nat. size.
,, 123. —— lens, *Sow.* nat. size.
,, 124. Avicula echinata, *Sow.* $1\frac{1}{3}$.
,, 125. Waldheimia obovata, *Sow.* $1\frac{1}{3}$.
,, 126. Terebratula intermedia, *Sow.* $\frac{2}{3}$.
,, 127. Waldheimia lagenalis, *Schloth.* nat. size.
,, 128. Echinobrissus clunicularis, *Lhwyd.* nat. size.

The following are the more abundant and characteristic species of the Cornbrash :—

Ammonites discus (Fig. 119).
—— macrocephalus (Fig. 118).
Nautilus.
Avicula echinata (Fig. 124).
Cardium Buckmani.
—— cognatum.
Ceromya concentrica.
Gervillia aviculoides.
Goniomya v. scripta.
Gresslya peregrina (Fig. 121).
Homomya gibbosa.
—— Vezelayi.
Isocardia minima.
Lima duplicata.
—— gibbosa.
Modiola imbricata.
—— Lonsdalei.
Myacites calceiformis.
—— decurtatus.
—— securiformis (Fig. 120).
Ostrea flabelloides.
Pecten demissus.
—— lens (Fig. 123).
—— vagans (Fig. 122).
Pholadomya deltoidea.
—— lyrata.
Trigonia elongata.
Rhynchonella concinna (Fig. 77).
Terebratula intermedia (Fig. 126).
Waldheimia lagenalis (Fig. 127).
—— obovata (Fig. 125).
Serpula tricarinata.
Acrosalenia hemicidaroides (Fig. 79).
Echinobrissus clunicularis (Fig. 128).
Holectypus depressus.
Pygurus Michelini.
Anabacia complanata.

As the Cornbrash exhibits so little variation in character, and if we except the Cornbrash Clays or "Avicula Shales" of Lincolnshire and Yorkshire, it admits of no subdivisions, and it will be unnecessary to give many detailed sections of the strata.

With regard to the fossils it may be stated that *Terebratula intermedia* occurs most abundantly in the lower beds, and *Waldheimia obovata* and *W. lagenalis* in the upper beds. These species, as well as *W. ornithocephala* and *W. digona* are, as Prof. Buckman remarked, very intimately connected.*

The Cornbrash belongs to the zone of *Ammonites macrocephalus*. Oppel placed it, together with the Forest Marble, in the zone of *Waldheimia* (*Terebratula*) *lagenalis*, but an Ammonite is a better zonal index. The zone of *A. macrocephalus* may be said to extend upwards into the Lower Oxfordian strata, and on the continent the Cornbrash and Kellaways Beds are sometimes grouped together under the general term Callovian.

Palæontologically the Cornbrash in this country is regarded as the uppermost stage of the Great Oolite Series, and the beds are connected by the occurrence of such common forms as *Pecten*

* Ann. Nat. Hist., ser. 2., vol. xii. p. 326; Quart. Journ. Geol. Soc., vol. xiv. p. 122; see also Davidson, Appendix to Brit. Ool. Brachiopoda, p. 16.

*vagans, Lima cardiiformis, Ostrea Sowerbyi, Rhynchonella concinna, Terebratula maxillata,* &c.

From a general consideration of the fauna of the Cornbrash, Prof. Buckman maintained that the organic remains had more affinity with those of the Inferior Oolite than with those of the Great Oolite. It is indeed true that the Cornbrash in its sedimentary characters much resembles the ragstones of the Cotteswolds, and the more earthy and partially oolitic limestones of Dorsetshire, belonging to the Inferior Oolite. The Lamellibranchs too in many cases comprise similar genera and species, such as *Ceromya concentrica, Pholadomya oblita, Modiola gibbosa, M. imbricata, Myacites calceiformis, M. decurtatus, Ostrea flabelloides, Pecten demissus, P. lens,* &c. Nevertheless the resemblance between the faunas of the Inferior Oolite and Cornbrash, according to Lycett, depends upon the fact that the Cornbrash fauna consists for the most part of a portion of those Cotteswold forms which have a great stratigraphical range, and pass upwards through the Great Oolite.*

The Cornbrash was a formation laid down in tranquil waters, its even-beds exhibiting none of the marked false-bedding so conspicuous in the Forest Marble beneath. The abundance of fossils, the clusters of *Waldheimia obovata,* and *W. lagenalis,* and also of *Avicula echinata,* indicate the slowness of deposition. A large specimen of *Ammonites macrocephalus,* obtained by Prof. Judd from Helpstone, near Peterborough, was covered with masses of *Ostrea* and *Serpula.*† We find no evidence of marginal deposits, in the shape of conglomeratic beds, and the strata were probably laid down in deeper water than other members of the Great Oolite Series that are exposed to view.

The rocks from various localities were examined under the microscope by Mr. Teall. They showed organic fragments and quartz grains in a matrix of granular or crystalline calcite. Foraminifera were noted in some rocks; and in a specimen from Wincanton, where the matrix was of clear crystalline calcite, the material preserved in the hollows of bivalves, differed from the general matrix in being nearly opaque.

## Local Details.

### *Weymouth to Bridport.*

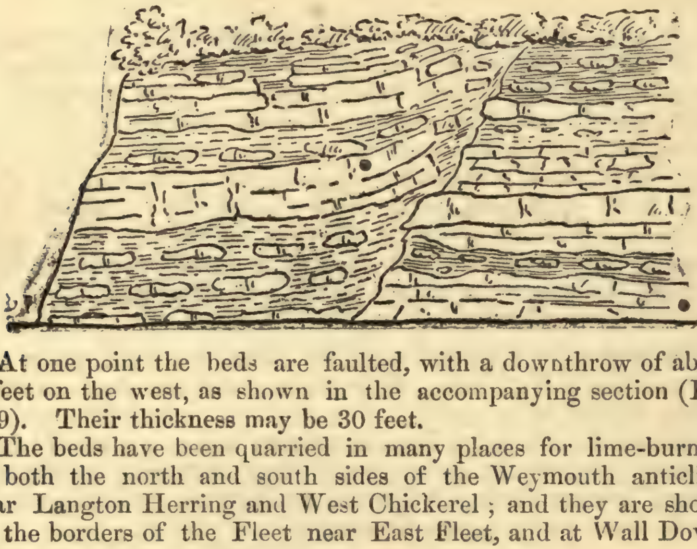
Commencing on the Dorsetshire coast, near Weymouth, we find the Cornbrash to be well exposed on the northern side of Radipole Lake, where the following succession of beds may be traced:—

* Cotteswold Hills, p. 110.
† Geol. Rutland, p. 225.

| | | Ft. | In. |
|---|---|---|---|
| Cornbrash | Rubbly and sandy marls, the concretionary masses containing large Oysters | 1 | 6 |
| | Flaggy earthy and nodular limestones and irregular beds of sandy marl—with *Pholadomya* | 9 | 6 |
| | Bluish-grey limestones, merging downwards into shaly marls | 3 | 0 |
| | Hard bluish-grey earthy limestone with *Rhynchonella* | 1 | 0 |
| | Rubbly and shelly limestones, with large *Pholadomya, Avicula echinata, Ostrea*, &c. | 3 | 6 |
| | Irregular shelly limestones | 4 | 0 |

Fig. 129.

*Section of Cornbrash at the north end of Radipole Lake, Weymouth.*



At one point the beds are faulted, with a downthrow of about 6 feet on the west, as shown in the accompanying section (Fig. 129). Their thickness may be 30 feet.

The beds have been quarried in many places for lime-burning on both the north and south sides of the Weymouth anticline, near Langton Herring and West Chickerel; and they are shown on the borders of the Fleet near East Fleet, and at Wall Down, by the Swannery at Abbotsbury.

The junction of the Cornbrash with the Kellaways Beds (Oxford Clay), was shown to the south of Rodden, in a pit on the east side of the road leading towards Langton Herring. The section was as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Kellaways Beds. | Bluish mottled clay with *Waldheimia* and *Serpula*. | | |
| | Sandy and shelly shale. | | |
| Cornbrash | Greyish-brown earthy limestone in solid beds, exposed to depth of | 2 | 6 |

Other sections of Cornbrash have been exposed near Puncknoll, and on North Hill, between Burton Bradstock and Bothenhampton. In a lane-cutting south of Bothenhampton, the junction with the

Forest Marble was exposed. The lower beds of the Cornbrash consist of grey earthy limestone, marly beds and clay, with *Avicula echinata*, *Terebratula*, and *Rhynchonella*; and they rest on the flaggy shell-limestones and clays of the Forest Marble. The beds here occur in proximity to a considerable fault, and they exhibit a local anticlinal disturbance.

From the Cornbrash between Weymouth and Bridport, I obtained the following fossils :—

Ammonites Bakeriæ.
Astarte.
Avicula echinata.
Ceromya concentrica.
Goniomya v. scripta.
Gresslya peregrina.
Homomya crassiuscula.
Isocardia.
Lima.
Lucina.
Modiola bipartita.
Myacites calceiformis.
—— decurtatus.
—— recurvus.
—— securiformis.
Ostrea costata.
—— Sowerbyi.
Pecten demissus.
—— fibrosus.
Pecten vagans.
Pholadomya deltoidea.
—— lyrata.
—— Phillipsi.
Thracia?
Trigonia.
Rhynchonella concinna.
—— varians.
Terebratula maxillata.
Waldheimia obovata.
—— ornithocephala.
Serpula intestinalis.
—— tricarinata.
—— vagans.
Acrosalenia spinosa.
—— Wiltoni.
Echinobrissus clunicularis.
Pygurus Michelini.
Anabacia complanata.

A small outlying mass of Cornbrash was noted by Bristow on the Geological Survey Map (sheet 17) at West Cliff south of Watton, near Bridport Harbour. I failed to observe this, coming to the conclusion that, owing to the waste of the cliffs, this patch of Cornbrash has been destroyed. In 1856 Dr. Wright gave a list of fossils from the Forest Marble of this locality,* including the following species which are very suggestive of the Cornbrash :—

Avicula echinata.
Terebratula intermedia.
Waldheimia obovata.
Acrosalenia hemicidaroides.
Acrosalenia spinosa.
Echinobrissus clunicularis.
Holectypus depressus.

*Rampisham to Sherborne and Temple Combe.*

For some distance north-east of Bridport, the Cornbrash is entirely obscured by the overstep of the Cretaceous rocks. It reappears in an inlier at Rampisham, and is again found near Corscomb and West Chelborough. From the neighbourhood of Melbury Sampford northwards, the outcrop is fairly persistent, being shifted only here and there by faults. The outcrop is an important one, for it is characterized by numerous villages and towns, whose sites were fixed by the readiness with which supplies of water could be obtained from the strata, not merely along the main outcrop, but from some of the larger outliers.

* Quart. Journ. Geol. Soc., vol. xii. p. 310.

The Cornbrash is exposed here and there in quarries at Sutton Bingham, Closeworth, Ryme, and Yetminster. The beds are shown to a depth of from 5 to 10 feet, and are usually very fossiliferous. A fine collection of specimens was made by the Rev. E. Bower, of Closeworth, from which locality remains of *Steneosaurus* were obtained.*

At Weston, between Sutton Bingham and Closeworth, the following section was exposed:—

| | | Ft. | In. |
|---|---|---|---|
| Kellaways Beds. | Thin flaggy beds of rubbly and sandy limestone - - - 1 0 to | 2 | 0 |
| | Brown and mottled loamy clay with (near the top) a layer yielding many fragile and crushed specimens of *Waldheimia* and *Serpula* - - Dark blue loamy clay - - - | 4 | 6 |
| Cornbrash - | Blue-hearted earthy limestones - | 3 | 0 |

This section corresponds with that seen between Rodden and Langton Herring (p. 436).

A somewhat similar section of clays overlying Cornbrash limestones, and filling pipes in the rock, was exposed in a quarry south-east of the Barn, between Closeworth and Melbury Osmund.

The following section, seen in a quarry by the high road east of Closeworth, is deserving of notice, as it shows the presence of clay-beds in the Cornbrash:—

| | | Ft. | In. |
|---|---|---|---|
| | Soil - - - - - - | 0 | 9 |
| Cornbrash - | Rubbly marl and limestone with many fossils - - - - - - | 1 | 0 |
| | Clay with "race" - - - | 0 | 7 |
| | Greyish-brown clay with *Ostrea* - | 1 | 0 |
| | Rubbly limestone and marl, passing down into more solid beds of grey earthy limestone, with few fossils - | 3 | 6 |

From this quarry I obtained the following fossils:—

Natica (a few badly preserved specimens).
Avicula echinata (abundant).
Gresslya peregrina.
Homomya crassiuscula ?
Isocardia minima.
Modiola Lonsdalei.
Myacites (abundant).
Ostrea Sowerbyi (abundant).
Pecten demissus.
Pholadomya ovalis.
Rhynchonella concinna (many specimens compressed).
Terebratula intermedia.
—— maxillata.
Waldheimia obovata.
Echinobrissus clunicularis.
—— orbicularis.
Serpula tetragona.

At Yetminster I obtained *Waldheimia lagenalis* in addition to many species found also at Closeworth. Other quarries may be seen at Long Burton, south of Sherborne, and from this neighbourhood 180 species of fossils were collected from the Cornbrash, by the Rev. H. H. Wood.†

There are several quarries in the neighbourhood of Bishops Caundle, one of which near the high-road to the south-west of the

* J. C. Mansel-Pleydell, Proc. Dorset Nat. Hist. Club, vol. i. p. 28.
† Proc. Dorset Nat. Hist. Club, vol. i. p. 22.

village and north-west of Holwell, showed the junction with the Forest Marble, as follows:—

| | | Ft. | In. |
|---|---|---|---|
| | Soil. | | |
| Cornbrash | Rubbly limestone, with *Avicula echinata*, &c. - - - - | 5 | 0 |
| | Marl, dark clay, and soft marly stone, with many bivalves - - - | 5 | 0 |
| | Shelly limestone - - - | 1 | 0 |
| Forest Marble | Grey clays with band of white marly stone: *Ostrea*-bed at base - - | 2 | 0 |
| | Shelly limestone - - - | 0 | 6 |
| | Bed made up of *Ostrea* (like the Cinder Bed of Purbeck) - - - | 0 | 10 |
| | Tough grey and blue limestone with lignite near top - - - | 2 | 0 |
| | Earthy and shelly limestones with ochreous and loamy partings 3 0 or | 4 | 0 |

Here we have some difficulty in fixing the limits of Forest Marble and Cornbrash. The lower beds clearly belong to the one, and the upper to the other formation. The intermediate *Ostrea*-beds may, however, be grouped with the Forest Marble, although we miss the thin gritty layers that are usually met with in the upper clays of that deposit. The Cornbrash here yielded *Cardium Buckmani, Ceromya concentrica, Gresslya peregrina, Rhynchonella concinna*, &c.

Other quarries, between Bishops Caundle and Stourton Caundle, opened to a depth of 9 or 10 feet, furnish rough building-stone and material for lime-burning. Most of the species noted from Closeworth were found here, together with *Gervillia acuta*? and *Ostrea costata*. Stalbridge and Henstridge have furnished sections of the Cornbrash, but the best exposures in the neighbourhood are in the quarries and railway-cuttings at Templecombe. From this locality Mr. John Rhodes and myself obtained the following species:—

Ammonites discus.
Bulla undulata (cast).
Avicula echinata.
Cardium (cast).
Gervillia monotis?
Gresslya peregrina.
Isocardia minima.
Lima gibbosa.
Myacites calceiformis.
—— securiformis.
Ostrea Sowerbyi.
Pecten demissus.
Pecten vagans.
Pholadomya.
Trigonia.
Rhynchonella varians.
Terebratula intermedia.
Waldheimia obovata.
—— ornithocephala?
Serpula limax.
Acrosalenia spinosa?
Echinobrissus clunicularis.
Holectypus depressus.
Pygurus Michelini.

### *Wincanton to Trowbridge and Bradford-on-Avon.*

The Cornbrash was well exposed at Wincanton, by the main roads on the southern and eastern sides of the town; and again to the north, about half-way between Moorhays and Shafford. The usual fossils are met with, including *Avicula costata*; and there is evidence of about 25 feet of earthy and sandy limestones with intercalated marly bands

Quarries are to be seen here and there along the outcrop at South Brewham, Upton Noble, and to the west of Quar Hill Farm, near Witham Friary. West of South Brewham church, shelly and sandy limestone was exposed, and the rock proved to be slightly oolitic. At Upton Noble, hard limestone, suitable for building-purposes is obtained. There is a quarry south-east of West End, Wanstrow, and thence towards Frome we see few places where the beds are now worked, although old quarries are to be found at Mitchels Elm and other places.

Near Frome the Cornbrash has been exposed west of Rodden, and again to the north-west of Berkley, but the quarries are shallow. The following fossils were found at Berkley:—

Ammonites Bakeriæ?
Avicula echinata.
Cypricardia caudata.
Ostrea Sowerbyi (abundant).
Ostrea subrugulosa?
Pholadomya deltoidea.
Rhynchonella varians.
Waldheimia lagenalis.

One of the most fossiliferous sections was seen to the east of Langham Mill, to the north of the village of Road, where a shallow quarry showed the following beds:—

| | | Ft. | In. |
|---|---|---|---|
| | Brown clayey soil - - - | 2 | 0 |
| Cornbrash | Rubbly limestone and marls, with many fossils - - - - - | 5 | 0 |
| | Blue shelly limestone - - - | 2 | 0 |

Some of the beds contain small hard nodules. To avoid repetition the fossils here obtained may be tabulated with those found in quarries near Trowbridge to the north-east.* Sowerby obtained a number of fossils from Chatley, between Road and Norton St. Philip: *Pecten vagans* was figured from a specimen there found.

List of fossils from the Cornbrash of Road (R), together with those obtained in quarries north-east of Hilperton (H), and east of Semington (S):—

Strophodus, R.
Natica, R.
Astarte, R.
Avicula echinata, R., S.
Ceromya concentrica, R.
Cypricardia caudata, R., S.
Gresslya peregrina, R., S.
Homomya, R.
Isocardia minima, R., H.
Lima duplicata, R.
—— gibbosa, R.
Lucina, R.
Modiola sowerbyana, R.
Myacites calceiformis, R.
—— securiformis, R., H., S.
Ostrea costata, R.
—— Sowerbyi, R.
Pecten vagans, R.
Pholadomya deltoidea, R., H., S.
Pinna ampla, R.
Trigonia, S.
Terebratula intermedia, R., H.
—— maxillata, R., H.
Waldheimia obovata, R., S.
Serpula intestinalis, R.
—— tricarinata, R.
Acrosalenia spinosa, R.
Echinobrissus clunicularis, R.
—— quadratus, R.

*Bradford-on-Avon to Chippenham, Malmesbury, and Kemble.*

No sections of particular interest have been noted along the outcrop near Bradford-on-Avon and at South Wraxall. The thickness of the Cornbrash was proved to be 20 feet in a well

* See also R. N. Mantell, Quart. Journ. Geol. Soc., vol. vi. p. 316.

sunk for the Melksham Spa Co. in 1815.* (See p. 514.) There are shallow quarries north-east of Thingley, near Corsham, where flaggy beds are broken up for local road-mending. *Avicula echinata* is abundant on some of the slabs, but fossils are scarce. The same is the case in the quarries about a mile west of Chippenham, and in those near Hardenhuish, though *Gresslya* and *Myacites* are fairly common.

East of Biddestone, and about half-way between the village and Starveall Farm, the junction with the Forest Marble was shown in a road-cutting, which I visited in company with the Rev. H. H. Winwood. The section was as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Cornbrash | Rubbly limestone, with *Trigonia*. Rubbly yellow marl, with *Terebratula intermedia*. | | |
| Forest Marble | Greenish-grey clay with "race," and band of thin shelly limestone with *Ostrea*: shown to depth of | 4 | 6 |

An adjoining quarry on the north-east, showed higher beds of Cornbrash, yielding *Cypricardia caudata, Lima duplicata, Myacites securiformis, Terebratula maxillata, Waldheimia obovata,* and *Serpula intestinalis. Pygaster Morrisi* was found by Prof. Hull in the Cornbrash near Folly Farm, Corsham.

To the north-west of Lower Stanton, near the 6th milestone south of Corston, there is a small quarry in the Cornbrash, and a brickyard in the lower beds of the Oxfordian, where red and bluish mottled bricks and tiles are manufactured. The section was as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Kellaways Beds. | Blue and brown mottled clay with "race" and selenite: passing down into beds below | 2 | 0 |
| | Laminated loamy clay and sand, with crushed specimens of *Waldheimia obovata ?, Rhynchonella varians, Myacites, Ostrea, Serpula vertebralis* | 1 | 6 |
| Cornbrash | Hard bluish shelly and marly limestone with many fossils: *Strophodus, Arca, Avicula echinata, Lima duplicata, Modiola Lonsdalei, Ostrea costata, Pecten vagans, P. demissus, Terebratula intermedia, Waldheimia obovata, Acrosalenia, Echinobrissus clunicularis, Pygurus Michelini, Serpula deplexa* | 4 | 0 |

There is an abrupt change at the junction of the Cornbrash and Oxfordian beds, while the limestones of the Cornbrash have been subsequently eroded by springs, and the overlying clay has been washed down into hollows. The junction above noted, corresponds with that seen at Rodden near Weymouth, and near Sutton Bingham.

* H. B. W., Quart. Journ. Geol. Soc., vol. xlii. p. 301.

There are several quarries near Rodbourne, and also at Corston, south of Malmesbury, where about 9 feet of shelly and pasty limestones, with marly layers, are exposed. *Avicula echinata* occurs here, but fossils are not abundant: in the neighbourhood of Foxley they are more plentiful. The Cornbrash is quarried at Charlton, north-east of Malmesbury, and Prof. Buckman notes the occurrence of *Waldheimia digona* in the Cornbrash of the neighbourhood. To the east of that town the total thickness of the formation was noted as but 6 feet by Prof. Hull,* but as a rule it is not less than 15 feet in the area between Chippenham and Malmesbury.

FIG. 130.

*Section north-west of Kemble Junction, Gloucestershire.*

4. Kellaways Beds.
3. Cornbrash.
2. Forest Marble clay.
1. Great Oolite.

The deepening of the lane north of Great Barn, near Kemble Station, to allow of a bridge being made for the new railway, afforded the following section (Fig. 130):—

| | | | Ft. | In. |
|---|---|---|---|---|
| Kellaways Beds. | Grey clay with traces of hard calcareous sandstone - Stiff bluish grey clay - | about | 10 | 0 |
| | Brown friable loam (at junction) - | | 3 | 0 |
| Cornbrash - | Rubbly marly rock and marly clay - | | 3 | 0 |
| | Rubbly and hard shelly limestone - | | 3 | 0 |
| | More fossiliferous rubbly limestones - | | 8 | 0 |
| Forest Marble - | Racy clay passing down into stiff grey clay - - - - - | | 3 | 0+ |

The Kellaways Beds and Cornbrash were not previously known to exist at this spot: but they occupy a very limited area. The highest beds are faulted against the Great Oolite: thin and fairly horizontal beds of which were exposed to a depth of 3 feet, nearer to the Great Barn.

The junction of the Cornbrash and Forest Marble was irregular—the clay being hollowed out in channels with pockets of Cornbrash rubble, evidently the result of comparatively recent meteoric action. Among the fossils of the Cornbrash I obtained the following species:—

Avicula echinata.
Pecten vagans.
Myacites.
Homomya.
Waldheimia obovata.
Terebratula intermedia.
Serpula.

* Geol. parts of Wiltshire, &c., p. 18.

*Cirencester to Fairford, and Swindon.*

The Cornbrash has been well exposed in several places near Cirencester, and is very fossiliferous.* *Ammonites macrocephalus* is usually to be found, and fine examples of *Waldheimia obovata* and *W. lagenalis* are abundant, and they exhibit forms that link the two species together. In quarries to the north of Sharncott, there may be found many fine specimens of *Ostrea flabelloides*.

The best section was that exposed on the Midland and South-Western Junction Railway, to the south of Watermoor Station, Cirencester, between Siddington St. Mary and Siddington St. Peter: the following beds were shown:—

| | | Ft. | In. |
|---|---|---|---|
| Cornbrash | 8. Earthy limestone - - - | | |
| | 7. Marly clay or loam - - - | 4 | 0 |
| | 6. Earthy limestone with *Modiola* and large *Pholadomya* - - - | | |
| | 5. Impure marly and sandy clay, with nodular masses of limestone containing clusters of *Waldheimia obovata*: also *Am. macrocephalus*, *Ostrea flabelloides*, *Echinobrissus*, &c. - - - - - - | 1 | 0 |
| | 4. Hard earthy limestone with few fossils - - - - | 3 | 0 |
| | 3. Earthy limestone and marl, large Ammonite, *Ostrea flabelloides* - | 1 | 0 |
| | 2. Earthy and shelly limestones with seams of marly clay, and many fossils, *Nautilus*, *Avicula echinata*, *Modiola*, *Myacites*, *Pecten vagans* (in bands), *Ostrea*, *Rhynchonella concinna*, *Waldheimia obovata* (large specimens), *Terebratula intermedia* (abundant near base), *Serpula*, &c. | 6 | 0 |
| Forest Marble - | 1. Dark clays with little or no stone - | 25 | 0 |

The beds are faulted in several places, as shown in the section. (Fig. 131, p. 444.) Further south near Nooks, the Cornbrash was again exposed in a railway-cutting to the depth of about 5 feet. *Waldheimia lagenalis* and *W. obovata* were found abundantly, as well as other fossils, including large specimens of *Homomya*. The beds exposed were the same as those shown in the central portion of the above section.

Other sections were to be seen north-east of Cerney Wharf, and north of Cerney Field Barn; and the junction with the Forest Marble was shown in quarries at Ampney Crucis and Driffield Cross. (See p. 366.)

The fossils found at Cirencester are noted in the accompanying list, with which we may conveniently include the species obtained at Fairford, and those procured from a well-sinking at Swindon, at depths of from 685 to 703 feet.

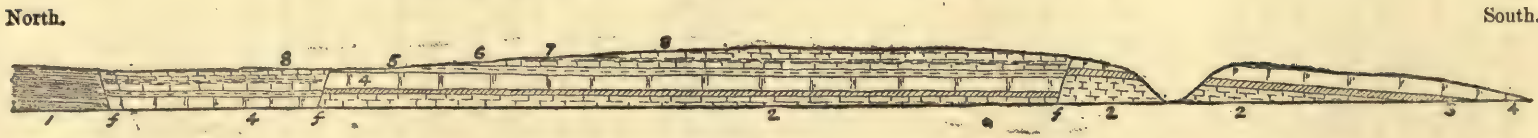
In the Swindon Well the thickness of the Cornbrash was estimated at 18 ft. 3 in. It consisted of hard grey shelly lime-

* See also J. Buckman, Quart. Journ. Geol. Soc., vol. xiv. p. 121, and Proc. Cotteswold Club, vol. i. p. 262.

FIG 131.

*Section along the Midland and South-Western Junction Railway, at Siddington, south of Cirencester.*

(Distance about 14 chains. Vertical scale, 40 feet to one inch.)




Cornbrash
- 8. Limestone.
- 7. Marly loam.
- 6. Limestone.
- 5. Marly and sandy clay.
- 4. Hard limestone.
- 3. Sandy marl and stone.
- 2. Shelly limestone.

Forest Marble.—1. Clays.

*f.* Faults.

stone and somewhat gritty limestone, with layers of sandy marl and clay. Near Fairford the Cornbrash was exposed to the west of the village, by the "Three Magpies" Inn; and also to the east of Blackford Farm, where it is opened to a depth of 6 or 7 feet, and presents its ordinary characters of rubbly earthy and shelly limestones with intercalated marly beds. Another quarry was situated by the Lechlade road, on the east side of Fairford.

The tract north-west of Fairford is noted as the locality for the Fairford Corals, which have been assigned to the Cornbrash: they belong in reality to the Great Oolite. (See p. 297.)

LIST of FOSSILS from the CORNBRASH of CIRENCESTER, including SHARNCOTT and SIDDINGTON (C.), FAIRFORD (F.), and SWINDON well-sinking (S.):—

Ammonites discus, C.
—— macrocephalus, C.
Nautilus, C., F.
Cylindrites ?, S.
Natica, C., S.
Avicula echinata, C., F., S.
Cardium Buckmani, C.
—— cognatum, F.
Ceromya concentrica, C.
Cypricardia, C.
Cyprina, C.
Gresslya peregrina, C., F., S.
Homomya gibbosa, C., F.
Isocardia minima, F.
Lima, S.
Modiola imbricata, C.
—— sowerbyana, S.
Myacites calceiformis, C.
—— decurtatus, C., S.
—— securiformis, C., F., S.
—— sinister, S.
—— Terquemeus, S.
Ostrea flabelloides, C.
—— Sowerbyi, C.
Pecten demissus, C., S.
Pecten vagans, C., F.
Pinna cuneata, C.
Pholadomya deltoidea, C.
—— lyrata, F.
Trigonia, C., S.
Rhynchonella concinna, C., F.
—— varians, S.
Terebratula intermedia, C., F.
—— maxillata, C.
Waldheimia lagenalis, C.
—— obovata, C., F., S.
—— ornithocephala, S.
Cytheridea subperforata ? S.
Serpula tetragona, S.
—— tricarinata, C.
Acrosalenia spinosa, C.
Echinobrissus clunicularis, C., S.
—— orbicularis, C.
—— quadratus, C.
Cristellaria crepidula, S.
—— cultrata, S.
—— rotulata, S.
Lituola nautiloidea, var. depressa ?, S.
(Lignite), C.

*Fairford to Witney and Woodstock.*

From Fairford to Witney the Cornbrash is exposed over a broad band of country. It is locally known as the "stone brash," in distinction from the "flat stone" of the Forest Marble. Shallow quarries are seen here and there, near the cross-roads between Shilton and Black Bourton, and eastwards on the road to Norton Brize. *Nautilus* is usually to be found in this area, also *Holectypus depressus* and many of the common forms noted in the list from Cirencester, &c.

Prof. Hull notes a section near Alvescott Downs Farm, south-east of Shilton, where some of the beds are perforated by *Lithodomus ;* he also refers to other sections near Black Bourton and Marsh Hadden.* (See Fig. 132, and p. 371.)

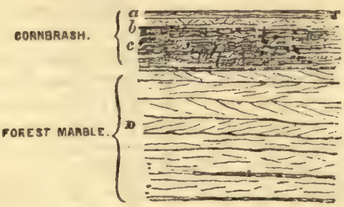
* Geol. Cheltenham, p. 74; and Geol. parts of Oxfordshire and Berkshire, p. 4.

Near Witney the Cornbrash has been exposed on the side of the Woodstock road and also on Curbridge Common. The beds have been described by W. S. Horton, who obtained at the former locality, *Ammonites macrocephalus, A. discus, Nautilus, Pholadomya, Isocardia, Gresslya, Terebratula maxillata, Echinobrissus clunicularis, Holectypus depressus, Glyphea rostrata,* &c. At Curbridge Common he found *Waldheimia obovata* to be very abundant; and species of *Trigonia, Lima, Astarte,* and *Modiola,* together with *Acrosalenia hemicidaroides,* were also obtained.*

Several outliers of Cornbrash are met with on Wychwood Forest, but the most northerly trace in Oxfordshire occurs at Epwell. (See p. 376.)

FIG. 132.

*Section at Alvescott Downs, south-east of Shilton, Oxfordshire.* (Prof. E. Hull.)




| | | Ft. | In. |
|---|---|---|---|
| Cornbrash | *a.* Soil | 0 | 6 |
| | *b.* Hard thin-bedded ragged limestone | 0 | 6 |
| | *c.* Loose rubbly limestone, very fossiliferous | 3 | 0 |
| Forest Marble. | D. White fine-grained oolitic freestone, obliquely laminated | 10 | 0 |

The occurrence of Cornbrash in the railway-cutting east of Pest House, between Hook Norton and Chipping Norton, was pointed out by Prof. Morris and Mr. Hudleston. From the rubbly grey limestones there exposed, I obtained *Terebratula intermedia, Waldheimia obovata, Myacites,* and *Pecten vagans.* Mr. Beesley notes also *Avicula echinata.*† The same observer mentions that Cornbrash fossils (*A. echinata, Wald. obovata,* &c.) were found in a ploughed field on the hill north of Lower Tadmarton, south-west of Banbury.‡ From Witney to Church Handborough the outcrop of the Cornbrash is narrow, but it again occupies an extensive area near Woodstock and Kirtlington. It was exposed above the Forest Marble in a quarry at Bladon (see p. 373); and again in Blenheim Park, near Old Woodstock.§ The new railway to Woodstock opened up some fine sections in this formation, which I visited in company with Prof. Green.

* Geologist, vol. iii. p. 251.
† Proc. Geol. Assoc., vol. v. p. 177.
‡ *Ibid.*, vol. iii. p. 202.
§ Hull, Geol. Woodstock, p. 24.

The beds were faulted in several places, but the sequence shown was as follows (See Fig. 108, p. 374):—

| | | Ft. | In. |
|---|---|---|---|
| Kellaways Beds. | Fine yellow and grey sands - - | 5 | 0 |
| | Dark bluish-grey clay, and stiff mottled grey and brown clay, with "race" in the lower part; and much ferruginous matter at the base - - | 10 | 0 |
| | Thin layer of sand overlying seam of clay - - - - - | 0 | 5 |
| Cornbrash - | Rubbly and fissile marly limestone, with lignite, *Waldheimia lagenalis*, large *Ostrea* - - - - | 1 | 0 |
| | Impure limestones with lignite, pyrites and ferruginous matter: *Rhynchonella varians* - - - - - | 1 | 2 |
| | Hard mottled limestones: *Modiola*, *Pecten lens*, *Trigonia*, *Waldheimia lagenalis*, *W. ornithocephala* - - | 1 | 6 |
| | Soft earthy and shelly marl and mottled blue and grey limestone: *Astarte elegans*, *Avicula echinata*, *Isocardia*, *Homomya Vezelayi*, *Myacites*, *Ostrea*, *Pecten vagans*, *Pholadomya Phillipsi*, *Trigonia*, *Waldheimia obovata*, &c. - - - | 4 | 0 |
| | Hard bluish-grey limestones with marly patches: *Avicula echinata*, *Gresslya*, *Myacites*, *Pecten vagans*, *Trigonia*, *Echinobrissus clunicularis* - | 2 | 0 |
| | Fissile marly beds and tough brown and grey shelly limestone, with *Avicula echinata*, and *Terebratula intermedia* (very abundant) - - | 2 | 0 |
| Forest Marble | Blue and greenish-grey clays, &c. (See p. 373.) | | |

The details of the Cornbrash were seen to vary from point to point, and the thickness may be stated at from 12 to 14 feet. The basement-bed crowded with fine specimens of *Terebratula intermedia* was the most noticeable feature; and it was interesting to compare these forms, with the allied and even more abundant specimens of *T. maxillata* found in the Great Oolite below. The limestones of the Cornbrash, as seen in this railway-cutting, were variable in character and induration; where under the Kellaways Clay the rock was usually a hard dark blue or bluish grey stone, much of it having a mottled appearance, not unlike a bed seen at Akely near Buckingham, and not unlike the Great Oolite of Bedford. Other beds are fairly uniform in character. The mottled beds are caused by irregular admixture of marly matter.

At Sturdys Castle, between Woodstock and Tackley, quarries have been opened, and Prof. Hull obtained from them a number of fossils.*

In the quarry south of Bletchington railway-station, the Cornbrash to a thickness of 7 feet was well shown, overlying the

* Geol. Woodstock, p. 25.

Forest Marble. The higher beds consisted of rubbly shelly limestones and clays. The basement-bed was a hard marly and shelly oolitic limestone, which might from its lithological character be assigned to the Forest Marble; but it merged into the Cornbrash, and contained *Terebratula intermedia, Avicula echinata,* and *Trigonia.*

Further south the junction of Cornbrash and Forest Marble was exposed in a quarry on the north side of the road, and about half-way between Kidlington Station and the village to the south-east. The section (to which my attention was directed by Mr. E. A. Walford) is as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Cornbrash | Rubbly limestone, with *Avicula echinata* (abundant) | 4 | 0 |
| | Grey racy clay | 0 | 8 |
| | Rubbly limestone: with very fine examples of *Waldheimia obovata* in upper portion, and *Terebratula intermedia* in lower part | 3 | 0 |
| Forest Marble. | Blue-hearted gritty limestone | 0 | 6 |
| | Laminated calcareous sands and clays | 1 | 0 |
| | Fissile shelly and oolitic limestone: false-bedded. Seen to depth of | 3 | 0 |

The following species were obtained by me from the Cornbrash at Woodstock:—

Ammonites macrocephalus.
Nautilus.
Astarte elegans.
Avicula echinata.
Gresslya.
Homomya Vezelayi.
Isocardia (cast).
Myacites recurvus.
—— securiformis.
Ostrea (large flat form).
Pecten lens.
—— vagans.
Pholadomya Phillipsi.
Trigonia (costate form).
Rhynchonella concinna.
—— varians.
Terebratula intermedia.
—— maxillata.
Waldheimia lagenalis.
—— ornithocephala.
—— obovata.
Serpula tricarinata.
—— intestinalis?
Echinobrissus orbicularis.

A large collection of Cornbrash fossils, including about 76 species, was made in this neighbourhood by Mr. J. F. Whiteaves.*

### *Islip to Bicester, Buckingham, and Newport Pagnell.*

The tract of country from Islip to Marsh Gibbon shows a succession of inliers of Cornbrash, &c., which rise in low dome-like masses. The Cornbrash is shown to a depth of 3 or 4 feet in the quarries, and presents its usual characters of rubbly limestone. Its full thickness appears not to exceed 6 feet.

At Blackthorn Hill near Bicester we find the following section (see Fig. 109, p. 377):—

* Rep. Brit. Assoc. for 1860, p. 107. See also Hull, Geol. Woodstock, p. 25; and Phillips, Geol. Oxford, p. 238.

| | | Ft. | In. |
|---|---|---|---|
| Kellaways Beds. | Stiff greenish clay (traces). | | |
| Cornbrash | Rubbly shelly and earthy limestone and marl: *Waldheimia obovata*, *Avicula echinata*, *Pholadomya* (large), and *Myacites* - - - - | 4 | 0 |
| | Hard earthy and shelly limestone: *Pecten vagans* - - - - | 1 | 3 |
| Forest Marble | Pale greenish grey clays: the top part used for making bricks—the lower part too "stony" - - 9 0 to | 10 | 0 |
| | Tough blue shelly oolite, with masses of lignite, and greenish marly galls 4 0 to | 5 | 0 |
| | Clay (thickness not seen) - about | 3 | 0 |
| [Great Oolite ?] | "White stone."* | | |

The beds are faulted with downthrow on the north-west. The Cornbrash was formerly burnt for lime, and is used in an adjoining quarry for road-metal, but it is a poor stone. The Forest Marble clay is used for making red and yellow bricks, tiles, &c. The beds are variable in character and thickness; from the lowest beds exposed, I obtained *Ostrea*, *Waldheimia digona*, and *Acrosalenia*.

Many sections have been opened in the Cornbrash which comes to the surface over a broad area between Weston-on-the-Green and Middleton Stoney, at Bicester, Bucknell, Stratton Audley, and Fringford.

In some places, as near the Workhouse at Bicester, we find the Cornbrash resting directly on oolitic shelly limestones belonging to the Forest Marble; in other places as at Blackthorn Hill the beds rest on Forest Marble clays. The Cornbrash consists of rubbly and shelly limestones and marls, and is employed for road-metal and burnt for lime. Occasionally we find a hard and compact bed of limestone, but the quarries do not expose more than 7 feet of the beds, and their total thickness in this area probably does not exceed 10 feet. Some of the sections are described by Prof. Green, who found fossils to be plentiful at Stratton Audley. To the north-east of Fringford the beds are largely concealed by Drift, so that sections become less frequent.

The Cornbrash was exposed in a quarry above Tingewick Mill, and also in the cemetery at Buckingham, where it consisted of hard sandy limestone, with *Avicula echinata*, &c.† The thickness seen, was from 4 to 6 feet; but it is probably more, judging from the sections in the brickyard north-east of Akeley.

The following sequence of strata was shown at Akeley Brickyard (see Fig. 133):—

* See section by A. H. Green, Geol. Banbury, pp. 36, 37; also, J. F. Blake, Proc. Geol. Assoc., vol. xiii. p. 71.

† Green, Geol. Banbury, pp. 30, 31.

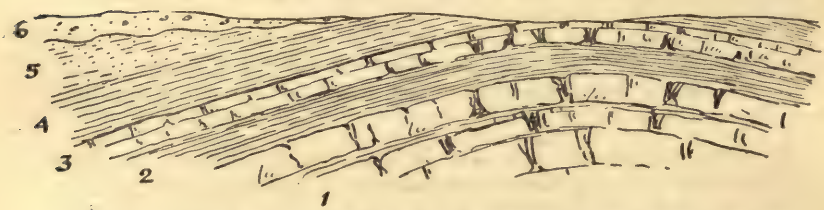
| | | Ft. | In. |
|---|---|---|---|
| Drift - | - 6. Gravelly and clayey soil. | | |
| Kellaways Beds. | 5. Yellow sandy loam - 3 0 or | 4 | 0 |
| | 4. Blue clay, with *Ostrea* at base about | 10 | 0 |
| Cornbrash - | 3. Blue and grey mottled limestone: (rather like Bedford Great Oolite, and like the Cornbrash of Woodstock) - - - about | 8 | 0 |
| Great Oolite Clay. | 2. Grey and black clay and marl (a few feet) | | |
| Great Oolite Limestone. | 1. Brown and white compact limestone Marly beds, &c. - - - | 12 | 0 + |

The stone at base is burnt for lime. Red bricks, tiles, and flower-pots are manufactured from the clays.

The strata were bent over in an anticline that trended in a northerly and southerly direction, so that the beds dipped away towards the east and west. The full thickness of the Great Oolite Clay could not be measured. The accompanying section is diagrammatic, although based on the evidence furnished in different parts of the pits opened.

Fig. 133.

*Section at Akeley, north of Buckingham.*




The evidence on which we have to rely in this neighbourhood, shows that the Cornbrash maintains its ordinary characters; and that we are not justified in including with it those clayey beds, which, when the Geological Survey was made, it was considered desirable to associate with the Cornbrash, and which gave a thickness of 40 feet or more to the formation.*

In the country extending by Beachampton and Stony Stratford to Newport Pagnell, the upper boundary of the Cornbrash is hidden by Drift, but occasional sections are afforded of the junction with the Forest Marble or Great Oolite Clay and the Great Oolite.†

*Bedford to Oundle and Stilton.*

In Bedfordshire again the outcrop of the Cornbrash is to a very large extent obscured by Boulder Clay. Evidence obtained by Mr. A. C. G. Cameron, here and there in the country to the west and north-west of Bedford, shows not only that the

* Green, Geol. Banbury, pp. 31–33, 41.
† See foot-note, p. 379.

Cornbrash is persistent, but that it occupies a more extensive tract in the country to the north-west of Olney and Harrold, and west of Sharnbrook, than was shown on the Geological Survey Map. It had been supposed that the Cornbrash died out at Kempston in the vicinity of Bedford,* as the outcrop had not been traced so far as Stagsden, on the south side of the Ouse Valley; although it was continuously mapped from Clapham northwards, on the other side of the valley.

The presence of Cornbrash near Bedford was known in the early days of geology, the rubble on the surface of the "Bedford Limestone" being called "Cornbrash soil."† The term "Bedford Limestone" would apply most appropriately to the Great Oolite Limestone, which is quarried on the west side of the town; but in old days the name seems to have been given to the Cornbrash, and judging by the fossils mentioned by Parkinson, to have included also the Kellaways Rock.‡ Among the fossils of the Cornbrash are *Ammonites discus, Ostrea flabelloides, Pecten demissus, P. vagans, Waldheimia ornithocephala, W. obovata*, &c., the known species being all included in the list (p. 453) from Oundle, &c.

At Franklin's Pit, by the Waterworks, Bedford, I noted the following section, in company with Mr. Topley, and under the guidance of Mr. Cameron:—

| | | Ft. | In. |
|---|---|---|---|
| Kellaways Beds. | Sands and clays. | | |
| | Clay - - - - - | 10 | 0 |
| Cornbrash - | Stone, termed "Pendle rock" 2 0 to | 3 | 0 |
| Great Oolite Clay. | Mottled yellow green, red, grey, and purplish clay with selenite; Dark carbonaceous clay, with concretionary ferruginous bed - | about 10 | 0 |
| Great Oolite Limestone. | Tough grey limestones, and shaly beds, obtained in massive blocks: some beds 3 feet thick - - - | 12 | 0 |

At Bone or Bourne End, Bletsoe, the following section was noted:—

| | | Ft. | In. |
|---|---|---|---|
| Kellaways Beds. | Grey and yellow clay, overlaid by greenish and yellowish sand, concretionary in places - - - | 5 | 0 |
| Cornbrash - | Sandy and calcareous fissile layers with *Ostrea flabelloides* - - - | 1 | 6 |
| | Tough grey and brown limestone - | 1 | 3 |
| | (Water.) | | |

The Cornbrash here yields *Ammonites macrocephalus, Pecten, Pholadomya*, and *Waldheimia lagenalis*.

The brickyard ¾ mile north-west of West End, Stevington, showed, beneath the Kellaways sands and clays, a band of tough shelly limestone representing the Cornbrash. This bed yielded

* A. C. Ramsay, Address to Geol. Soc. 1864, p. 28.

† Sowerby, Mineral Conchology, Supp. Index to vol. i., arranged by John Farey; also W. Phillips, Geol. Eng. and Wales, 1818, p. 63.

‡ Parkinson, Organic Remains, vol. iii. p. 446.

*Ostrea flabelloides*, *Pecten vagans*, *Waldheimia lagenalis*, *W. obovata*, and *Echinobrissus*. It here rests on bluish-grey oolitic limestone, which together with the Cornbrash, is burnt for lime. There was no appearance of Great Oolite Clay.

Cornbrash has been exposed here and there south of Olney Hide and south-west of Olney Court, as pointed out to me by Mr. Cameron. We there found about 6 feet of marly and shelly limestones, not very fossiliferous, but yielding *Avicula echinata*, *Pecten vagans*, *Trigonia*, *Ostrea*, and *Waldheimia obovata*. These beds are seen in the railway-cutting, to rest on about 10 feet of Great Oolite Clay, beneath which come the rubbly and marly beds, and the stone-beds of the Great Oolite, all dipping westwards.

The neighbourhood of Rushden has been rendered famous as a locality for Cornbrash fossils by the labours of the Rev. A. W. Griesbach, from whose collection the list tabulated (p. 453) was drawn up by Mr. George Sharman.* The quarries from which these specimens were obtained are no longer worked, but other sections are to be seen here and there along the outcrop, which occurs above the village of Raunds and to the east of Thrapston.

A large quarry opened for the purpose of quarrying the Great Oolite Limestone, afforded a section also of the Cornbrash. It is situated to the south-east of Thrapston, and not far from the Midland railway-station. The section showed the following beds:—

| | | Ft. | In. |
|---|---|---|---|
| | Soil with Drift pebbles. | | |
| Cornbrash | Rubbly and marly limestone with *Waldheimia lagenalis*, *Goniomya*, *Myacites* (abundant), *Serpula*, *Holectypus depressus* - - . - - | 3 | 0 |
| | Rubbly marl with *Waldheimia obovata* at top, *Terebratula intermedia* at base; *Isocardia*, *Ostrea*, *Myacites*, *Pholadomya*, &c. - - - - | 1 | 0 |
| Great Oolite Clay. | Brown clay, shelly and racy - - | 1 | 0 |
| | Dark blue clays, &c. | | |

The Cornbrash thus maintains its ordinary characters. Outliers occur to the west and south-west of Thrapston, near Islip, and Great and Little Addington.† Further north it extends along the borders of the Nene Valley by Thorpe Achurch to Overton Longville, near Peterborough, while large straggling outliers, covered in many cases with Oxford Clay and Drifts, extend between Oundle and Brigstock and around Kings Cliffe.‡

The thickness of the Cornbrash in this area is stated by Prof. Judd never to exceed 15 feet, and it is often much less: it consists of ferruginous and earthy limestones, with marly and sandy beds, and is usually very fossiliferous. The more abundant

* Judd, Geol. Rutland, p. 220.

† Sharp, Quart. Journ. Geol. Soc., vol. xxix. p. 281.

‡ Sowerby records specimens from Bulwick; there are outliers of Cornbrash, to the east of the village, and south of Kings Cliffe. See also Ibbetson and Morris, Rep. Brit. Assoc. for 1847, p. 128.

species are *Ammonites macrocephalus, Avicula echinata, Gervillia aviculoides, Waldheimia lagenalis, W. obovata, Echinobrissus clunicularis, E. orbicularis, Holectypus depressus,* together with the usual forms of *Pholadomya, Gresslya, Myacites,* &c.; and these show that the beds do not differ in any particulars from those near Cirencester, &c. Prof. Judd mentions that *Ostrea flabelloides* usually forms an oyster-bed at the top of the Cornbrash.*

Many fossils have been obtained by Prof. Judd in the neighbourhood of Oundle, near Churchfield Lodge, Polebrook, and Cotterstock; and a large series was obtained by J. F. Bentley and others, from the faulted inlier of Cornbrash between Stilton and Yaxley in Huntingdonshire. Among the more noticeable forms from Stilton, are *Terebratula Bentleyi* and *T. coarctata;* the latter being especially characteristic of the Bradford Clay. The fossils at this locality are exceedingly well-preserved, the bivalves as remarked by Prof. Judd, often retaining their pearly lustre†.

The occurrence of Cornbrash at Stowe-nine-churches has been mentioned. It was first observed there by Mr. Beeby Thompson. (See p. 398.) *Avicula echinata, Pecten vagans, Waldheimia obovata,* and other fossils are met with. Mr. Thompson informs me that the Cornbrash has recently been exposed at Roade.

Lists of fossils recorded by Mr. G. Sharman, Prof. Judd, and S. Sharp from the Cornbrash of Rushden (R.), Oundle (O.), and Stilton (S.):—‡

Ichthyosaurus, S.
Plesiosaurus, R., S.
Teleosaurus, S.
Asteracanthus, S.
Lepidotus, S.
Mesodon (Pycnodus) Bucklandi, S.
Strophodus magnus, S.
Ammonites discus, R.
—— macrocephalus, R., O., S.
—— modiolaris, S.
Belemnites, S.
Nautilus, R.
Bulla, S.
Natica, R.
Pleurotomaria granulata, R.
Pseudomelania simplex, S.
—— vittata, R., S.
Dentalium, S.
Astarte, R., O.
Avicula echinata, R., O., S.
—— Münsteri, R.
Cardium citrinoideum, R.
—— cognatum, S.
Ceromya concentrica, R.
Cypricardia bathonica, R.,
Cypricardia caudata, S.
Gervillia aviculoides, R., O.
Goniomya literata, R., O.
—— v-scripta, S.
Gresslya peregrina, R.
Gryphæa mima, O.
Hinnites abjectus, R.
Homomya crassiuscula, S.
—— gibbosa, S.
Isocardia minima, O., S.
Lima duplicata, R., S.
—— gibbosa, R.
—— impressa, S.
—— læviuscula, S.
—— ovalis, R.
—— pectiniformis, R., S.
—— rigida, S.
—— rigidula, R., O., S.
Lucina striatula, S.
Modiola cuneata, R.
—— gibbosa, S.
—— imbricata, R., O., S.
—— Lonsdalei, R., S.
—— sowerbyana, R., S.
Myacites calceiformis, O., S.
—— decurtatus, O., S.

* Judd, Geol. Rutland, pp. 218, &c.
† *Ibid.*, p. 230.
‡ *Ibid.*, pp. 220, 230, 291; and Sharp, Quart. Journ. Geol. Soc., vol. xxix. p. 278.

Myacites recurvus, S.
—— securiformis, R., O., S.
—— sinister, S.
Ostrea acuminata (rare), O.
—— flabelloides, R., O., S.
—— lingulata, S.
—— Sowerbyi (rare), O.
Pecten anisopleurus, R., S.
—— annulatus, S.
—— arcuatus, R.
—— articulatus, S.
—— demissus, R., O., S.
—— inæquicostatus, O., S.
—— intertextus, S.
—— lens, R., O., S.
—— peregrinus, R.
—— retiferus, R.
—— vagans, O., S.
—— wollastonensis, O.
Pholadomya acuticosta, S.
—— deltoidea, O., S.
—— Heraulti, R.
—— lyrata, O., S.
—— Murchisoni, R.
—— Phillipsi, S.
Placunopsis semistriatus, S.
Quenstedtia lævigata, R.
Trigonia costata, R.
—— elongata (abundant and characteristic), R., O.
—— impressa, R.
—— Moretoni, var., O.
—— pullus, R.
—— scarburgensis, S.
Trigonia tuberculosa, R.
Unicardium impressum, R.
Rhynchonella concinna, R., O., S.
—— Morierei, R., S.
—— obsoleta, S.
—— varians, S.
Terebratula Bentleyi, R., O., S.
—— coarctata, S.
—— intermedia, R., S.
—— maxillata, O., S.
Waldheimia cardium, R.
—— lagenalis, S.
—— obovata, R., O., S.
—— ornithocephala, R., O., S.
Diastopora diluviana, R.
Entalophora straminea, R.
Glyphea rostrata, R., S.
Serpula intestinalis, S.
—— squamosa, S.
—— tetragona, S.
Acrosalenia spinosa, R.
Clypeus Mülleri, R., S.
Echinobrissus clunicularis, R., O., S.
—— orbicularis, R., O., S.
—— quadratus, R.
Holectypus depressus, R., O., S.
Pedina rotata, R.
Pseudodiadema pentagonum, R.
Pygurus Michelini, R.
Stomechinus intermedius, R.
Pentacrinus, R.
Anabacia complanata, R.
Coniferous wood, S.

### *Peterborough to Sleaford*

The Cornbrash has been well exposed near Peterborough, and its fossils have been collected by J. F. Bentley and Dr. Henry Porter. It has been opened up in the railway-cuttings between Peterborough and Walton, and very fossiliferous beds were noticed on Ailsworth Heath by Prof. Judd, who there obtained *Ammonites discus*, *Lima pectiniformis*, &c. At Helptone he noticed the oyster-bed with *Ostrea flabelloides*, in the top layer of the Cornbrash; and he obtained large specimens of *Ammonites macrocephalus* (one example being 18 inches in diameter), and also quantities of fossil wood from the beds. Large Ammonites were also obtained from a quarry near Uffington Lodge, together with other fossils. The specimens of *Waldheimia obovata* include forms which here, as well as in some other localities, approach closely to *W. digona*. Cuttings on the Great Northern Railway, to the north of Casewick, showed fossiliferous beds of Cornbrash, and these were originally described by Morris.*

* Judd, Geol. Rutland, pp. 224, 225; Morris, Quart. Journ. Geol. Soc., vol. ix. p. 332; and Sharp, *Ibid.*, vol. xxix. pp. 260, 269.

Prof. Judd notes a number of pits about Wilsthorpe and Braceborough, where the rock is for the most part coated with white stalagmitic carbonate of lime. At Lound, to the south-west of Bourn, the following section was described by him*:—

| | | Ft. | In. |
|---|---|---|---|
| | Boulder clay and trace of Oxford Clay (?) | 3 | 0 |
| Cornbrash | Laminated stone full of *Ostrea flabelloides*, &c. | 0 | 9 |
| | Soft sandy stone | 0 | 6 |
| | Hard whitish stone crowded with fossils, *Lima*, &c. | 0 | 9 |
| | Light-brown sandy clay | 0 | 6 |
| | Hard blue-hearted stone | 1 | 6 |
| | Rubbly stone. | | |

Along the new Midland railway between Bourn and Saxby, the cutting by the Lound road was sloped, but I saw the Cornbrash west of the road, in ditches along the side of the railway. It consisted of tough grey limestone with *Ostrea flabelloides*, *Myacites*, &c. (See also p. 422.)

The neighbourhood of Bourn has yielded a good many Cornbrash fossils, including *Ammonites* and *Nautilus*, and other species which have also been recorded from Rushden and Stilton. *Terebratula Bentleyi* was first found at Hanthorpe, to the west of Morton.

An outlier of Cornbrash (about 4 feet thick) crowns the hill north of Stamford,† and larger outliers occur further north: that at Clipsham North Wood yielded *Am. macrocephalus*, &c.

Between Bourn and Folkingham the general easterly dip of the strata is modified by gentle undulations which have produced a series of inliers. Westwards there are outlying masses of Cornbrash, but the beds are largely concealed beneath a covering of Oxford Clay and Drift. The sections afford evidence of from 5 to 8 feet of the strata; ferruginous flaggy sandy and shelly limestone, and bands of clay, with at the base, beds of hard and compact blue limestone. *Ostrea flabelloides* and other common fossils are to be met with. Sections of the strata have been observed near Edenham, Haconby, and Dunsby. At Dunsby the beds, noted by W. H. Holloway, consisted of sandy limestone and marl, resting on compact blue limestone.‡

At Quarrington the beds appear much more sandy in character. There was a quarry on the south side of the village, near the 114th milestone on the London road, which showed very gritty limestones unlike the Cornbrash of other parts, but containing *Ostrea flabelloides* as near Cirencester. Among other fossils were *Ammonites macrocephalus*, *Lima rigidula*, *Pecten demissus*, *P. lens*, *Pholadomya*, and *Myacites*. The stone was here quarried for road-metal, and the section was as follows:—

* Geol. Rutland, p. 227.
† Sharp, Quart. Journ. Geol. Soc., vol. xxix. p. 249.
‡ Jukes-Browne, Geol. S.W. Lincolnshire, pp. 69, &c.

| | | Ft. | In. |
|---|---|---|---|
| | Brown brashy clay - - - - | 0 | 6 |
| Cornbrash - | Calcareous and fissile gritty rock, with *Ostrea costata* - - - - - | 1 | 6 |
| | Rusty brown and grey clay and rubbly calcareous and ferruginous grit, with *Ostrea flabelloides* (abundant), *Lima*, &c. - - - - 1 6 to | 2 | 0 |
| | Fissile calcareous gritty rock - - | 2 | 6 |

The greatest thickness of the Cornbrash appears to be 19 feet, judging by the record of a well at Pinchbeck North Fen, between Folkingham and Spalding; but it was estimated at 5 ft. 9 in. in a well-section at Swarby, south-west of Sleaford. In the latter case probably the full thickness of the Cornbrash was not passed through, for at Aswarby a little to the south-east the thickness was proved to be 15 feet. A deep well at Quarrington reached Upper Lias at a depth of about 295 feet.* (See also p. 426.)

*Sleaford to Sudbrook, Appleby, and Winterton.*

The Cornbrash has been exposed at Sleaford Station, but we have no records of any important sections along the outcrop from this neighbourhood onwards to that of Lincoln. Ferruginous and shelly limestone has been opened up near Scopwick, and near Cherry Willingham similar stone and siliceous ragstone have been observed by Mr. W. H. Penning.

The shallow quarries in Sudbrook Park, north-east of Lincoln, expose about 4 feet of rubbly and shelly limestone, yielding (with five exceptions) the following species:—

Acrodus.
Ammonites Bakeriæ.
—— macrocephalus.
Alaria.
Chemnitzia?
Natica punctura.
Nerinæa.
Pleurotomaria.
Astarte ungulata.
Avicula echinata.
Ceromya concentrica.
Gervillia.
Goniomya v. scripta.
Gresslya peregrina.
Isocardia minima.
Lima gibbosa.
—— rigidula.
Lucina burtonensis.
Modiola bipartita.
—— imbricata.
Myacites calceiformis.
—— decurtatus.
Nucula.
Ostrea acuminata.
—— flabelloides.
Pecten articulatus.
—— demissus.
—— lens.
—— vagans.
Pholadomya deltoidea.
Pholadomya lyrata.
—— ovalis.
—— parvula.
Placunopsis.
Quenstedtia lævigata. Normanby.
Trigonia elongata.
—— Moretoni.
—— scarburgensis.
Unicardium gibbosum. Normanby.
Rhynchonella concinna.
—— Morierei?
—— varians. Cherry Willingham.
Terebratula intermedia.
Waldheimia obovata.
—— ornithocephala.
Serpula convoluta.
—— deplexa.
Acrosalenia spinosa.
—— Wiltoni.
Clypeus Ploti.
Echinobrissus clunicularis.
—— orbicularis.
Holectypus depressus. Normanby.
Pseudodiadema.
Anabacia complanata. Normanby.

* Jukes-Browne, Geol. S.W. Lincolnshire, pp. 139, 152, 153, 156.

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Many of the species were obtained by Mr. W. D. Carr, of Lincoln, and others by Mr. John Rhodes. It will be seen that the list corresponds closely with those of species obtained from other parts of the country. The number of Gasteropods is larger, but they are by no means abundant, and too poorly preserved, as a rule, for specific identification.

Further north, although fossils have been obtained near Normanby and Bishops Norton, there are no very good sections.

The total thickness of the Cornbrash is from 3 to 5 feet, and as remarked by Mr. W. A. E. Ussher, it is the most distinctive and persistent member of the Great Oolite Series. Nevertheless there are beds locally present in the Great Oolite Limestone of Lincolnshire, which are hardly distinguishable from it.* (See p. 428.)

Wherever there are exposures along the valley of the Ancholme, there the Cornbrash, presenting its ordinary characters of rubbly and fossiliferous limestone, is present—in this northern tract not exceeding 3 feet in thickness. It is possible, as suggested by Mr. Ussher, that the beds are faulted on the west side of Brigg, for the Lincolnshire Limestone appears at the surface at so short a distance in this direction.†

Fossils have been obtained by Mr. Ussher to the east of Waddingham, and further north, to the west of Atkinsons Cover, and south of Gander Hill. The Rev. J. E. Cross obtained a large collection of fossils from the Cornbrash near Appleby, the rock being well exposed near the railway-station, and by Thornholme Priory. From this region near Appleby, many of the species noted from Sudbrook have been obtained, and to these may be added *Avicula braamburiensis*, *Ostrea Sowerbyi*, *Trigonia striata*, *Waldheimia lagenalis*, &c.

Cornbrash is not again seen, beyond a mile north of Appleby, for at Winterton Holme the probable outcrop was masked by Drift.

On the northern side of the Humber near Elloughton and South Cave, the Cornbrash has nowhere been identified, indeed as Mr. Fox-Strangways remarks, from the most northerly exposure near Appleby in Lincolnshire, it is not again seen until we come to the north side of the Yorkshire basin, a distance of about 46 miles.

It was questioned by Lycett whether the Cornbrash of Yorkshire is equivalent in age to the beds in the district to the south; but the assemblage of fossils is so strongly in favour of their identity, that it is difficult to understand how any doubt should have arisen.‡ The beds are described by Mr. Strangways as consisting of grey rubbly and iron-shot limestone, partially oolitic, and a few feet in thickness: they are overlaid by about 6 feet of finely laminated bluish-grey shales, containing *Avicula echinata*, &c.

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* Geol. Lincoln, p. 70; and Geol. N. Lincoln, p. 86; see also Judd, Geol. Rutland, p. 187.

† Geol. N. Lincoln, p. 93.

‡ Supp. Monograph on Gt. Oolite Mollusca, p. 117; see also Judd, Geol. Rutland, p. 9.

(termed the "Clays of the Cornbrash"), which pass gradually up into the yellow argillaceous base of the Kellaways Rock.* These shales evidently correspond, stratigraphically, to the clays which, in the southern and midland counties of England, form the basement-portion of the Oxfordian strata.

* Geol. of Oolitic, &c. Rocks south of Scarborough, p. 10; Jurassic Rocks of Yorkshire, vol. i. pp. 261, &c.

# CHAPTER XV.

## SCENERY AND AGRICULTURE.

### *Form of the Ground*

THE general easterly and south-easterly arrangement of the rocks, modified though it be by local flexures, and by denudation at different periods, has caused the Oolitic rocks to outcrop in a line trending to the north and north-east.

The results of denudation on strata of varying durability have led to the production of a series of long and diversified ranges of hills separated by vales—the former being marked by the outcrop of the stone-beds (Stonebrash Hills) and the latter by the clays. The outcrop being as a rule on the west or north-westerly slopes of the hills, there we find scarps, and comparatively steep slopes, while in the opposite direction, the dip-slopes incline very gently towards the outcrop of the succeeding formation. The Midford Sand and overlying Inferior Oolite, the Northampton Sand and Lincolnshire Limestone, the Fuller's Earth Rock, the Forest Marble limestone, and (to a minor extent) the Cornbrash, form the ridges, hills, and escarpments; while the Lias clays, the Fuller's Earth clays, the Estuarine and Forest Marble clays, the Oxford Clay, &c. occupy the vales.

It is important to note that while each great division of stone-beds forms a marked feature, this varies much in importance in the same formation when traced across the country. The difference is partly owing to variations in the nature and thickness of the beds, to the amount of inclination, and to the breadth of outcrop: but of course it is mainly dependent on elevation and denudation. Thus various divisions in turn form the dominant heights.

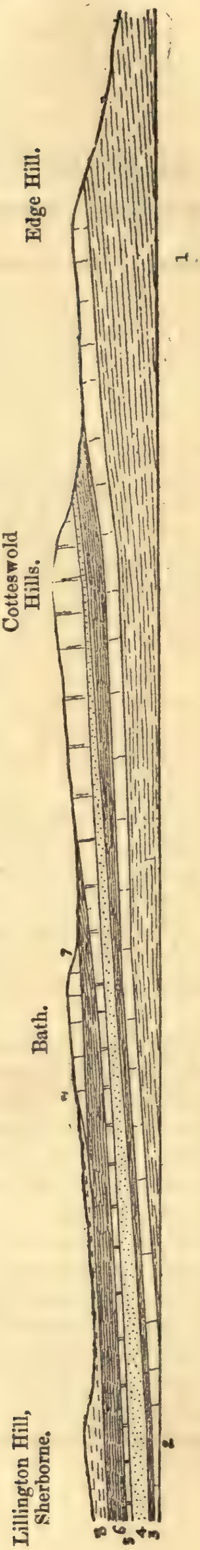
In Dorsetshire the Forest Marble forms the most prominent of the Jurassic escarpments; near Bath the Great Oolite is the main feature; further north the Inferior Oolite above Cheltenham; and still further north the Marlstone at Edge Hill forms the dominant features. (See Fig. 134.) Thus in going northwards, we find the lower beds standing out more and more prominently, and we may trace evidence of a great plain of denudation, such as must have been formed during Neocomian or Lower Cretaceous times, and have been modified and extended in Upper Cretaceous times.

The Cotteswold Hills, varying in elevation from 700 to a little over 1,000 feet, may be said to extend from Bath to Chipping Campden, a distance of about 50 miles, although nearer 60 if we allow for the varying direction of the range.

Near Bath the Great Oolite forms the dominant heights as at Lansdown, and this formation further north, although attaining

FIG. 134.

*Diagram-section of the chief Escarpments from Dorsetshire to Warwickshire.*




8. Forest Marble.
7. Great Oolite.
6. Fuller's Earth, (Fullonian).
5. Inferior Oolite.

4. Midford Sand.
3. Upper Lias.
2. Middle Lias.
1. Lower Lias.

high elevations at Marshfield, Hawkesbury Upton (by the Somerset Monument), Symonds Hall Hill, and Minchinhampton, forms a less prominent escarpment than the Inferior Oolite. North-west of Minchinhampton the Great Oolite is much broken up by faults and isolated by denudation. From the higher grounds of this formation we overlook the dip-slope, and the comparatively flat and monotonous tracts of the Forest Marble bordered by the Cornbrash (which seldom forms any marked feature); beyond which is the low-lying vale of Oxford Clay, &c.

The Inferior Oolite, which makes no very conspicuous feature at Bath, becomes more and more prominent further north, for the strata increase in thickness, and the escarpment of the Great Oolite is more distant. This is more especially the case near Wotton-under-Edge and north of Stroud. The line of hills is but little broken from Dyrham and Dodington to Hawkesbury, while beyond there are the fine and bold spurs of Nibley Hill (crowned by the Tyndale Monument); Stinchcombe Hill, a bold grassy promontory, perhaps the boldest of all the Cotteswold Hills (720 feet); Uley Bury (755), and the outlier of Cam Long Down; Selsley Hill, and Rodborough. The escarpment is broken by the deep valley at Stroud and Nailsworth, whose sharp slopes contribute to form a highly picturesque region. Beyond this valley we have Randwick Hill, Haresfield Beacon, Painswick Hill (800), Coopers Hill, Birdlip (963), Crickley Hill, Leckhampton Hill (900), Cleeve Cloud (the highest point 1,071 feet); and further on, Stanway and Broadway Hills (about 900 feet). Many of these heights are crowned by ancient camps, and they have been utilized as beacon hills.* The slopes and summits in many places are richly wooded with beech, fir, ash, &c.—the beech especially growing with luxuriance. Fine views in various directions across the Vales of Gloucester and Berkeley are obtained from the different hills.

The northern end of the Cotteswolds is a plateau intersected by deep valleys, while the strata are comparatively flat, and to a certain extent synclinal; so that instead of a dip-slope towards the east, we have an escarpment also on that side overlooking the vale of Moreton. To the south we have the elevated tracts, of Great Oolite, &c., which extend from Cirencester to Northleach; and which, between Fairford and Burford, form the Oxfordshire Downs; eastwards we find the old Forest of Wychwood, a tract formed partly of Great Oolite, partly of Forest Marble, and higher beds. Northwards lies a plateau of Great and Inferior Oolite, which extends from Stonesfield to Chipping Norton and North Aston.

The general trend of the outcrop of the Oolites is now towards the east, and while we find broad and deep valleys running across the dip-slope, there are other valleys in the country between Chipping Norton and Banbury, that traverse the area in an east and west direction. In this area the country is a fairly open one,

* See G. F. Playne, Proc. Cotteswold Club, vol. vi. p. 202.

but thin hedgerows for the most part replace the stone-walls of the Cotteswolds. The escarpment turns northwards and north-eastwards at Heyford by Aynho, towards Brackley.

The general character of the Oolitic district east and north-east of Banbury, by Buckingham, Towcester, Northampton, and Olney, is a gently undulating tract of country, well-timbered and largely under the plough, contrasting in some respects with the more open country of the Cotteswolds. Over much of the area there are coverings of Boulder Clay, and to this formation the growth of trees is mainly owing, although the Estuarine clays and the Great Oolite clays contribute to the fertility. Thus we have remnants of the old forests of Whittlebury or Whittlewood, Salcey Forest, Yardley Chase, Rockingham Forest, and further on the Bedford Purlieus. The Oolitic tracts are much broken up by deep valleys, and the main mass of the strata is fringed with numerous outliers, mostly of Northampton Sand.

A fine escarpment, of Northampton Beds, extends from Desborough, by Rockingham to Gretton, and further on the broad valley of the Welland is spanned by the Midland Railway in a series of 82 arches. Northwards about Seaton, near Uppingham and Manton, the gently sloping and flat-topped hills of Northampton Beds, rise to fair elevations. They are mostly grassy with rather poor hedgerows, and occasional trees, but the summits are well-wooded in places.

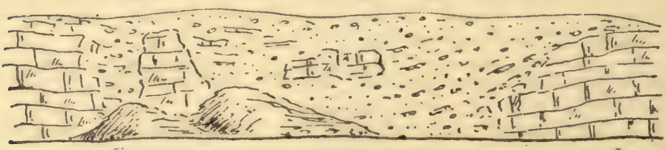
The escarpment of the Northampton Sand and Lincolnshire Limestone, borders the eastern side of the Vale of Catmos, and extends by Waltham-on the-Wolds to Grantham and Sleaford.

In the vale east of Little Ponton, the features are bold, and recall the Cotteswold scenery. Occasional stone-walls are seen on the uplands, but the fields are mostly divided by rather meagre hedgerows. Here and there well-wooded tracts occur.

The same general features occur at South Rauceby near Sleaford, to the north of which the escarpment of the Lincolnshire Limestone forms the well known "Cliff," stretching with but slight deviations past Lincoln and Kirton Lindsey to Winteringham on the Humber Shore.

FIG. 135.

*Quarry on Bredon Hill, Gloucestershire.*



*Superficial Accumulations and Drift.*

Fringing the northern portions of the Cotteswold Hills, there are extensive accumulations of oolitic rubble, opened up in places to a depth of 20 or 30 feet, and dug as "gravel" for mending paths. Some of the more remarkable accumulations occur north-west of Break Heart Hill, south of Dursley; near Gravel Farm, south of Harescomb; at Leckhampton Hill, where the rubble is seen to be banked up at angles of 30° to 40°; and west of Syreford near Andoversford.

Perhaps the most instructive sections are those on Bredon Hill (see Fig. 135), where the Inferior Oolite is shown to be broken up and irregularly weathered into a fine and coarse gravelly-looking rubble. This rubble at one part of the large quarry, was from 25 to 40 feet deep (base not seen), and about 60 yards wide, with isolated masses and pinnacles of unweathered limestone.

These accumulations of Oolitic detritus, that occupy various positions on the borders of the Cotteswold Hills, were considered by Strickland to be contemporary with the General (Glacial) Drift, and to have been formed along old sea-margins.* Such a view of their origin however is no longer entertained. Mr. W. C. Lucy, in 1869, expressed the view that the material was "attributable to frozen snow or land ice, which when the thaw set in, would slip down, carrying with it the *detritus* of the Freestone." Witchell showed that in places the rubble was intercalated with the rolled oolitic gravel of the river-valleys, and on these grounds he considered that it belonged to the latter part of the Glacial period. No indigenous fossils have been recorded from this "Angular Drift," but as the gravels at Stroud have yielded Pleistocene remains, Witchell's conclusion is justified. In his opinion some of this Drift was "due to storm waters or surface drainage, which brought the detritus down the hill upon a frozen surface, and deposited it in those places where the frost usually disappeared in spring before it left the higher ground."†

Distinct evidence of Glacial Drift is found only to the north of the Cotteswold Hills, and in the Vale of Moreton on their eastern side.

The Oolitic region from Chipping Norton to Banbury is practically free from Drift; but further east and south-east in the area north-east of Brackley, Buckingham, and Aylesbury, away to Lincolnshire, the Oolites are in many places concealed by coverings of Boulder Clay and Drift Gravel.

At Tingewick and Radcliff near Buckingham there are good sections in the Drifts, which in places are seen to a depth of over 40 feet; being mainly gravel and sand, and coarse boulder gravel, with occasional layers of Boulder Clay. Similar beds occur at Stoke Plain, north of Stoke Bruerne, and east of Towcester.

Chalky Boulder Clay occurs over much of the surface in Whittlewood Forest, it is found near Newport Pagnell, Towcester, Roade, Blisworth, Northampton, Rockingham Forest, and onwards in patches through Lincolnshire. Considerable thicknesses of this Boulder Clay were opened up in some of the railway-cuttings near South Witham, Castle Bytham (see p. 422), and between Essendine and Great Ponton.

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* Memoirs, pp. 92, 103; see also Hull, Quart. Journ. Geol. Soc., vol. xi. p. 477.

† Proc. Cotteswold Club, vol. vi. p. 150; G. F. Playne, *Ibid.*, vol. v. p. 23; W. C. Lucy, *Ibid.*, vol. v. p. 71, vol. vii., p. 50; Prestwich, Quart. Journ. Geol. Soc., vol. xlviii. pp. 314, &c.

To the south of Great Ponton tunnel an enormous boulder of Lincolnshire Limestone (143 yards long and 60 feet thick) was observed in the Boulder Clay, by Professor Morris; a still larger boulder (300 yards long by 100 yards broad) has recently been discovered by Mr. Fox-Strangways in the Boulder Clay north-west of Melton Mowbray. Quarries have been opened in this mass, in one place to a depth of 15 feet.

### *Landslips.*

Landslips are met with here and there along the escarpments, where the beds of the Inferior Oolite Series rest on the Lias clays, and where the Great Oolite rests on the Fuller's Earth clays.

Some of the more remarkable slips have taken place near Bath. Thus in 1828, 300 or 400 tons of earth fell away from Beechen Cliff, where the Inferior Oolite rests on the Lias. Again much trouble has been caused at Bath itself by the slipping of the ground at Hedgemead, below Lansdown; this slipping occurs on the Lias, and may possibly be in part caused by the underground loss of material, that is carried away by the Bath springs.

Great slips have occurred from time to time at Bathampton, Claverton and Winsley, where the Great Oolite rests on the Fuller's Earth.

Along the Cotteswold Hills, landslips have taken place at Cowcomb, south of Chalford, where 15 acres foundered about the year 1800; near Dowdeswell; at Hewlets Hill, near Cheltenham; and under Cleeve Cloud.

Other instances have been noted where the Lincolnshire Limestone and Northampton Beds rest on the Upper Lias clay, as at Gretton, and near King's Cliffe.*

## Soils.

The Oolitic uplands are for the most part under cultivation, and there are few areas of "waste" land.

In those tracts, south-west of Buckinghamshire, where there is little or no Drift, the soil on the Oolites is generally speaking of a brashy nature, being composed of reddish-brown calcareous loam with irregular and more or less rounded, and sometimes flat, pieces of the underlying rock. This "top-soil" is called "stone-brash," and it results from the decomposition of the strata, the brown earth being to a large extent the residue of the limestone-rubble of which only fragments are left. That this is the case will be admitted by anyone who notices the "piped" surface in gravel-pits, where the gravel is composed of oolitic stones commingled with flints and other siliceous materials. Rarely will any but siliceous stones be found in the brown soil that has mainly resulted from the dissolution of the calcareous stones. (See Fig. 105, p. 368.) Instances may be seen near Peterborough. In the counties of Dorset, Wiltshire, Somerset, Gloucester, and Oxford, the strata are practically free from Drift, and we find only occasional pebbles of quartz in the soil. The brown earthy residue (before mentioned) is in itself by no means a fertile soil, it is only very good when mixed with fragments of limestone, as otherwise it is apt to get pressed down into a dense impervious layer.† The decomposed rubble and earth are

* Judd, Geol. Rutland, p. 261.

† J. C. Morton, Nature and Property of Soils, Ed. 4, p. 60; see also Rutley, Quart. Journ. Geol. Soc., vol. xlix. p. 377.

washed down the slopes, and form in some places a practically impervious coating on the borders of the valleys.

Analyses of soils are of but little use, as the soils may vary considerably in the same field.*

### *Inferior Oolite Series.*

The Midford (Bridport and Yeovil) Sand forms conspicuous grassy knolls in the neighbourhood of Bridport, &c.† Colmer's Hill west of the town is one of these conical hills, about 370 feet high, the summit being scarcely two chains by one. (Fig. 136.) There are many others around Bridport, near Beaminster, and northwards bordering the escarpment at Montacute, near Yeovil, and further to the north-east.

There are many lynchets or terraced-fields in this neighbourhood, as near Loders, indicating that the hills were early under cultivation: others may be seen here and there in the escarpment near Crewkerne, at Brent Knoll, and Glastonbury Tor. At the present time the lower slopes of the hills are more usually under cultivation; corn, roots, and even beans being grown in places.

The soil on the Sand is generally fertile, although scrubby patches with gorse may be seen here and there: but as a rule the land formed by the Midford Sand is rich in comparison with that formed by the Upper Greensand in Dorsetshire. In that county the hedgerows grow luxuriantly, oak, ash and elm appearing to thrive as well as fir. The soil is a deep friable sand, more or less calcareous and somewhat loamy, especially when the lower portions of the Midford Sand come to the surface: hence it varies to some extent in different places. The pasture is usually rich.

In Dorsetshire and South Somerset the district is characterized by deep sandy lanes or "hollow-ways," which afford a pleasant shelter for many ferns.‡

FIG. 136.

*Colmer's Hill, Bridport.*

North of Bath and along the Cotteswold Hills the Midford (Cotteswold) Sand outcrops usually along steep slopes of the escarpment and the ramifying valleys.

In the neighbourhood of Bridport and Beaminster the Inferior Oolite is much broken up, so that there is no regular escarpment. The hills formed of stone are usually flat-topped, and are thus readily to be distinguished from those formed of the sands: the latter being more or less conical. Northwards of Yeovil and Sherborne the escarpment of Inferior

* For analyses of Oolitic rocks, see Voelcker, Journ. Bath & W. Eng. Soc., ser. 2, vol. vi. pp. 232, &c.

† H. B. W., Proc. Bath Nat. Hist. Club, vol. vi. p. 125.

‡ H. B. W., Proc. Geol. Assoc., vol. ix. p. 208; and Memoir on the Lias of England and Wales, pp. 201, 311, 314, 315.

Oolite is more marked, and it thus continues, broken only by the Mendip Hills, through Bath to the Cotteswold Hills, where it forms the principal escarpment. There are occasional sheep-sleights on the uplands of Dorsetshire and Somersetshire.

The soil is reddish-brown loamy and brashy. It forms good corn-land, and roots and vegetables are cultivated in some places. As a rule there is a considerable thickness of rubbly oolite beneath the soil.

On the higher grounds, especially in the Cotteswold district, which was not enclosed until the 18th century, the land is largely laid out in more or less permanent pasture. Here, and further to the south-east, partly on the Inferior Oolite and partly on the Great Oolite Series of the Oxfordshire Downs, the famous Cotteswold sheep are bred. Turnips, vetches, clover, and sainfoin are cultivated as food for the stock. In this region we find also a good deal of arable land, while the steeper slopes of the combes are almost always under grass.

The land is divided by dry-walls or stone-fences, there being few hedge-rows and few trees on the main platform formed by the dip-slope, except in certain situations on the margins of the escarpment, which are well-wooded. Here the beech more especially thrives—as in the plantations known as Cranham Woods near Painswick, again near Dursley and Wotton-under-Edge. In the Stroud valley we find terraces on the sides of the hills; these were used as "racks" for drying cloths in olden times, and they resemble some of the lynchets.

Between Chipping Norton and Banbury the soil in many places is very sandy and comparatively sterile, so that we find occasional furzy commons; but the Oolitic tract generally is an undulating series of dome-shaped downs, chiefly devoted to agriculture. The fields are more frequently divided by hedgerows than is the case on the Oxfordshire Downs near Burford, as the soil is on the whole deeper. Where the soil is thin the hedgerows "wear away soon," and they are replaced by stone-fences.

Passing to the north-east we come to a region where the characters of the country are more or less modified by coverings of Drift Gravel and Boulder Clay. On the whole however these superficial deposits more largely conceal the beds of the Great Oolite Series and higher divisions, than those of the Inferior Oolite Series. In some cases they extend to a thickness of over 200 feet.

The Northampton Sand yields a variable soil but in the main a light one. Prof. Judd remarks that the soil is very rich, and especially adapted for the growth of spring-crops. It is ferruginous and often of a red colour. He remarks that the Lincolnshire Oolite forms a light and not very productive soil, which is apt to be very treacherous in dry seasons; it is usually of a red colour, owing to the comparative indestructibility of the thin band of ironstone which lies upon it.*

Rutland owes its name to the "red land" which forms much of the Vale of Catmos. The term "creachy" or "creech land" is applied to the brown ironstone soil found in south-west Lincolnshire, both on the Northampton Sand and Middle Lias; and also to the deep red brashy loam that occurs on the Lincolnshire Limestone from Lincoln to Ancaster and Honington.† (See also p. 468.)

The outliers of Northampton Beds form flat-topped and often grassy hills in the country to the north-east of Banbury, near Daventry, and onwards to Maidwell; and the same remarks apply to those, mentioned by Prof. Judd, at Whadborough, Robin-a-Tiptoes, Barrow Hill, the high grounds about Uppingham, and the Neville-Holt, Slawston, Dingley and Brampton outliers.‡

Much of "Lincoln Heath," a tract on the Lincolnshire Limestone both north and south of Lincoln, was improved and enclosed at the end of last century.

* Geol. Rutland, pp. 93, 141.

† J. A. Clarke, Journ. R. Agric. Soc., vol. xii. p. 259; and H. B. W., Memoir on the Lias of England and Wales, p. 311.

‡ Geol. Rutland, p. 264.

### *Fullonian or Fuller's Earth Formation.*

The soil is generally cold, wet, and heavy, and it supports poor grass with here and there barren patches, and a good deal of rushy ground. Most of the fields are devoted to pasture, but there are tracts of woodland, and of arable land where corn, beans, &c. are cultivated.

In Dorsetshire the pasture is variable, the soil being in places improved by a downwash of Greensand. This is probably the case south-east of Mosterton near Crewkerne, where there is good pasture-land, and some of the best Dorset cheese is made in the neighbourhood. In some parts, as west of Toller Porcorum there is a good deal of chert detritus covering irregular slopes of the ground, and there the gorse and heath flourish.

Again near the coast-guard station at Langton Herring, much of the land is dry owing to the thick oyster-bed, many of the fossils appearing in the soil, and here the gorse has established itself in places.

On the Fuller's Earth Rock the soil, although somewhat brashy, is heavy; corn, roots, and potatoes are grown near Bruton.

East of Milborne Port the Lower Fuller's Earth Clay forms park-like tracts of meadow-land, well timbered in the hedge-rows with oak and ash, and there are occasional orchards.

In Gloucestershire the Fuller's Earth areas are mostly grass-land, but the ground is often irregular and broken owing to landslips. Fine elms grow in places, and there are tracts of woodland, and occasional orchards, especially on the more marly beds.

### *Upper Estuarine Series.*

With regard to the Upper Estuarine Series, Prof. Judd remarks "These beds form a cold, stiff land, which, even when well-drained, gives rise to a very unkindly soil. Consequently, the tracts occupied by these beds are often left waste, and constitute some of the few heaths and commons in this highly cultivated district; among these may be instanced Ailsworth, Helpstone, and Luffenham Heaths."

The clays of the Upper Estuarine Series do not, as a rule, cover any very extensive areas. "On the contrary, they usually constitute the short and somewhat steep slopes between the tabular masses formed by the limestones of the Great and Inferior Oolite respectively; and, in fact, their mode of occurrence is very similar to that of the Fuller's Earth in the Cotteswold Hills. Where, however, these clays do cover any considerable area, they are almost always obscured by drift, while in the steep slopes between the two limestone series, clear and valuable sections are often afforded to us."

In the woods of the Bedford Purlieus, now to a great extent cleared, the beds of Estuarine Clay can be traced below the Great Oolite.*

### *Great Oolite.*

The Great Oolite in Somersetshire, Wiltshire, and Gloucestershire, forms, as a rule, a thin stonebrash or brown brashy soil, on which corn, turnips, potatoes, and other crops are grown.†

Near Bradford-on-Avon and Bath, we find in many cases, small enclosures bounded by hedge-rows and stone-walls, and with fir plantations on the slopes. North of Marshfield we come to a more open country, but the fields are divided by stone walls, and there are few trees, the tract sloping gently towards the east.

Old cultivation-terraces or lynchets may be seen on the slopes east of Farleigh, and here and there in the Avon valley between Bradford and Avoncliff. Vineyards formerly existed near Bath and on Claverton Down.‡

* Judd, Geology of Rutland, &c., pp. 189, 194.

† For analyses of Great Oolite soils, see Voelcker, Quart. Journ. Geol. Soc., vol. xi. p. 495.

‡ H. N. Ellacombe, Proc. Bath Nat. Hist. Club, vol. vii. pp. 36, 42.

The term "Downs" is applied to the Oolitic uplands north and south of Burford. These comprise a somewhat bleak-looking country of arable land, divided into large fields for the most part by stone-walls, with a few hedgerows and a tree or clump of trees here and there, but more wooded as a rule on the slopes.

Towards Wychwood scrubby tracts of Forest land (chiefly Oak and Holly) occur here and there. There are many shallow pits on the area of Wychwood and elsewhere, opened for the construction of the stone-walls. On the plateau north of Stonesfield we find a mixture of arable and park land, with fine holly trees about Ditchley. Referring to this part of Oxfordshire, Mr. C. S. Read has remarked that "the sides of the hills are wet from clay partings in the rocks, and when these partings of clay become extensive and form beds, they produce a wet, tenacious, calcareous soil."*

Much of the land becomes heavy in the tract north of Wootton; in the valley of the Dorne east of Wootton Down Farm, and onwards to Purgatory, where the lower beds of the Great Oolite locally comprise marls with occasional bands of limestone.

South-west of Banbury, near Hinton-in-the-hedges and Croughton, the Great Oolite forms an open country with large fields. The land is mostly under cultivation and is less timbered than the Marlstone. A few scattered quartz pebbles occur in the soil.

In Northamptonshire, Rutlandshire and Lincolnshire, where the rocks are not concealed by Drift, the Great Oolite Limestone forms fertile tracts of clayey soil with rubbly limestone. The soil itself is usually of a dark colour, but as remarked by Prof. Judd, it is occasionally of the same red tint as the Cornbrash and Lincolnshire Limestone. These two formations yield soils lighter as a rule than that of the Great Oolite, hence in seasons of drought the heavier soil on the Great Oolite possesses a greater value to the farmer.

### *Forest Marble.*

The boldest feature among the Jurassic rocks in Dorsetshire and Somersetshire is formed by the Forest Marble. We see this to the south-east of Sutton Bingham, in the wooded tracts of Birts and Abbots Hills, and the ridges at Hardington. The escarpment of Lillington Hill and Gainsborough Hill is continued in the southern part of Sherborne Park; and the feature is maintained in Holt Hill north of Bishops Caundle, Bullstake Hill, and Bowden, Windmill and Charleton Hills, above Charleton Horethorne, and Bratton Hill. Scale Hill near Bruton is a steep and somewhat bare grassy and scrubby scarp; this high ground is wooded further north, the steep dip-slope overlooking the vale of Oxford Clay. Barrow Hill and Buckland Downs form marked features north of Mells.

The soil is dark brown clay, and reddish-brown brashy clay; and on this formation it is varied, and on the whole poor. The limestone generally forms a steep scarp, and being overlaid and underlaid by clay, the arable land is for the most part heavy along the dip-slope. These clay-lands are improved by lime-manure, but they are cold, wet, and heavy, and require deep draining. In dry weather the land is often much fissured. In some tracts there is much pasture and meadow-land with good hedgerows, with oak and ash timber; and occasionally fine elms, horn-beams, &c. are to be seen, as in Orchardleigh Park, Frome. In some places the fields are divided by stone-fences. Corn, beans, grasses, and roots are cultivated in places.

The escarpments are frequently wooded, and here and there covered with patches of gorse. Where sandy beds occur we find scrubby tracts and an occasional rabbit-warren. In other places the ground forms pasture-land for sheep.

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* Journ. R. Agric. Soc., vol. xv. p. 197.

The uplands of Forest Marble north and north-east of Cirencester, form flat monotonous tracts of chiefly ploughed land, with stone walls, and few trees. Much of the subsoil is a tenacious clay of variable thickness intermingled with the "flat stones."

### *Great Oolite Clay.*

In reference to the Great Oolite Clay, Prof. Judd remarks that "The beds of this formation give rise to a cold and wet soil, very similar in character to that of the lower beds of the Upper Estuarine Series. Fortunately, however, they do not occupy any considerable areas in the district, but form only the short slopes between the Cornbrash and Great Oolite limestones; and even in these, the unkindly nature of the soil is usually somewhat tempered by the downwash from the overlying strata. Some of the tracts based on this division of the series have only recently been brought under drainage and cultivation."*

### *Cornbrash.*

The Cornbrash forms a reddish-brown and stony or "brashy" soil, the stones being embedded in loam of a rather tenacious character when wet. As remarked by William Smith "it is kept loose enough for cultivation by the small rubble stones thickly strewed on the surface of its ploughed fields, but which disappear when laid down to pasture."† In many fields fossils may be picked up, especially *Pholadomya*, *Myacites*, *Gresslya*, &c. The fields are usually divided by hedgerows. The rock outcrops in a gentle feature above the Forest Marble clays, and dips beneath the low ground formed of Oxford Clay. The quarries are seldom deep, but opened over considerable areas in the fields. Smith observed that after the stone has been stripped off, and the pits "well levelled, resoiled, and drained," the land may be rather improved than injured. On the other hand H. W. Bristow informed me, that in a field south of Sherborne, where there was formerly a Cornbrash soil and good land, the farmer by degrees had all the stones removed, and then complained that the field was not so fertile—the fact was, there was but a thin layer of rubbly Cornbrash on the clays of the Forest Marble.

In the south-west of England corn and sometimes beans and turnips are cultivated. The name "Cornbrash" was applied in Wiltshire in distinction from the "Stonebrash" of the Great and Inferior Oolites.

An analysis of Cornbrash by Prof. A. Voelcker, showed ·177 of phosphoric acid and ·241 per cent. of sulphate of lime, and their presence, according to Prof. Buckman, contributes to the fertility of the Cornbrash soil.‡

In Northamptonshire, as remarked by Prof. Judd, the soil formed by the Cornbrash has usually a reddish hue like that of the Lincolnshire Limestone, while that of the Great Oolite has more commonly a black tint. Locally the name "Redbacks" has been applied to the rubbly rock. In the midland counties the Cornbrash "does not enjoy the reputation among agriculturists which it has in the south of England."§

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* Geol. Rutland, p. 218.

† Strata Identified by Organized Fossils, 1816, p. 25.

‡ Quart. Journ. Geol. Soc., vol. xiv. p. 120; Ann. Nat. Hist., ser. 2, vol. xii. p. 325, and Proc. Cottesw. Club, vol. i. p. 262.

§ Geol. Rutland, p. 219.

# CHAPTER XVI.

## ECONOMIC PRODUCTS.

### BUILDING STONES.

THE Oolitic rocks furnish some of the most important building-stones in this country: and among the Lower Oolites the following are the chief localities that have yielded freestones and ragstones that have attained fame in architectural works:—

Great Oolite:—Bradford-on-Avon, Bath, Box, Corsham, Minchinhampton, Windrush, Taynton, Milton.
Inferior Oolite Series:—Ham Hill, Doulting, Dundry, Painswick, Cheltenham, Duston, Weldon, Ketton, Barnack, Stamford, Casterton, Clipsham, Great Ponton, Ancaster.

Over the Lower Oolitic areas the strata have naturally influenced the character of the buildings. Hence in the villages and towns, the houses and more especially the older ones, are constructed of stone; and in some cases as at Bradford-on-Avon, Burford, Stonesfield, Woodstock, and Stamford, these are roofed with stone-tiles. Now-a-days, even in famous freestone-districts, many of the cottages are built of brick with Welsh slates, instead of the more picturesque, but doubtless more expensive local materials. The freestone and stone tiles are still used in mansions where a pleasing architectural effect is desired.

When we consider that the Oolites were deposits laid down under the sea, distributed to some extent by currents, and that the accumulations due to organic agencies may be intermingled with detritus brought into the ocean by rivers, we are prepared for many changes in the character of each set of strata. Hence the deposit that may have become a good building-stone at one spot, may be of little or no commercial value at another; and this is actually the case. The Portland Stone, the Bath Stone, the Ketton, Ham Hill, and Doulting Stones, possess great repute; and yet, as their names suggest, the good stone is more or less local. These and other freestones occupy different horizons in the Oolitic series, and all change laterally into beds of varied and often far inferior quality.

Thus the chief building-stone at Portland is an oolitic limestone; at Tisbury and Chilmark in the Vale of Wardour, and also at Swindon, the best beds in the Portland formation are calcareous sandstones. Again the Great Oolite, that yields good freestone at Bradford-on-Avon, Bath, Michinhampton, and Milton near Taynton, yields comparatively little freestone in its course to the north-east through Oxfordshire, Northamptonshire, and Lincolnshire.

The term *Freestone* is applied to stone that "will cut and rive in any direction." It may be either a sandstone or a limestone; and in the case of the Oolites, the freestones are usually ferruginous or calcareous sandstones, or limestones with closely-packed oolite grains. The rock should be free from prominent planes of lamination, as distinct from those of bedding.

The word *Rag* is applied to beds, which contain many shells or fragments of shells, and which on this account are not easy to work. Some freestones, like the Ham Hill Stone, are however composed largely of comminuted shells.

The term *Weatherstone* is employed for any layers of building-stone that well withstand the action of the weather, and may be employed as corner blocks or for foundations; for sills, mullions, &c.

The term *Planking* is used for thin-bedded stone that may be seviceable for paving.

The term *Bastard Stone* is applied to inferior or decomposed beds; as Bastard freestone, Bastard Blues (Purbeck Beds of Sussex).

The terms *Ridding, Riddingtop, Quarry-head* or *Rubbish*, are applied by quarrymen to the rubbly rock, Drift, "Head," or other material to be removed as waste in working a quarry.

In Northamptonshire the term *Kale* (or *Cale*) is used for the soft weathered beds of ferruginous sandstone belonging to the Northampton Sand; and in Lincolnshire the same name is applied to soft and rubbly beds of the Cornbrash, which is then said to be "kaly." It is also applied to other rubbly or rotten beds in these counties.

Not only do the freestones vary in quality when traced laterally, but the different layers even in the same quarry are liable to variation in character and thickness.

Much depends too on the position of the stone with relation to the surface. Where the beds are covered up by a stratum of clay, the stone usually appears sound all through. Where the stone actually occurs at the surface, the uppermost layers are much broken up. Hence, as remarked by William Smith, the strata frequently occur as follows beneath the surface-soil :—

| | |
|---|---|
| Rubble - - - - - | Used for road-stone. |
| Thin shattered beds - - - | Used for dry walling. |
| Freestone - - - - - | Building-stone. |

These characters are shown in the section near Ancaster. (Fig. 59, p. 213.) As the beds are worked further into the hill-side, the thin shattered beds pass into Freestone, and the Rubble may become Wallstone, and eventually Freestone.

Firmly compacted oolites and ragstones of uniform character, are more durable than the compact and somewhat argillaceous limestones, with scattered oolitic grains, that are frequently met with in the Lincolnshire Limestone and in the Great Oolite. These compact limestones, like many of the Lower Lias limestones, split up irregularly, and will not withstand frost.

A crystalline or shelly limestone is more durable than these compact and earthy limestones, although the shelly stones may exhibit the action of the weather more prominently, as then the shell-fragments usually stand out in relief.

Uniform physical structure is more important than chemical composition, for the value and durability of a stone cannot be determined by analysis. Attention has been drawn by Mr. H. W. Burrows to the value of a microscopical examination of building-stones; but, in reference to the oolites, I think we cannot at present speak confidently on the matter, and that it would be difficult to tell a good, from an inferior, freestone, in a microscopic slide.

Analyses of Inferior Oolite from Dundry and Painswick, and of Great Oolite from Bath, show from 94 to nearly 98 per cent. of carbonate of lime and from ·19 to ·93 of silica.

Stones that are readily dissolved by carbonated waters, exhibit in buildings and often in quarry-faces a lime-wash over their surfaces. The presence of much earthy or readily wasted matter, may be tested by C. H. Smith's plan of immersing small pieces of the rock in a glass of clear water, as the water after half an hour will become slightly turbid.

The weight of different Oolitic building-stones varies from about 116 to 155 pounds per cubic foot: but it is no test of the relative durability: it is of importance mainly with reference to the particular work for which the stone is used. Again the weight which any particular stone will bear should be ascertained if it is to be subjected to particular stresses; but in an ordinary way the greatest strain is less than 16 tons to the square foot, and even poor freestones will bear about eight times that amount.*

The following analyses may be useful to show the composition of Oolitic building-stones:—

| —— | Box. | Ancaster. | Ketton. | Barnack. | Ham Hill. |
|---|---|---|---|---|---|
| Carbonate of lime - - | 94·52 | 93·59 | 92·17 | 93·40 | 79·30 |
| Carbonate of magnesia - | 2·50 | 2·90 | 4·10 | 3·80 | 5·20 |
| Silica - - - - | 0·0 | 0·0 | 0·00 | 0·00 | 4·70 |
| Iron, alumina - - - | 1·20 | 0·80 | 0·90 | 1·30 | 8·30 |
| Waert and loss - - | 1·78 | 2·71 | 2·83 | 1·50 | 2·50 |
| | 100·00 | 100·00 | 100·00 | 100·00 | 100·00 |

Traces of bitumen were noticed in all these analyses. Another analysis of Bath stone showed ·50 per cent. of silica. Traces of sulphate of lime and phosphoric acid have been observed in some Oolitic freestones.†

The following statistics show the density and absorbent powers of some of the rocks:—

* See remarks in Notes on Building Construction, Part 3, ed. 2, p. 6; C. H. Smith, Lithology, Journ. R. Inst. Brit. Archit. 1840, p. 167; papers by G. F. Harris, in the "Builder" for 1886; and H. W. Burrows, Journ. R. Inst. Brit. Archit. ser. 2, vol. ix. p. 284.

† See Analyses by Prof. Daniell, in Report on the Selection of Stone for the New Houses of Parliament; Mem. Geol. Survey, vol. ii., part 2, p. 690; A. Voelcker, Journ. Bath and W. of Eng. Soc., ser. 2, vol. vi. p. 64; and Builder, vol. lix. p. 324.

| — | Specific Gravity of Dry Specimens. | Bulk of Water absorbed. | Weight: per Cubic Foot. |
|---|---|---|---|
| | | Per cent. | lbs. |
| Ancaster - - | 2·18 | 16·6 | 133 to 139 |
| Barnack Rag - - | 2·09 | 20·0 | 136 |
| Bath - - | 2·5 | 17·0 | 116 to 123 |
| Doulting - - | 2·6 | — | 134 |
| Dundry - - - | 2·45 | 18·8 | 126 |
| Ham Hill - - | 2·26 | — | 141 |
| Ketton Freestone - | 2·04 | 15·1 | 128 |
| „ Rag - - | 2·49 | 7·0 | 155 |
| Taynton - - - | — | — | 135 |

The "crushing weight" for a two-inch cube of Ketton Rag is stated to be 321 cwt.: and it is distinguished by its great cohesive strength and high specific gravity. For similar cubes of Ketton, Ancaster, and Barnack freestones, the crushing weights were 91, 83, and 65 cwt. respectively.*

Good stone must of course, in all cases, be seasoned. It should not be taken from the quarry and used at once, in the "green" state. In fact a year's exposure after quarrying in the spring-time, may be good and even necessary in some cases. By this process the stone being stacked in suitable positions, the inferior or faulty stone will be weeded out, for the action of the atmosphere will tend to crack it up, while the good stone will stand; and most stones in drying will become harder.

In old times it was more customary than it is now to dress the stone on the spot where quarried. At the present day huge blocks of Bath Stone and other materials, are often sent by rail, and sawn up and dressed near the buildings where the stone is wanted. Such a plan has its drawbacks. Blocks sawn up and dressed ready for the builder when in the green state, and then allowed to dry, are better than those shaped from large blocks that have been left to weather for a season. This is because the process of carving and cutting opens fresh surfaces to the atmosphere. Whereas when the stone has been exposed to the weather, the "quarry-water" or "sap" dries up and forms a kind of cementing glaze over the surface, and this I am told renders the stone less liable to atmospheric influence. The quarry-water may hold in solution a certain amount of calcareous, siliceous or ferruginous matter.

In old times moreover the building-stone was almost invariably quarried from the surface where the beds outcropped, and had no

* See Report (above mentioned); Judd, Geol. Rutland, p. 181.

protecting cover. Thus although the blocks obtained, were as a rule comparatively small in size, compared with those that may be sawn out at a depth below ground, yet Nature had to some extent sorted the good from the bad stone, and the materials used have in most cases proved their durability. More stone, of course, can be obtained for the labour, when the strata are protected by clay, and if the material be properly seasoned the results will be found satisfactory.

Good and sound stone is usually sonorous, and the blocks will ring when struck with a hammer. If unsound or "venty" the note will be discordant; and Mr. A. M. Wallis, a practical worker at Portland, states that "by placing the hand on the stone when striking it, the vent may be detected by a slight undulating motion."

Sandstones with calcareous cement are not very durable as a rule, although the Chilmark Stone may be taken as an exception. The purely siliceous varieties of sandstone are however too hard to admit of being readily dressed, and are more usually employed for road-metal.

Stones that absorb a large amount of water may be acted upon more readily by frost; but the durability of a rock does not necessarily decrease according to the absorbent powers.*

The Portland Whit Bed is said, when dry, to be capable of absorbing from 6 to 7 per cent. of its weight of water in 24 hours.

In the applications of stones it is necessary to consider the aspect of the building in reference to prevalent rains, &c.; and also the situation in large towns and cities, where the atmosphere may be impregnated with an excess of carbonic acid, and even with sulphuric, nitric, and hydrochloric acids from various manufactories. To some extent, as remarked by Mr. F. W. Rudler, the smoke of London gives a protective coating to the stone of buildings.

Most of the beds, and especially those with any tendency to a laminated or flaggy structure, should be placed in their natural position in buildings. In some cases however where the rock is much false-bedded, the stone may be better placed on end or "surbedded," and this is said to be the case with the Taynton Stone. Moreover in the case of mouldings and fine carvings attention must be paid to the position the stone will occupy.

For the artificial protection of stone, various solutions and other preparations (silicates of soda and potash, &c.) have been suggested. The building-blocks in some cases may be immersed in the solution before use; in other cases the stone in the buildings may be painted or coated with the material. At present the expense has been the chief drawback to the adoption of these processes.† The "Bath Stone Firms," however, have lately introduced a "fluate" for the preservation of limestones, and rocks containing over 25 per cent. of carbonate of lime. The process, which was originated by M. Kessler, is described as "fluosilicatization." The liquid is applied with a brush, and it acts chemically on the stone, leaving it as calcium fluoride, and silica; and thus rendering it insoluble by rain-water. The liquid naturally extends further into porous and loose-textured stone; and in the oolite rocks it acts more readily on the matrix. It does not, however, entirely close the pores. The cost of the

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* See C. Lloyd Morgan, on Bristol Building Stones, Proc. Bristol Nat. Soc., ser. 2, vol. v. p. 95; and remarks on Stone in "Notes on Building Construction," Part 3, ed. 2, 1889, pp. 11, 76; Wallis, Proc. Dorset Nat. Hist. Club, vol. xii. p. 191.

† G. P. Merrill, Smithsonian Report for 1886, Part 2.

material is estiamated at 1*d*. per superficial foot. It has been applied to the south front of Westminster Abbey, to portions of Buckingham Palace, Magdalen College, Oxford, &c.

Statistics of the production of building-stone from underground-workings in the counties of Somerset, Gloucester, and Wilts, are published in the Reports of the Inspectors of Mines. These statistics are admittedly incomplete, and it is therefore best to omit them. As an example of the value of the stone at the different localities, including Great and Inferior Oolite, it may be stated that for the year 1887 the following statistics are given:—

| —— | Tons of Stone. | Value at Mine. |
|---|---|---|
| | | £ |
| Gloucestershire - - - | 1,254 | 620 |
| Wiltshire - - - - | 107,610 | 64,566 |
| Somersetshire - - - | 2,748 | 1,648 |

### Inferior Oolite Series.

#### *Northampton Sand.*

The ferruginous and calcareous sandstones of the Northampton Sand have been quarried in many places for building-stone, the material much resembling that of the Middle Lias quarried at Hornton, on Edge Hill. It has been extensively used in Northamptonshire and Rutlandshire.

Soft sandstone known as Oven-stone, from its frequent use in former days in the construction of ovens, was obtained in the neighbourhood of Chipping Norton and Steeple Aston.* (See p. 163.)

Helmedon was long celebrated for its freestone quarries, but the stone, which was used in the mansions of Stowe and Woburn, is not now worked. Similar stone was obtained at Thorpe Mandeville, near Byfield, and also at Eydon.†

The principal quarries now open are those of Duston and Harleston, where the stone is known as Duston freestone and Harleston stone. Coping, paving, and building-blocks, and tombstones are prepared. Some of the soft (yellow or red) beds of Duston are used for rubbing hearths or door-steps. At Harleston the stone is used for pitching and edging-stones. At Desborough, Cottingham near Rockingham, and near Uppingham, and other places stone has been quarried.

#### *Inferior Oolite, &c.*

The Inferior Oolite of Somersetshire and Gloucestershire furnishes very many important building-stones.

The Ham Hill stone quarried to the west of Yeovil, is a brown limestone, mainly composed of comminuted shells of *Pecten*, *Ostrea*, &c., cemented together by ferruginous matter. It occurs in the upper part of the Midford Sand. (See p. 72.) An analysis mentioned by Charles Moore, showed 14 per cent. of metallic iron.‡ The stone is very much false-bedded, and the thickest layers are seldom more than two feet. The mass of the stone-beds is from 50 to 60 feet thick. The stone has been worked since the time of the Roman occupation, for some Roman coffins are made of it. It has proved a very durable material in the

* Memoirs of William Smith, pp. 3, 61.

† John Morton, Nat. Hist. Northants, 1705, pp. 126, &c.; and George Baker, Hist. and Antiq. of Northampton, 1822–30, vol. i. pp. 440, &c.

‡ Moore, Proc. Somerset Arch. Soc., vol. xiii. p. 143.

district, to which the churches and halls, as those of Montacute and Brympton, and other buildings, bear witness, while its tones of colour render it very pleasing to the eye. Recently it has been used in the construction of the building for the New Traveller's Club in Piccadilly and in Daly's Theatre, Cranbourn Street.

The deep quarries on Ham Hill, as Mr. C. Trask has stated, have only been opened in the present century: that in which the section (p. 72) was taken, being made about 35 years ago. The Grey Beds are said to yield the best weather-stone. Blocks of stone, 4 or 5 tons in weight, and from 2 ft. 6 in. to 6 feet thick, are raised for building-purposes. The stone is occasionally used for paving, but it is too soft to be well adapted for the purpose.

Shelly beds of somewhat similar character to the Ham Hill Stone, have been quarried at North Perrot, and also near Yeovil Junction, where the stone (which occurs only in thin bands) has been used for building bridges, &c., on the London and South-Western Railway.

The Doulting Stone, quarried at Doulting near Shepton Mallet, is a pale-brown, somewhat sparry, limestone, of apparently loose texture; but the stone hardens and becomes paler in tint, and very durable on exposure. Some local varieties are known as the Chelynch and Brambleditch Stones, from the quarries whence the stone is extracted. The particular beds exposed in one of the Doulting quarries have been already noted (p. 88). The stone is not so readily carved as Bath Stone, but it is more durable. It was used in old times in the construction of Wells Cathedral and Glastonbury Abbey.

The Dundry Stone, quarried and mined on Dundry Hill, south of Bristol, is a hard pale brown limestone of imperfectly oolitic character. (See p. 99.) It has been largely used in Bristol; parts of the Cathedral, the church of St. Mary Redcliffe, and other edifices having been constructed of the stone. It has also been used in Llandaff Cathedral. Analysis of the rock shows 96·14 per cent. of carbonate of lime, and 1·35 of silica.* (See p. 472.) One cubic foot of the stone weighs about 1¼ cwt.

The Freestones of the Inferior Oolite are quarried at numerous places along the Cotteswold Hills, both on the western and eastern sides. In some localities as at Dowdeswell, Nailsworth, and at Walls Quarry, Brimscombe, there have been underground workings.

The beds known as the Lower Freestone are those principally worked, and there are quarries at Uley Bury, Selsley Hill, Ball's Green near Nailsworth, Stroud, Quar Hill by the Horsepools, Painswick Hill,† Haresfield, Birdlip, Leckhampton, Brookhampton, Temple Guiting, Stanway, Broadway, Bourton-on-the-Hill, Seizincote, Longborough near Bourton-on-the-Water, &c. The Upper Freestones are quarried at Nailsworth. Other beds belonging to the Pea Grit Series have been worked near Haresfield, Crickley, and Cleeve.

From the fact that escarpments usually face the west, arises the common opinion that the best stone occurs on the west side of the hills; and this is a fact so far as regards the Cheltenham freestone (of the quarries before mentioned), and of the Hornton Stone which occurs in the Middle Lias of Edge Hill.

The Bourton Stone (of Bourton-on-the-Hill) is not considered so good as the Cheltenham or Painswick Stones. It comprises an upper bed of oolite, known as the White Rock, which is used for rough inside-walling, and is burnt for lime. The best freestone is the Yellow Bed, an oolite, of which blocks about 40 cubic feet in size are sometimes obtained, but those of 10 or 12 feet are the usual size. 16 cubic feet go to the ton. The Red Bed, a ferruginous and cellular oolitic stone, is used for foundations, but it is a hard rock that "breaks all tools." (See p. 143.)

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* Mem. Geol. Survey, vol. ii., part 2, p. 688; see also Voelcker, Journ. Bath and W. of Eng. Soc., ser. 2, vol. vi. p. 223; and Stoddart, Proc. Bristol Nat. Soc., ser. 2, vol. ii. p. 286.

† For analysis of Painswick Stone, see Mem. Geol. Surv., vol. ii., Part 2, p. 693.

At Westington Hill Quarry, above Chipping Campden, oolitic freestones are worked beneath a covering of 18 or 20 feet of marly limestones, &c. The upper bed of freestone is a false-bedded shelly oolite, with closely packed grains: it is used for planking, covering drains, culverts, and road-mending. The White post below is used for building; and still lower is the Yellow Bed, used for carving, for which purpose it is better adapted than the White Bed, as it is moister. 12 to 14 cubic feet go the ton, one cubic foot weighing about 1½ cwt. (See p. 141.)

The Chipping Norton limestone is locally used for building-purposes, and some beds are employed for paving, but it is a rock of variable character.

*Lincolnshire Limestone.*

It is only at certain horizons in the Lincolnshire Limestone that we find beds of good freestone, or rag suitable for building-purposes. The mass of the formation consists of more or less earthy and compact limestones with scattered oolite grains, that seldom yield durable material for outside work. The better kinds of stone of this character are the Stamford Marble and the Silver Bed of Lincoln.

Sometimes the best freestone or rag occurs at or near the top of the series, as at Ketton, Stamford, Casterton, Clipsham, Ponton, and Ancaster (Haydor and Wilsford quarries); or at a somewhat lower horizon, as at Weldon; and sometimes, near the base, as at Barnack.

Locally, hard beds occur at different horizons, and in the lower portion of the series west of Ancaster railway-station, there is a rough rock that has been used for harbour works.

The Ancaster Stone comprises about 12 or 13 feet of freestone. (See p. 212.) It has been used in Lincoln Cathedral, Belvoir Castle, Wollaton Hall, Belton House, Boston Church, and numerous other churches in Lincolnshire. Some of the stone used (before 1889) in the University College, Nottingham, failed, from the fact that although the best stone or "Firsts" was contracted for, a great deal of "Seconds" or worse (inferior or unseasoned stone) was obtained by the sub-contractor.

The Barnack Rag is coarsely-bedded shelly oolite, 3 or 4 feet thick, and blocks of 30 cubic feet and upwards, weighing 2 or 3 tons have been obtained. (See p.199.) The stone has been used in Peterborough Cathedral, Croyland Abbey, Burleigh House, and in Boston, Stamford, Ketton, Collyweston, Kettering, Moulton, Spalding, Holbeach, and other churches in Lincolnshire and Cambridgeshire.

No doubt this was one of the earliest formations quarried; and it is interesting to read of the freestone "at Barneck, Barnack or Barnoak, from whence King Wolfere, A.D. 664, built Peterborough Abbey: here eight pair of oxen were required to move one block. From Barneck quarries were built the Abbeys of Rumsey and St. Edmunds Bury."*

The Ketton freestone is a pale oolite. As remarked by Prof. Judd, it is highly valued by architects, and its employment is frequently specified by them in cases where great strength is required in any particular construction. The slight thickness of the bed, however (only 3 or 4 feet), and the large quantities of "bearing" which require to be removed in order to obtain it, renders it expensive and prevents its more general use.†

Blocks measuring $3 \times 2 \times 3$ feet, and others of smaller size, are now obtained. The stone was employed in the construction of St. Dunstan's, Fleet Street (upper part), of some of the Colleges at Cambridge, parts of Ely and Peterborough Cathedrals, and of the Abbey at Bury St. Edmunds.

The Weldon freestone is worked partly in the open and partly underground. It is sawn out *in situ*. Blocks from 40 to 140 cubic feet in size, and weighing 16 cubic feet to the ton, are obtained. It has been used in the reparation of the west front of Rochester Cathedral (1892). (See also pp. 191, 204.)

* Townsend, Character of Moses, p. 151.
† Judd, Geol. Rutland, p. 155.

*Great Oolite.*

The Bath Stone is quarried and mined over an extensive area between Bradford-on-Avon and Corsham. Some of the underground tunnels on Corsham Down are said to extend for several miles, and they are connected with the surface by an incline up which the stone is taken along a tram-line. The open works date from a very early period; and some of the deeper works date from the time when the Box tunnel was constructed (about 1845). There is from 6 to about 25 feet of freestone, and the layers are from 1 to 6 feet thick. (See p. 261.)

At Bradford-on-Avon, the best freestone is about 6 feet thick: and it is worked underground. The stone above it is cleared off for about 8 inches or 1 foot, and then the rock is sawed out in huge blocks of from two to five tons in weight. The average size of the blocks is about 40 cubic feet, but sometimes blocks of 70 or even 90 cubic feet (5 tons) are obtained. It is a good weather-stone, and is obtained not only at Bradford, but at Upper Westwood and Avoncliff (Ancliff). (See p. 261.) At Winsley a good weather-stone is obtained; the best bed, known as Winsley Ground, is from 3 to 4 feet thick. At Limpley Stoke, the best freestone is about 6 feet thick; it is known as Stoke Ground, and is a good weather-stone.

On Odd Down and Combe Down,* near Bath, there are extensive quarries where 10 or 12 feet of freestone is worked. The stone contains thin and impersistent veins of spar, and iron-stains, which do not however affect its durability. I was informed by Mr. Love that the stone, although more or less fissured, does not deteriorate when near the surface; that, at Odd Down, which in places is covered only by a foot or two of rubble, being sound and durable, while the Farleigh Down Stone of Monkton Farley (or Farleigh) obtained beneath clays, is not reckoned so good a weather-stone. The best stone is about 4 feet 6 in. thick; but very large blocks are not to be had. (See p. 265.) Larger blocks can of course be obtained where the stone is mined, and it is free from the disturbing influence of the weather.

The stone is quarried and mined in several places at Box, the details varying in different places. (See p. 267.)

The Box Scallett Stone, said to be excellent for carving, is not now much worked, probably on account of the expense. The main freestone 12 to 14 feet) occurs lower down, and this can be mined beneath the hard rags, which constitute a Roof Bed. One of these rags known as the White Rag is an oolite that "dries as white as snow." Very similar beds occur between Tetbury and Kemble, and near Minchinhampton.

The Box freestone or Ground bed forms a good weather-stone, it whitens on exposure. Blocks weighing 6 tons are sometimes obtained; about 14 cubic feet of stone weighing one ton. The stone is often so broken up that much refuse has to be extracted. The good stone is from 9 inches to 3 or 4 feet in thickness: it is said to be a better weather-stone than that at Bradford, but is not usually obtained in such large blocks. The Rag bed is so hard that the freestone is seldom worked beneath it in open quarries. Overlying the Rag bed, there is a freestone, known as the Corngrit; the best beds attain a thickness of 4 feet. The rock is a somewhat earthy and shelly oolite, suitable for inside work.

The Corsham Bath-stone, which is mined on Corsham Down and Ridge and at Monks Park to the south, comprises from 15 to 25 feet of freestone in several beds. These are worked underground, to a depth sometimes of 100 feet. The best beds, known as Corsham Down and Monks Park stones, are about 4 feet thick. The stone is a fine uniform oolite, with few fossils. Blocks about 100 cubic feet, and weighing about 7 tons, are sometimes brought up: as a rule about 16 cubic feet of stone go to the ton. The blocks are stacked in summer; being raised above the ground, to dry; and they are ready for use in the

* For Analysis, see Mem. Geol. Survey, vol. ii., Part 2, p. 690; also Builder, vol. lix. p. 324 (1890).

winter time. If used when "green," the stone easily falls to pieces through the action of frost, &c. The yellow oolitic freestone dries paler and almost white in tint. The stone is suitable for outside facings, and tracery, and for all inside work.

Speaking generally, the Bath Stone, which is comparatively soft and moist when mined, hardens on exposure. It is said that a cubic foot of the stone will absorb one gallon of water. The best stone will stand a weight of about 70 tons to the square foot.

The Stone from Lodge Hill, Combe Down, was used in the restoration of Henry VII.'s Chapel at Westminster (1819). That from Baynton (Bathampton) quarry, was used in the construction of Windsor Castle, and Bowood House. That from "Haselbury Quarre," Box (still worked by the Bath Stone Firms), was used in Malmesbury Abbey, Laycock Abbey, and the mansion of Longleat. That from Drewes Quarry, Monkton Farley, was used in Buckingham Palace (1827).* Corsham Ridge Stone was used in the Royal Aquarium, at Westminster.

Bath Stone was employed in the building of the Royal College of Physicians (1824), Apsley House, Piccadilly (1828), Exeter Hall, &c.

The Stone at Minchinhampton has been very extensively quarried, and here there are no protecting beds of clay. (See p. 278.)

The Weatherstone, is a hard oolitic and shelly limestone, of coarse aspect, and sandy in places, but very durable when dried by exposure to the sun. The stone does not readily absorb water, and consequently it resists the action of frost. A careful selection is however necessary.†

White limestone, hard and compact (like the White Lias of the Rhætic Beds) was used by the Romans to form tesseræ for pavements. Examples have been obtained at Cirencester and probably at Silchester, though of course it is almost impossible to definitely fix the age of the rock used, from the small fragments preserved. Some of these hard beds, which belong to the Great Oolite, are obtained, as in the neighbourhood of Cirencester, for paving; and other beds are used for building and walling; but Bath Stone has been employed in the more important buildings, for quoins, sills, mullions, &c., as it is better able to withstand the frost.‡

Building-stone of excellent quality has been obtained from Windrush, and Taynton, in the neighbourhood of Burford. At the former locality it has been mined, while at Taynton the stone was obtained in quarries at or near the surface. The remarkable false-bedded character of the Taynton or Teynton stone, may have led to the opinion that when used for building it is best surbedded, that is, set "edgewise, contrary to the posture it had in the quarry."§ (See p. 306.)

The best stone is of a dark brown colour, and this occurs sometimes at the base and sometimes at the top. There is no reason to believe that all the good stone has been exhausted at this locality, but I was informed that the present owner (E. R. Wingfield, Esq., of Barrington) is not desirous of further breaking up the ground. The stone now obtained is employed only on the estate. Building-blocks and crests for ridging are shaped; and formerly, cisterns, troughs, coping-stones, &c., were produced.

As remarked by Prof. Hull, "The freestone at Tainton quarries has furnished the stone for some of the oldest buildings at Oxford, viz., those of the 12th, 13th, and 14th centuries, and is still in good preservation; the mouldings being sharper and less weathered than of some buildings of the 17th and 18th centuries, which are cut out of blocks from Heddington Hill quarries, near Oxford."|| Thus it has been used in the ancient parts of the Cathedral (Christ Church), in Merton College and Chapel, also in Blenheim Palace.

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* See Report with reference to the Selection of Stone for building the New Houses of Parliament, 1839; and the Builder, Sept. 18, 1858.

† Lycett, Proc. Cotteswold Club, vol. i. p. 17.

‡ J. Bravender, in Hunt's Mineral Statistics, Part II. for 1858, 1860, p. 154.

§ See Plot's, Oxfordshire, p. 77.

|| See Hull, Geol. of the country around Cheltenham, p. 58.

Freestone of good quality is now largely quarried, beneath a considerable thickness of superincumbent strata, at Milton (see p. 307); and formerly stone was obtained at Pudlecote, near Charlbury.

Here and there in the area to the north and north-east, as at Tadmarton, building-stone is obtained. At this locality it is a close-grained shelly oolite. At Shalstone, north of Shalstone Hill Farm, a hard white shelly limestone is said to yield "a beautiful building-stone."* At Olney and Bedford building-stone is also obtained.

In Northamptonshire the Great Oolite Limestone yields stone that is locally used for building-purposes, but no freestone of great repute.

White stone from Culworth quarry has been used for paving together with a black stone (probably Middle Lias) from Byfield. In the Manor Houses the halls have been paved with these two rocks; alternately set in squares. Morton remarked that "Both of these may be wrought to a considerable Degree of Smoothness, so as nearly to approach a Polish."†

At Blisworth an oolitic limestone belonging to the Great Oolite, is sawed up and faced, for flooring, window-sills, chimney-pieces, &c.‡

At Denton, south-east of Northampton, white and blue beds of limestone have been quarried. At Gretton near Uppingham, the limestone has been used for pitching. Good freestone, as remarked by Prof. Judd, has been obtained at Oundle and Geddington Chase. (See p. 411.)

In parts of Lincolnshire the Great Oolite Limestone yields material for rough walling, &c.

### *Forest Marble.*

The shelly and oolitic limestones of this formation are extensively quarried for building-stone, wall-stone, paving-purposes, pedestals for ricks, &c. Slabs or stone-planks 3 to 5 inches thick, from 3 to 4 feet in length, and 18 inches to 4 feet in width, are obtained in places. These slabs, as a rule, cannot be neatly squared; but they have been used for floors of kitchens, courts, and yards, for stiles, as rough coping for walls, or as pitching for stables.§

The principal quarries have been already mentioned; among them the more important are those of Bothenhampton, Long Burton, North Cheriton, Windmill Hill above Charleton Horethorne, Bratton, Wanstrow, &c. The Forest Marble is largely quarried at Frome, where it is known as the Frome Stone (see p. 349), also near Cirencester, Norton Brize, Kirtlington, Bicester, &c. Beds of similar age have been quarried at Lillingston Lovell (p. 378).

### *Cornbrash.*

As a rule the Cornbrash is too much broken up to yield building-blocks; but it is quarried in places for building-purposes and for stone-fences.

The stone as a rule breaks up somewhat irregularly and does not yield a good "face."

It has been used for building, at Radipole near Weymouth, where the unweathered beds yield a tough bluish shelly limestone; also at East Coker near Yeovil, near Templecombe, Upton Noble, &c.

Reference may here be made to the Caen Stone, of Normandy, which in old times was extensively used in this country. It is a fine-grained limestone, with few oolitic grains, and contains about 13 per cent. of silica.|| It has been employed, mostly for inside-work, in the construction of portions of the Temple Church, and of the cathedrals of Canterbury, Rochester, Winchester, and Salisbury; it was also used in the east facade of Buckingham Palace, and for internal work in the present Houses of Parliament.

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* Green, Geology of Banbury, p. 20.

† John Morton, Nat. Hist. Northants, 1705, pp. 108, 126, 484.

‡ Sharp, Quart. Journ. Geol. Soc., vol. xxvi. p. 378.

§ J. Bravender, in Hunt's Mineral Statistics for 1858, Part 2 (1860), p. 155.

|| See analysis in Mem. Geol. Surv., vol. ii., Part 2, p. 692.

## *Marble.*

Some of the Oolitic limestones have been polished for economic purposes; but their use has been very local.

The Campden Stone, a pisolitic limestone that occurs in the Inferior Oolite near Chipping Campden, has been used for the reredos of Brailes Church, and has been occasionally polished for mantelpieces.

In the Lincolnshire Limestone at Stamford, there are layers of buff and blue-hearted limestone, which under the names of Stamford Marble and Stamford Stone were formerly used for chimney-pieces, &c. (see p. 205). The Weldon Rag, a shell-limestone belonging to the same formation, is also polished for ornamental purposes (see p. 192).

Some of the Ammonites (*A. Parkinsoni*, *A. concavus*, &c.) and Nautili (*Nautilus clausus*, *N. polygonalis*, &c.) from the Inferior Oolite of Bridport and Bradford Abbas are cut and polished for sale.

The shelly and oolitic limestones of the Forest Marble were in old times polished for chimney-pieces, &c. in the Forest of Wychwood, but the stone is now rarely if ever used for the purpose in the district; and I failed to obtain any polished specimen.

The stone contains "galls" or irregular cavities filled with ochreous or clayey material, and on this account it is an uncertain rock: moreover the shelly fragments are apt to break away. The colour of the rock is often of a dull yellowish-grey and by no means of an ornamental character. Stone obtained at Bothenhampton, and also at Long Burton near Sherborne, in Dorset, is occasionally polished for local use: there are specimens in the Museum at Jermyn Street. The name Yeovil Marble was employed in 1818 by Buckland for the local beds of Forest Marble, but the term has been misapplied to the Liassic "Ammonite Marble," found at Marston Magna in the same neighbourhood. The Forest Marble at Bowden has in the early part of the present century been polished, under the name of Bowden Marble.

A shelly limestone, "Crackment Marble," was employed in Sherborne Abbey, and an example is preserved in the Museum of Practical Geology: this probably belongs to the Forest Marble.

Shelly limestone, obtained at Buckingham, has been used for ornamental purposes under the name of Buckingham Marble.* (See p. 379.)

Prof. Judd remarks that beds of hard blue shelly limestone, in the Great Oolite Series, were formerly quarried for ornamental purposes, and were known as "Alwalton (pron. Allerton) Marble." This material was employed in the Early English portions of Peterborough Cathedral, as a substitute for the celebrated Purbeck Marble, in the small clustered columns which characterize that style.† (See p. 415.)

The Stanwick Ragstone, a bluish-grey shelly limestone, resembling Forest Marble, that was quarried near Higham Ferrers, was formerly polished for ornamental purposes. This bed is probably on a similar horizon in the Great Oolite as a stone (mentioned by Sharp) at Oundle, and which is there worked into lintels, and sills of windows, &c.‡ (See p. 411.)

## *Road Metal.*

Various limestones and sandstones in the Oolitic Series have been employed for road-metal, but their use is becoming more and more restricted to the by-roads, owing to the introduction by rail of better materials. As a rule the shattered stone, rubble, and waste of the quarries are employed for the purpose.

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* Buckland, Ann. Phil., ser. 2, vol. i., 1821, p. 464.

† Geol. Rutland, p. 202; see also Sharp, Quart. Journ. Geol. Soc., vol. xxix, p. 278, and Porter, Geol. Peterborough, p. 96.

‡ Conybeare and Phillips, Geol. Eng. and Wales, p. 217; and Sharp, *op. cit.*, p. 281.

The Inferior Oolite in Dorsetshire, Somersetshire, and the Cotteswolds; the Fuller's Earth Rock of Dorsetshire; the Chipping Norton Limestone in Oxfordshire; the Lincolnshire Limestone; and the Great Oolite, are locally employed.

The "White bed" in the Northampton Sand of Harleston near Northampton, has been used for road-mending and for foot-paths.

Some of the harder beds in the white limestone of the Great Oolite (Dagham Stone) are used near Cirencester; also the Great Oolite Limestone in Northamptonshire and Lincolnshire.

Of the local material the Forest Marble is usually preferred: the hard shelly limestones being employed along the outcrop from Dorsetshire to Oxfordshire, and locally at Lillingston Lovell in Buckinghamshire. Belonging to the same division, the hard calcareous sandstones of Charterhouse Hinton, near Bath, are also employed.

The Cornbrash is also largely used for road-metal, material being obtained from most of the quarries.

Limestone is in places quarried for use as a flux in the Iron-furnaces; in smelting ores, which, containing a good deal of earthy impurity (silica and alumina), are not readily fusible.

The Lincolnshire Limestone of Glendon is thus employed; the Great Oolite of Bradford-on-Avon was formerly sent to the Westbury Ironworks; and the Great Oolite of Thrapston is locally used.

### *Stone-tiles or "Slates."*

The calcareous "slates" of the Jurassic system are strictly speaking flagstones or tilestones. The more important of them are fissile calcareous sandstones or sandy limestones, more or less oolitic and micaceous. Organic remains are sometimes abundantly distributed over the surfaces of the rock, and Dr. Sorby has remarked that "the fissility of the Stonesfield Slate is, in great measure, due to minute laminæ derived from *Ostrea* and Brachiopoda."* The rock splits according to the plane of deposition, hence the slates vary in thickness and are not uniform individually: but they are found serviceable for roofing-purposes.

Other stone-slates consist of thin layers of shelly and oolitic limestone that occur interstratified with shaly clays, as in the Forest Marble.

Stone tiles have been in use since Roman times, and they have been obtained from the Inferior Oolite, including the Northampton Sand and Collyweston Slate; as well as from the Great Oolite Series, including the Stonesfield Slate and Forest Marble.

Referring to the roofing-tiles obtained from the Forest Marble of Chavenage, near Tetbury, Lycett remraks that the weight of these flags is fully three times that of ordinary slate; "the tile, however, possesses much advantage in point of comfort compared with slate, as it is a much worse conductor of heat, the upper parts of houses covered with the stone tiles are much less exposed to the vicissitudes of the external temperature."†

#### *Northampton Sand.*

Thin fissile calcareous sandstones have yielded material that has been used for roofing-purposes, under the name of Duston Slates. (See p. 182.)

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* Quart. Journ. Geol. Soc., vol. xxxv. p. 83 (Proc.).

† Cotteswold Hills, p. 106.

*Collyweston Slates.*

These slates have been worked for upwards of 350 years at Collyweston and Easton near Stamford, Duddington, Medbourn, Kirby, and Dene Park, near Rockingham.

Prof. Judd has remarked that the Collyweston Slates have been dug over a considerable area, old pits being traceable from Wothorpe near Stamford to the western side of Collyweston, a distance of more than three miles. He has given the following full account of the method of working, &c., to which I have added a few notes. "The valuable fissile character of the beds is merely a local accident; and in some directions the bed of stone has been followed and found to become non-fissile and in consequence worthless for roofing purposes. There is only a single bed of stone (the lowest limestone of the series) which is used for making roofing-slates. This varies greatly in thickness, being often not more than 6 inches thick, but sometimes swelling out to 18 inches, and in rare cases to 3 feet; while, not unfrequently, the bed is altogether absent and its place represented by sand [or sandstone]. Rounded mammillated surfaces, like the "pot-lids" of Stonesfield, abound in these beds."

"The slates are worked either in open quarries or by drifts (locally called "fox-holes") carried for a great distance under ground, in which the men work by the light of candles. The upper beds of rock are removed by means of blasting, but the slate-rock itself cannot be thus worked, for though the blocks of slate-rock when so removed appear to be quite uninjured, yet, when weathered, they are found to be completely shivered and consequently rapidly fall into fragments. The slate-rock is therefore entirely quarried by means of wedges and picks, which, on account of the confined spaces in which they have to be used, are made single sided. The quarrying of the rock is facilitated by the very marked jointing of the beds, a set of master-joints traversing the rocks with a strike 40° W. of N. (magnetic), while another set of joints, less pronounced, intersect the beds nearly at right angles."

"During the spring of the year the water in the pits rises so rapidly that it is impossible to get the slates out. The slates are usually dug during about six or eight weeks in December and January. The blocks of stone are laid out on the grass, preferably in a horizontal position. It is necessary that the water of the quarry shall not evaporate before the blocks are frosted, and they are constantly kept watered, if necessary, until as late as March. The weather most favourable to the production of the slates is a rapid succession of sharp frosts and thaws. If the blocks are once allowed to become dry they lose their fissile qualities, and are said to be "stocked." Such blocks are broken up for road-metal, for which they afford a very good material. The limestone beds above the slate-rock are burnt for lime."

After the blocks are split, the slates are stacked on edge in circular piles or heaps. Subsequently they are shaped, and again stacked on edge according to size.

"The slates are cleaved at any time after they are frosted. Three kinds of tools are used by the Collyweston slaters. The 'cliving hammer,' a heavy hammer with broad chisel-edge for splitting up the frosted blocks. The 'batting hammer' or 'dressing-hammer,' a lighter tool for trimming the surfaces of the slates and chipping them to the required form and size. The 'bill and helve,' the former consisting of an old file sharpened and inserted into the latter in a very primitive manner. This tool is used for making the holes in the slates for the passage of the wooden pegs, by means of which the slates are fastened to the rafters of the roof. These holes are made by resting the slate on the batting hammer and cutting the hole with the bill."

"The slates are sold by the 'thousand,' which is a stack usually containing about 700 slates of various sizes, the larger ones being usually placed on the outside of the stack. The slates when sold on the spot fetch from 23*s*. to 45*s*. per thousand. Many of the Collyweston slaters except contracts for slating, and go to various parts of England for the purpose of executing their contracts."

"The land at Collyweston is generally held by slaters by copyhold, the slaters paying 6*s*. 8*d*. per 'pit' to the lord of the manor (a 'pit' is 16 square yards) with an extra charge of 1*s*. 6*d*. per pit to the measurer. A few workings are rented of the lord of the manor, the slaters paying 30*s*. per pit with an additional 1*s*. 6*d*. for the measurer. These payments are made every year at the annual 'slaters' feast' held in January."

"The manner in which the slates are placed on the roof is as follows:—The largest are laid on nearest the wall plate, and the size of the slates is made gradually to diminish in approaching the ridge. The ridge itself is covered by tiles of a yellowish white tint, made at Whittlesea, and harmonising well in colour with the slates themselves. The larger slates are, in the ordinary way, fixed to the rafters of the roof by means of wooden pegs driven through a hole in the upper part of each slate. But roofs are often covered with small slates which are fixed by mortar."

"On the ground floor of the Museum of Practical Geology at Jermyn Street, London, specimens of the 'slates' made at Collyweston, and of the various tools employed by the workmen are exhibited."*

The slates of Collyweston are worked with more or less vigour at the present time (1889), although in many new houses built in the neighbourhood of the quarries, and at Stamford, brick and Welsh slates or red clay-tiles are employed, in place of the freestone and Collyweston slate.

In colour the rock is a buff and blue-hearted stone, so that some of the slates are blue, others yellow, and many are parti-coloured. The pale coloured slates when put up, are said to darken on exposure. The slates are usually cemented as well as pegged on to the roofs, hence they do not fall away if cracked. The blocks that are raised from the open quarries and galleries are of irregular shape.

The slate-pits at Kirby are now almost entirely abandoned, and they are only occasionally worked near Dene Lodge.

The slabs known as Whittering Pendle, were obtained from beds of the age of the Collyweston Slate; but the material was used mainly for paving. (See p. 195.)

### *Inferior Oolite.*

Thick and heavy "slates" have been obtained from the Inferior Oolite in the northern portion of the Cotteswold Hills near Snowshill, Condicote, and Lower Swell.† The principal workings were at a spot known as Hyatt's Pits (see p. 140).

### *Stonesfield Slates.*

At the base of the Great Oolite there are thin bands of sandy and oolitic limestone that have been long worked for "slates." The principal quarries and mines are at Stonesfield, near Woodstock, in Oxfordshire; but beds on, or about, the same horizon have been worked in many parts of Gloucestershire at Througham near Bisley, Nettlecomb near Birdlip, Miserden, Rendcomb, Chedworth, Pewsdown west of Hasleton, Sevenhampton, Kyneton, Eyeford, Naunton, Hampton Field, Ablington near Bibury, &c. Occasionally in Somersetshire, as on Lansdown, north of Bath, fissile limestones at the base of the Great Oolite have been employed for roofing-purposes.

At Stonesfield the slate is now mostly obtained by means of shafts, there being one mine worked on the level. The shafts are from 20 to 70 feet deep.

The beds worked, are from 2 ft. 6 in. to 3 feet thick, and they yield brown sandy slates, hard grey and slightly oolitic slates, and blue and grey or brown oolitic slates. In size they are obtained 1 ft. 6 in. square and less. The blocks of fissile oolite, fine-grained calcareous sandstone with courses of oolite, and calcareous sandstone, when dug out, must be kept damp, and then exposed to a winter's frost. After that they can be split up evenly at any subsequent time. If they have been allowed to

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* Geol. Rutland, 1875, pp. 182, 183.

† Hull, Geol. Cheltenham, p. 39.

dry before the frost comes, so that the "sap" is dried up, no frost will move the layers, and the rock is then "bound." Formerly it was the custom to begin digging the stone about Michaelmas time or before; now the men commence about the end of October, and work till the end of January. When dug and raised, the stone is banked up and covered with earth, to keep the moisture in, until a frost comes. In dry seasons, the quarrymen even water the blocks to keep them moist. It requires three or four good frosts to act upon the stone; hence a mild winter is disastrous to these toilers. Sometimes the stone is put out and then covered up, again and again, until a sufficiently long frost is experienced. As a rule a week's frost is needed.

The stone can be split up any time after it has been "frosted," and of course it can be dressed any time after it has been split. Splitting is usually commenced about the middle of February.

The only qualities in the slates are the first and second, the former being thinner and the latter thicker, though both may be composed of the same kind of stone. The more oolitic slates as a rule are a trifle thicker than the sandy slates, but no particular difference in quality and durability is recognized.

It is thought that the slates do not last well in cities. Mr. Barrett informed me that Exeter College Chapel at Oxford was roofed with Stonesfield slates, but after 20 years had elapsed the stone had become so "bent, broken, and perished," that it had to be removed.

Deal pegs are used for fixing the slates. Oak pegs were formerly used, but it is found that deal forms a better head when driven in than oak, and not so many slates are broken. Copper and iron nails have also been used. In the district around Stonesfield, not only the houses but the porches are roofed with the stone-tiles.

At Througham Field, where Stonesfield Slate is worked, the blocks are improved by lying out all the winter—the second or third frost breaks them up. Slabs 6 feet square or even more are obtained. They furnish material for cow-sheds, mangers, bordering for gardens, and pitching for stables. There is not more than 18 inches of good tile-stone at this locality, but it occurs at slightly different horizons. I obtained some examples of the tools used at Througham Field, and these are placed in the Museum of Practical Geology.

### *Forest Marble.*

Over a large area of Wiltshire, Gloucestershire, and Oxfordshire, where the Forest Marble is exposed, the beds have been worked for "slates." Some of the pits are known as "Slate and plank quarries"; and the material is obtained at or near the surface.

These stone-tiles do not require to be split: hence no exposure to frost is necessary. They occur as thin flags or leaves of limestone (or occasionally calcareous sandstone), often ranged in oblique bands separated by horizontal layers of clay and shale. All that is necessary is to dress them to the required shape. They resist frost and are considered to be more durable than the Stonesfield Slate, but they are heavier and coarser.*

They have been obtained at Atford, in Wiltshire; and many of the old buildings at Bradford-on-Avon are roofed with them. J. Woodward mentions "Plates, or thin Strata of Stone, used as Slate for covering the Houses at and about *Bath*. These were taken out of the Slate-Quarries, in *Charlwood*, in the Parish of *Box*, about five miles from *Bath*, and about a Mile from *London* Road." This slate, as in other cases, often has "a thin Crust of reddish Spar on its Surface."† (See p. 355.)

Other localities for these Forest Marble Slates, are Beverstone and Charlton near Tetbury, Avening, Chavenage, Cirencester, Aldsworth,‡ Burford, between Holwell and Shilton, Poulton, and Fairford. (See p. 369.)

In addition to slates, large slabs $5 \times 3$ or 4 feet are obtained from the Forest Marble for piggeries, garden-edgings, planks, pitching, &c.

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* See Lycett, Quart. Journ. Geol. Soc., vol. iv. p. 185.
† J. Woodward, Nat. Hist. Foss. Eng., Tome II., 1729, p. 101.
‡ See Hull, Geol. Cheltenham, p. 70.

### *Sandstones and Sands.*

Irregular concretions of sandstone, and huge spheroidal masses known as "Doggers" or Sand Burrs" are found in the sandy strata. These are cemented by carbonate of lime; and they occur in the Midford Sand, in the Northampton Sand, and in the Hinton Sands that belong to the Forest Marble.

Sometimes irregular flaggy beds are formed, and these pass into spheroidal or mammillated masses that retain the marks of bedding or false-bedding, while sometimes the upper or under layers when split off resemble "Pot-lids" (lids of saucepans).

Such "Pot-lids" are found in the fissile calcareous sandstones of the Collyweston Slate, Stonesfield Slate, and Forest Marble: and they sometimes may be split up into slabs suitable for roofing-purposes. Examples occur in the Forest Marble near Cirencester, where they have been used to support Bee-hives.

Of the smaller concretions, examples have been noted in the sands belonging to the Inferior Oolite, at Snowshill on the Cotteswold Hills, and associated with the Collyweston Slate near Stamford. Prof. Judd mentions that "On the surfaces of the flags obtained from these pits, which can sometimes be raised of considerable size and are used for rustic-bridges, peculiarly shaped concretionary masses are sometimes found. One concretion of this character, found on a slab near King's Cliffe, has attracted much attention in the neighbourhood from the popular belief that it is a 'fossil carrot.' Small recesses or caverns are sometimes formed by the weathering out of the sands from beneath the hard rock; one of these is known in the district as 'the Robber's Cave.'"*

The layers and concretions of calcareous sandstone, called "sand-bats" or "sand-burrs," are occasionally employed for building-purposes. They have been thus used at Yeovil junction and Burton Bradstock, as they furnish larger blocks than the Oolite above.

Dr. Wright has stated that the Cotteswold sands are "well adapted for foundry purposes, as they receive sharp impressions of bodies pressed upon them"; in most cases however they would be too calcareous for the purpose, though such sands, as noted by Dr. Percy, may be useful for the bottoms of copper-furnaces.

Above the Horsepools, west of Painswick, the beds comprise very fine mealy sand that has been used for polishing purposes† (cleaning silver, &c.). In some places as at Snowshill, the sand is used for making mortar.

Soft fissile sandy beds, belonging to the Stonesfield Series at Througham Field, Bisley, were formerly used for sharpening shears for shearing cloth. The material was obtained every winter for the purpose.

Sands, belonging to the Northampton Sand, as at Kingsthorpe (p. 184), have been used for mortar-making; ‡ also for foundry and scouring purposes; while indurated beds have been employed for lining ovens, &c. The white siliceous sands, such as occur at Epwell, and other localities in Oxfordshire, might be serviceable for glass-making, but I am not aware that they have been employed for the purpose. They have been used at Wansford, Apethorpe, Blatherwycke, and Burghley Park.§

### *Lime and Cement.*

The Limestones of the Inferior Oolite and Great Oolite Series are burnt in many places for lime; and different beds of limestone yield material adapted more especially for agricultural or

* Geol. Rutland, &c., p. 170.
† Lycett, Cotteswold Hills, p. 17.
‡ Judd, Geol. Rutland, p. 179.
§ Hunt, Mineral Statistics, Part 2, 1858, p. 375.

building-purposes, and occasionally for the preparation of hydraulic lime.

The more compact limestones, as a rule, yield the stronger limes, for they are more argillaceous than the closely-packed oolites. These latter yield lime more suited for manure.

References have already been made, in the accounts of the subdivisions of the Lower Oolites, to the uses of particular beds.

The Inferior Oolite is burnt for lime in many parts of the west of England, and the material is used on the land and for the preparation of mortar. Stronger limes are made from the more compact varieties of the Lincolnshire Limestone.

Calcareous beds associated with the Northampton Sand, have been burnt for lime: but in some cases, as near Hazlebeech, in Northamptonshire, it was found that great part of the rock ran into slag.* In old times a "whitish gritty earth," obtained in the same district, at the Clipston stone-pit, was used to make a kind of plaster, "mixed only with Water, without previous burning."† Earth at Oundle has been similarly used (see p. 411).

West of Ancaster railway-station some of the lower beds of the Lincolnshire Limestone are burnt for lime, that is used in the preparation of plaster, and also for agricultural purposes.

At the "Tunnel Works," Kirton Lindsey, "Blue Lias Lime" as it is called, is manufactured by Messrs. H. Parry and Co. from the lower beds of the Lincolnshire Limestone. These beds are bluish argillaceous and oolitic limestones (Kirton Beds), that in general aspect much resemble Lower Lias. They yield a natural hydraulic lime. The several layers are mixed so as to yield a lime of uniform strength. The "Lump Lime" is used for mortar in stone and brick-work, and it is found to stand the weather well. The "Ground Lime" is used more generally for wet work, in Reservoirs and for concrete in Foundations. The Lime is also used for plaster. (See analyses in Memoir on the Lias, pp. 291, 292.)

The Fuller's Earth Rock has been burnt for lime near Sherborne in Dorsetshire: this is an argillaceous limestone that yields a good building-lime. The Fuller's Earth Clay has in old times been used for marling land in Gloucestershire.

The Great Oolite is burnt for lime at Bradford-on-Avon, Bath, and onwards to Minchinhampton.

The white limestones in the upper part of the series are burnt for lime, and as the layers vary in quality, it is usual to mix them: these beds, alternating as they do with marls, are capable of yielding a strong lime.

An excellent white lime is made at Whitehill Wood near Ashford Bridge; and the beds are worked to the south of Great Rollright, at Tadmarton, Kirtlington, Aynho, and many other places.

In Buckinghamshire, Bedfordshire, and Northamptonshire the Great Oolite Limestone is burnt for lime, both for agricultural and building-purposes—the lime, in some cases when made from the compact marly limestones, being too strong for application on the land. There are lime-kilns at Duston, Kingsthorpe, Maidford, Newport Pagnell, Bedford, Stevington, and many other places.

The Forest Marble is in many places burnt for lime; but this is not as a rule so good for mortar as that obtained from the Cornbrash. It is mostly used on the land. There are lime-kilns at Bothenhampton and other places in Dorsetshire, at Scale Hill, near Bruton, near Wanstrow, and Frome.

The Cornbrash has been extensively burnt for lime: in many parts of Dorsetshire, between Weymouth and Bradford Abbas; indeed its outcrop is marked by old lime-kilns, as at Upton Noble and onwards to Bicester. The thin band has also been utilized at Stevington, near Bedford; and the beds are burnt for lime at Peterborough.

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* Aveline, Geol. parts of Northamptonshire and Warwickshire, p. 10.

† J. Woodward, Nat. Hist. Foss. Eng., Part 1, 1729, p. 7.

### *Fuller's Earth.*

In the Fuller's Earth or Fullonian formation, between the Inferior and Great Oolite of Somersetshire and Gloucestershire there occur beds of economic Fuller's Earth.

This Fuller's Earth, as previously described, is a greenish or bluish-grey calcareous clay that weathers brown; and so far as can be judged, it occurs sometimes in impersistent and lenticular masses that attain in places a thickness of 5 or 6 feet; in other cases it gradually passes into ordinary marl or clay. Its soapy character is considered to be due to the presence of a small proportion of magnesia; while its detersive property is attributed to the alumina.

From the fact of its imbibing oily matter, it has been extensively used for cleansing woollen cloths, in the factories that in the West of England were at one time in a more flourishing state than they now are.*

Fuller's Earth is largely used for washing rugs and blankets, carpet and worsted yarns, woollen and worsted cloths and silk, and other fabrics in the course of manufacture and dyeing. In addition to this use there is a great demand for the Earth (in a highly powdered and refined condition) for chemical and toilet purposes, and also in various states for refining oils, tallows, fats, and wax, and for numerous other purposes.

The value of Fuller's Earth has long been known, it is the *Creta Cimolia* of Pliny, and little more than a hundred years ago a special Act of Parliament was passed to prohibit the exportation.†

Near Bath, Blue and Yellow Fuller's Earth is obtained; the latter being the weathered portion obtained near the surface. The Yellow Earth is sometimes esteemed the better, but according to notes made by H. W. Bristow, the Blue Earth "is frequently of as good a quality as the yellow for particular purposes, as in fulling coarse cloths." The "veins" vary in thickness from about 18 inches to 5 feet. "If good, a vein 18 inches in thickness could be worked with profit, but not if of less thickness. Sometimes the vein stops suddenly, at others it gradually thins out."

There appears to be a gradation from Earth having fulling properties, to ordinary clays, through varieties known as Bastard Fuller's Earth. Hence the earth obtained at different places is subject to variation in quality as well as in thickness.

The Fuller's Earth is worked in some cases, as at Combe Hay, by means of shafts sunk to depths of from 20 to 30 feet, when the earth is procured from levels driven in different directions. The shafts are sunk at or near the base of the Great Oolite. In other cases, as at Midford and Wellow, the earth is obtained from levels driven into the outcrop of the Fuller's Earth: the galleries being from 4 to 6 feet in height. (See pp. 240–243.)

Through the kindness of Mr. H. N. Garrett (Proprietor of the Midford Fuller's Earth Works), I was enabled to see the various processes undergone by the Fuller's Earth clay, to render it marketable. The raw earth is dug in the hill-side not far from the Cross Keys Inn, and it is conveyed in trucks down a steep incline to a "Pug-mill." There it is ground up, with about three times its own bulk of water. The compound, known as "slurry," is then turned into a series of little tanks or "catch-pits," and while the fine Fuller's Earth remains in a state of suspension, the coarser particles sink to the bottom. The liquid, which still contains "impurities," is then allowed to run into a long earthenware drain, laid

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* The Fuller's Earth has been much used in the Cloth Mills at Frome, Bradford-on-Avon, Stroud, and other places. There are old Fulling Mills, west of Broughton, near Banbury, and west of Blakesley, near Towcester.

† Jameson, Mineralogy, ed. 3., vol ii. pp. 302, 303; and J. Woodward, Nat. Hist. Foss. Eng., 1729, Part 1, p. 5.

underground, which conveys it to the works, more than half-a-mile distant. Here the turbid water flows into a long shallow trough called a "maggie," and the coarser particles still contained in it then subside, and are caught by a series of little wooden steps placed across the bottom of the trough. By these processes the Fuller's Earth is purified. It is now run into large tanks, and the suspended earth is allowed to settle down gradually; while the surface-water that is drained off, is said to be very soft, pure, and drinkable. These operations take about thirty days; and now a damp clayey mass remains in the tank. This material is removed to a large drying shed, where by means of a furnace and hot-air flues, it is thoroughly dried, and is then ready for market.*

In Gloucestershire an occasional bed of impure Fuller's Earth has been noticed: I found a layer in the railway-cutting near Notgrove (see p. 246). Fuller's Earth has also been noticed at Stonesfield (p. 312).

Near Bath the Fuller's Earth has been worked at Combe Hay (C.), English Combe (E.), Odd Down (O.), South Stoke (S.), Midford (M.), Lyncombe (L.), Widcombe (W.), and Wellow (We.). The following statistics are taken from the Reports of the Government Inspector of Mines:—

*Statistics of the Production of Fuller's Earth.*

| Years. | Localities. | Tons. | Value at the Mine or Open Work. |
|---|---|---|---|
| | | | £ |
| 1882 - - - | C., E., S., L. and W. - | 1,002 | 500 |
| 1883 - - - | C., S., L. and W., M. - | 1,752 | 876 |
| 1884 - - - | C., E., L. and W., M. - | 1,865 | 933 |
| 1885 - - - | C., E., L. and W., M., S. | 2,244 | 1,132† |
| 1886 - - - | C., O., L. and W., M., S. | 3,156 | 1,603‡ |
| 1887 - - - | W., C., O., M., S., We. - | 4,944 | 2,472 |
| 1888 - - - | No separate returns. | | |
| 1889 - - - | W., C., M., S., We. - | 6,528 | 8,160§ |
| 1890 - - - | C , M., O., S., We. - | 6,605 | 9,900 |
| 1891 - - | C., M., O., S., We. - | 5,004 | 7,506 |
| 1892 - - - | C., M., O., S., We. - | 4,965 | 4,300 |

Prices have varied from 30*s*. to over 6*l*. per ton: but in recent years the value has been from 10*s*. to 2*l*. according as the earth is dressed or undressed.

* These notes are taken from an article printed in "Bladud," for March 16th, 1887; see also Proc. Geol. Assoc., vol. xiii. p. 126.
† Value of 120 tons of White Clay from Cheddar Hill included.
‡ Do. of 50 tons.
§ Includes White Clay (as above, no amount stated).

It may be remarked that Fuller's Earth has been found in other formations, especially in the Lower Greensand of Nutfield and Woburn: and in old times in Hampshire, a fact verified by Mr. T. W. Shore. Impure Fuller's Earth has been noted also in the Ludlow Beds of Ludlow, Buildwas, and Hales End, Malvern, and I have observed it near May Hill. Fuller's Earth has also been discovered at Rhiwlas, near Bala. Locally thin beds have been found in other formations.

The question of the origin of Fuller's Earth, is difficult of solution, and more experiments are needed in reference to its physical properties.

Dr. Percy has remarked that the fictile or plastic property of clay depends on the presence of the water of *combination*. All clays contain water of absorption or *hygroscopic* water, which may be expelled without lessening their plasticity. Clay heated to redness loses not only its hygroscopic water but also its water of combination: in this dehydrated state it cannot directly *combine* with water and regain its plasticity, though it may *absorb* water with avidity. Thus pounded brick may absorb water, but regains no plasticity.*

Messrs. S. W. Johnson and J. M. Blake† point out that "The plasticity of clay is a physical character, and appears to have a close connection with the fineness of the particles." It may be "related to the form of the plates of kaolinite, perhaps to their thickness, but this is a subject that requires further investigation. Our observations indicate that the impurer sedimentary clays are the most plastic * * The plasticity may be, therefore, in part due to the impurities;" but as remarked by Dr. Percy the plasticity must obviously be lessened by the presence of intermixed non-plastic matter, such as silica. Analyses by Messrs. Johnson and Blake show that clays identical in composition may differ notably in degree of plasticity.

Colonel C. W. Pasley mentions that he tried the Fuller's Earth of Reigate mixed with Chalk in the making of artificial cement, and it entirely failed. He inferred that plasticity was essential in the clay used for cement; and adds, "But on washing the Fuller's Earth repeatedly, in order to get rid of the small portion of salt, also said to form a part of that substance, we found that it became more plastic, and in this state it frequently succeeded in forming a water cement, but inferior to that of the plastic clays."‡

Mr. J. Hort Player, to whom I am indebted for analyses of Fuller's Earths, tells me that he has "come to the conclusion that the choice of the various varieties of Fuller's Earth, for fulling and detergent purposes, has been determined by their physical properties as distinguished from their chemical composition. In composition they vary at least as much amongst themselves, as they differ from clays unsuited to the purpose for which they are used. As a matter of fact, they do not absorb oil more readily nor to any greater extent than does dried London Clay; but then they fall to pieces more easily in water, they do not become plastic, and they are much more cleanly in appearance than London Clay. I expect too that from the crude earth, the marketable Fuller's Earth is readily prepared, and that whilst other argillaceous deposits might yield an equally serviceable detergent material, they would not be so easily dealt with." §

* Metallurgy: Refractory Materials, &c., ed. 2, 1875, p. 87.
† Amer. Journ. Sc., ser. 2, vol. xliii., 1867, pp. 357.
‡ Observations on Limes, Calcareous Cements, &c., 1838, p. 57.
§ Letter dated June 1st, 1891.

| Analyses of Fuller's Earth. | A. Midford Blue Earth. | B. Midford Yellow Earth. | C. Woburn Blue Earth. | D. Woburn Yellow Earth. | E. Nutfield. | F. Perth. |
|---|---|---|---|---|---|---|
| Silica - - - | 54·0 | 59·3 | 60·0 | 56·9 | 58·66 | 62·60 |
| Alumina - - | 18·6 | 20·8 | 15·2 | 15·7 | 17·33 | 17·65 |
| Ferric oxide - - | 3·9 | 4·2 | 7·8 | 9·5 | 7·21 | — |
| Ferrous oxide - - | ·8 | — | 1·7 | ·1 | — | 1·84 |
| Lime - - - | 7·0 | 2·5 | 2·7 | 2·1 | 3·17 | 2·55 |
| Magnesia - - | 2·3 | 1·9 | 3·3 | 2·7 | 3·26 | 2·05 |
| Soda - - - | ·7 | ·6 | ·2 | ·3 | 1·63 | 1·27 |
| Potash - - - | 1·8 | 1·7 | ·6 | ·7 | | 0·50 |
| Carbonic acid - - | 3·4 | ·3 | — | — | — | — |
| Loss by ignition (besides carbonic acid) - | 7·2 | 8·6 | 8·4 | 11·9 | 8·74 | 10·95 |
| | 99·7 | 99·9 | 99·9 | 99·9 | 100·00 | 99·41 |

The analyses A, B, C, D, were kindly made for the Geological Survey by Mr. Player in 1890. The Earths were dried at 100° C.

In the Blue Midford Earth the iron is to a large extent peroxidized, in the yellow earth it is altogether so.

In the Woburn Earths there is no Carbonate of Lime, considerably more iron and less alumina than in the Midford Earths. Moreover the difference in colour between the Blue and Yellow Woburn Earths does not appear to be explained by their difference in composition.

The analysis E is one of the purified Fuller's Earths by Mr. Bernard Dyer, July, 1885.

The analysis F is by Mr. Charles Tookey (1863) of clay used for fulling cloth at Duncrab Keltie, near Perth. He observes that the presence of free Alkali in this clay, was shown by moistening it on red test-paper, when the paper was rendered *distinctly blue.*

Other analyses of Fuller's Earths, from Nutfield, and from Vrongoch, Rhiwlas, have been published by Mr. P. Gerald Sanford.*

## *Brickearth, Potter's Clay, &c.*

In both Inferior Oolite Series and Great Oolite Series, clays are met with that are found serviceable for the manufacture of bricks, tiles, &c.; and locally there are clays that have proved valuable for terra-cotta ware, and as fire-clays.

Some of the clays contain a good deal of "Race" or "Rance," small concretions, often septarian, of carbonate of lime; these as

* Geol. Mag., 1889, p. 455; 1893, p. 160. See also J. Brierly, Proc. Hampshire Field Club, 1891, p. 84.

well as shells and small bits of limestone are apt to "blow" the bricks.

Clays belonging to the Lower Estuarine Series have been dug for brick-making at Water Newton, Cottingham, Dene, and other places. At Stamford Baron, west of Burghley Park, clay has been used for the manufacture of terra-cotta. (See p. 203.)

Fuller's Earth clay has been used for brick-making and burnt for ballast, at Powerstock. Bricks and tiles are made from it near Broadwindsor, Crewkerne, and Bradford Abbas. At High Cross Hill, between Haselbury and East Chinnock, red and mottled or yellowish tiles, drain-pipes and bricks are manufactured. Bricks, drain-pipes, and coarse earthenware were formerly made from the Fuller's Earth clay, west of Newbury, north-east of Mells: but the bricks, as I was informed by the Rev. George Horner, were of inferior quality. The clay is usually calcareous and often contains racy nodules. In Gloucestershire it is generally too calcareous to be of service for brickmaking.

In the Upper Estuarine Series, as remarked by Prof. Judd, the clays are admirably adapted for brick-making, for which purpose they are dug at Stamford, Great Oakley, Water Newton, Wood Newton, between Stanion and Brigstock, and between Pilton and Luffenham. There are brickyards also at Buttocks Booth, south of Moulton, and north of Duston, near Northampton. In the lower part of the series at Little Bytham, clays are dug, from which are made bricks of singular hardness and durability ("clinker-bricks"). (See p. 418.) The Castor or Durobrivian Pottery, was made from Estuarine clays, worked in Roman times in Normangate Field, Castor, west of Peterborough.* (See p. 202.)

In reference to the Upper Estuarine Series, Prof. Judd states that "The clays contain just such a valuable admixture of siliceous matter in a finely divided state, as to adapt them for the manufacture, in some cases, of fire-bricks, and in others of tile-ware of peculiar hardness and soundness."

At Wakerley, "the white clays at the base of this formation, are dug rather extensively by the well-known makers of terra-cotta, Messrs. Blashfield of Stamford. It is an excellent fire-clay, and is said often not to contain more than 15 per cent. of alumina; it is, however, largely made up of finely divided quartz, with a considerable quantity of carbonate of lime, the latter sometimes in small oolitic grains, and at other times even occurring in the form of lumps of oolitic limestone, which are occasionally of considerable size. The muffle-tiles made of these Wakerley clays are said to withstand the severest heat for a longer time than the celebrated Stourbridge Clay. For pillars of terra-cotta, which are required to sustain a considerable weight, and at the same time to endure a considerable amount of heat (as, for instance, the columns employed in the construction of hospitals and other large buildings, which also serve as flues for conducting hot air), the Wakerley clays forms an excellent 'body.' For the finer classes of white and ornamental terra-cotta ware the Wakerley clays are of no use, as the roots and vegetable matters which abound in them (the masses being penetrated in every direction by the roots of trees) give the material made from them, when burnt, an unpleasant yellowish tint."

"The red ware at Stamford is usually made of a mixture of clays. These are as follows:—The weathered Upper Lias of the valley of the Welland, which is of a dull brown colour, and full of selenite formed by the decomposition of nodules of iron pyrites; the unweathered clays of the same formation, which are dug at greater depths at Stamford, and the similar Lias Clay from Manton tunnel; and, lastly, the lighter Oxford Clay from the London Road, Peterborough, which is of a more sandy texture, and is found to prevent the other materials with which it is mixed from shrinking and cracking. These several materials are well crushed and ground together, and for the finer moulded work a proportion of

* See E. T. Artis, The Durobrivæ; fol. Lond. 1828.

pounded felspar, kaolin, or other ingredients according to circumstances are added."*

Clays belonging to the Forest Marble have in some places been worked for brick-making, as at Siddington, near Cirencester, Badminton, Blackthorn near Bicester, &c.

The Great Oolite Clay is occasionally employed for brick-making, as noted by Prof. Judd, at Bedford Purlieus, and New England near Peterborough.

### *Lignite and Bituminous Shale.*

No beds of lignite and bituminous shale that have proved to be of economic value, are known to occur in the Lower Oolites of our district. Their presence has in some instances led to futile searches for coal.

The Upper Estuarine Beds at Aunby, Lincolnshire, contain bituminous layers with lignite and impure coal, as noted by Prof. Morris. In the Great Oolite Clay of Silk Willoughby, a thin band of lignite was proved in a well-boring. The Forest Marble frequently contains lignite. During the construction of the railway at Trowbridge specimens were used as fuel by the workmen. Occasionally the lignite approaches jet in character.

About the year 1835 an attempt to find coal was made by boring at Kingsthorpe, Northampton; and in reference to it Dr. Buckland is stated to have said, "You may fry me over the first shovel-full of coal that comes out of this pit."† The boring was carried through the Oolites and Lias 860 feet, and to a total depth of 967 feet.

Another useless trial for coal. is noted as having taken place in the Forest Marble near Cirencester,‡ probably on account of the lignite so often present in that formation; while a boring was commenced about 15 years ago in the same formation, at Luckington, east of Badminton, and this was not carried to a sufficient depth to prove the Palæozoic floor.

At Stratton Audley a boring in search of coal, was commenced in the Cornbrash, and carried to a depth of 243 feet, perhaps into the Middle Lias.§

In the Radstock district of Somerset, true Coal-measures are worked beneath the Inferior Oolite and Lias: in no other part of the country has coal yet been worked under a similar sequence of strata. At Dover, Coal-measures have been reached beneath Bathonian beds (p. 362); and they were proved beneath the Jurassic rocks at Burford (p. 304.).

### *Iron Ores.*

Iron-ore is extensively worked in the Inferior Oolite Series of Northamptonshire. It consists for the most part of Brown Hæmatite or Limonite, the hydrated peroxide of iron.

Prof. Judd, to whom we are most largely indebted for our knowledge of the strata, remarks that there is evidence that, at least as early as the period of the Roman occupation, the beds of brown ironstone were known and extensively worked. Thus in a wood near Oundle, heaps of broken ore, and large quantities of slag occur, associated with which have been found Roman coins and pottery. Again there is historical evidence that in mediæval times, the district of Rockingham Forest vied with that of the Weald of Sussex and Kent, as a great iron-producing district.

* Judd, Geol. Rutland, pp. 189, 201.

† J. L. Baker, Essay on the Farming of Northamptonshire, 1852, p. 22; Sharp, Quart. Journ. Geol. Soc., vol. xxvi. p. 364; Letters of J. B. Jukes, 1871, p. 468.

‡ J. Buckman, Geologist, vol. i. p. 186.

§ Green, Geol. Banbury, p. 23.

The Norman Castle of Rockingham is said to have been built for the protection of the iron-furnaces in Rockingham Forest; but, as the wood became less abundant, and the method of smelting iron with coal was introduced, this manufacture gradually forsook the district.*

It was not till the year 1851, that attention was again prominently drawn to the occurrence of workable ironstone in the Northampton Sand. Then Samuel Blackwell, of Dudley, sent specimens to the "Great Exhibition." Nine years later the production was estimated at 95,664 tons, valued at 23,416*l.*: and since that date the production has largely increased, while towns like Kettering and Wellingborough have expanded under the influence of the trade.

*Northamptonshire Iron-ore.*

The ironstone of the Northampton Sand has been worked at intervals along the outcrop of the formation from near Steeple Aston, Culworth, and Towcester to Thrapston, Kettering, and Rockingham Forest, also near Stamford, at Cottesmore, Waltham-on-the-Wolds, and again at Coleby, Waddington, Canwick, and Greetwell near Lincoln.

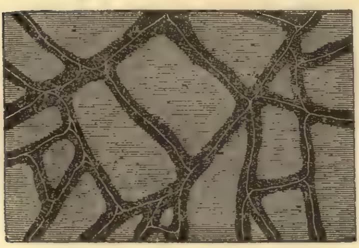
In some places the ironstone is as much as 25 or 30 feet in thickness, but rarely can the beds be profitably worked to a thickness of more than 10 or 12 feet.

The ore, which is of a yellow or brown colour, yields from 25 to 40, and rarely as much as 55 per cent., of metallic iron.† It is more or less oolitic and gritty, containing grains of quartz, &c.

The lower layers of the rock are frequently of a greenish colour or they comprise green cores: these are usually regarded as unprofitable beds. They comprise the less weathered beds which contain not only carbonate of iron, but some silicate and phosphate of iron. The green colour is attributed to silicate of alumina and iron; and it may be remarked that analyses of the brown ore, show sometimes more phosphoric acid than the green ore, so that the colouring matter is not due to phosphate of iron.

FIG. 137.

*Structure of the Ironstone in the Northampton Sand.* (G. Maw.)



The brown iron-ore is of a cellular character with coatings of darker brown ore of richer quality, so that in places, as observed by Mr. Maw, "the entire mass of the stratum is made up of the box-like structures." He remarks that the hard septa that separate the individual cuboidal masses, are generally distinct one from another.‡ (See Fig. 137.)

Prof. Judd observes that this cellular structure is in some way connected with the jointing and bedding of the rock; and this view is strikingly confirmed by the fact that in some places, as at Easton, the direction of one set of the sides of the cells is found to exactly coincide with that of the "master-joints" of the superincumbent limestones.

Reference has previously been made to the fossils that occur in the ironstone (p. 166); and Prof. Judd remarks that the dark brown, glazed

* Judd, Geol. Rutland, pp. 55, 99, 110.

† Sharp, Quart. Journ. Geol. Soc., vol. xxvi. p. 376; J. D. Kendall, Trans. N. of Eng. Inst. of Mining Engineers, vol. xxxv. p. 135; and Hudleston, Proc. Geol. Assoc., vol. iv. p. 129, and vol. xi. p. 123.

‡ Quart. Journ. Geol. Soc., vol. xxiv. p. 395.

surfaces of the casts of the fossils in the weathered ironstone-rock may be accounted for, when we consider the tendency which there will be for water to accumulate in the spaces left empty by the solution and removal of the substance of the shells.

He further remarks that "When the Northamptonshire iron-ore is met with at the bottom of very deep wells, it is, throughout its whole thickness, composed of the hard, compact, grey carbonate, and this is also the case when it is dug beneath beds of Boulder Clay * * * From a comparison of the various analyses it appears that the grey carbonated mineral in the Northamptonshire iron-ore, consists of from 60 to 80 per cent. of carbonate of iron, with from 10 to 25 per cent. of insoluble matter, principally sand and oolitic siliceous concretions; besides these, and existing in smaller proportions, we find the carbonates of the alkaline earths and alkalies, water, carbonaceous matter, sulphur, and phosphorus."*

Analyses show that the yellow ore contains less, and the brown ore more, iron than the grey ore, whence both were derived; the iron in the weathered beds being as it were more concentrated. Thus the weathering or oxidizing process causes a diminution in the bulk of the rock, to the extent of about 12 per cent.; and consequently we find the open joints and increased porosity of the rock along the outcrop.† Excepting in one place near Greetwell, the iron-ore is obtained in open quarry-workings by the removal of the 'overburden'; but it was formerly wrought in underground workings at Cogenhoe and Woodford."‡

Prof. Judd states that in connexion with the grey, carbonated condition of the rock, "there are two circumstances of great interest and importance which require remark:—firstly, that the fossils in it retain their shelly substance, though the carbonate of lime is frequently replaced by carbonate of iron, and are not, as in the weathered rock, merely double casts; and secondly, that there occur in the beds [pieces] of lignite, vertical plant remains and fragments of carbonaceous matter."

He remarks that "these ironstones vary greatly in thickness, occasionally constituting the whole of the formation, frequently forming the greater part of it, not seldom being reduced to very small proportions, and sometimes being wholly wanting"; moreover the "ironstone when present always constitutes the *lowest* portion of the formation and lies immediately upon the Lias Clay."

A careful examination of each tract of ground, accompanied in most cases by trial-holes and also by analyses of the rock, would be necessary to prove the occurrence of workable beds of ironstone in regions adjacent to those where the ore is now worked.

Observations on the probable source or origin of the iron-ores will be left for the volume dealing with the Middle and Upper Oolites.

The following statements concerning the structure of the rocks are by Prof. Judd:—

"Notwithstanding their great differences in *lithological* and *chemical* characters, the different varieties of the Northamptonshire iron-ore—namely, the gray carbonate, the light coloured earthy peroxide, and the hard, dark coloured laminæ,—the *microscopical* features presented by them all are essentially the same. In all, a slight examination is sufficient to show that there is a considerable amount of variation in the intimate structure of the rock from different localities, and of the different beds in the same locality; in some cases the whole mass is seen to be made up of oolitic grains, varying in diameter from $\frac{1}{50}$ to $\frac{1}{100}$ of an inch; in others the structure of the rock is seen to be throughout compact or granular; and in other cases again, and these are by far the most frequent, we find a compact matrix, with oolitic grains disseminated through it in greater or less abundance. In nearly all cases there occur, scattered throughout the mass, rounded or sub-angular grains of quartz."

"When fragments, not pulverized, of the Northamptonshire iron-ore are digested in hydrochloric acid, a white mass is left nearly equalling *in*

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* Geol. Rutland, pp. 116, 127, 133, 136.

† Kendall, *op. cit.*, pp. 147, &c.; and Iron Ores of Great Britain, 1893.

‡ See R. Meade, Coal and Iron Industries, 1882, p. 546.

*bulk* the material acted upon. The insoluble residue under the microscope is seen to be made up of several constituents. The principal of these are rounded or sub-angular grains of pure white quartz, varying in diameter from $\frac{1}{100}$ to $\frac{1}{500}$ of an inch, and rounded, siliceous, oolitic concretions of a pale-green colour, from $\frac{1}{50}$ to $\frac{1}{100}$ of an inch in diameter. Besides these, we frequently find in some specimens a number of scales of mica, and in others black fragments, which disappear on the ignition of the mass, and are thereby recognised as carbonaceous matter. The quantity of the latter substance is in some samples very considerable. Some of these facts concerning this insoluble portion of the Northamptonshire ore have already been noticed by Dr. Percy."* (See p. 12.)

The following are the localities and names of the present or former workings in the Northampton Ironstone† :—

*Oxfordshire.*

+ Steeple Aston. (See p. 163.)

*Leicestershire.*

+ Neville Holt, Medbourn, N.E. of Market Harborough.
+ Waltham-on-the-Wolds.

*Lincolnshire.*

Greetwell, Lincoln.
+ Canwick, Coleby, and Waddington.

*Northamptonshire.*

Great Addington, S.W. of Thrapston.
Barton Seagrave, S.E. of Kettering.
Blisworth.
Brixworth, N. of Northampton.
Burton Latimer, S.E. of Kettering.
Chelveston, near Higham Ferrers.
+ Cogenhoe, E. of Northampton.
Corby, N. of Kettering.
Cranford St. John, E. of Kettering.
Cransley, S.W. of Kettering.
+ Culworth, N. of Brackley.
Desborough, N. of Rothwell.
Ditchford, Irthlingborough, E. of Wellingborough.
Duston, W. of Northampton.
Easton Hill and Burleigh Park, S. of Stamford.
Easton Neston and Shuttlehanger, N.E. of Towcester.
Finedon (Thingdon), N.E. of Wellingborough.
Gayton, N.W. of Blisworth.
Glendon, N. of Kettering.
Gretton, N. of Kettering.
Harrowden Road, Great Harrowden, N. of Wellingborough.
Heyford, W. of Nether Heyford, near Weedon Beck.
Hunsbury Hill, S.W. of Northampton.
Irchester.
Irthlingborough, Wellingborough.
Islip and Slipton, W. of Thrapston.
Lamport, S.W. of Rothwell.
Loddington, W. of Kettering.
Newbridge, Twywell, W. of Thrapston.
Ringstead, S. of Thrapston.
Rushton, N. of Kettering.
Spratton, N. of Northampton.
+ Stowe-nine-Churches, W. of Northampton.
Warren Hill, N.W. of Kettering.
Wellingborough.
Wollaston, S. of Wellingborough.
Woodford, W. of Thrapston.

*Rutlandshire.*

Cottesmore, N.E. of Oakham.
+ Manton, S. of Oakham.

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* Judd, Geol. Rutland, pp. 116, 121; See also Dick, Iron-ores of Great Britain, Part I., p. 95.

† The localities marked +, and perhaps some others, are no longer worked for ironstone.

STATISTICS relating to the PRODUCTION of the NORTHAMPTONSHIRE IRON ORE.

| Year. | No. of Furnaces. | Average in Blast. | Tons. | Average Per-centage of Iron. | Value of the Ore at the Mine or Open Work. |
|---|---|---|---|---|---|
| | | | | | £ |
| 1882 - - | 26 | 15 | 1,333,085 | 38·00 | 172,772 |
| 1883 - - | 26 | 18 | 1,290,087 | 38·00 | 172,615 |
| 1884 - | 28 | $15\frac{1}{4}$ | 1,279,783 | 36·00 | 162,620 |
| 1885 - - | 30 | $15\frac{1}{2}$ | 1,160,000 | 36·00 | 147,500 |
| 1886 - - | 31 | $13\frac{1}{4}$ | 996,440 | 36·00 | 124,555 |
| 1887 - - | 28 | 15 | 935,473 | 36·00 | 116,934 |
| 1888 - - | 30 | 14 | 1,066,746 | 36·00 | 120,009 |
| 1889 - - | 24 | $16\frac{3}{4}$ | 1,257,080 | 36·00 | 157,135 |
| 1890 - | 24 | $14\frac{3}{4}$ | 1,278,381 | 36·00 | 143,818 |
| 1891 - - | 23 | $11\frac{1}{4}$ | 1,043,541 | 36·00 | 117,398 |
| 1892 - - | 26 | 10 | 1,120,365 | 36·00 | 116,704 |

Although a number of Blast-furnaces have in recent years been erected in the district, yet originally (as remarked by Prof. Judd) by far the larger portion of the ironstone of the Northampton Sand was sent away to the coal-bearing districts; the highly siliceous ore of the oolites being found better adapted for smelting in admixture with the calcareo-argillaceous ores of the coal-measures than alone, or with the simple admixture of a limestone-flux.*

The Ironstone raised near Lincoln is conveyed to Frodingham and mixed with the Lower Lias ore at that locality. "This admixture of the two ores in smelting produces excellent results, for the superabundance of lime in the one acts as a flux to the siliceous element of the other."† The Greetwell ore yields 33 or 34 per cent. of metallic iron.

ANALYSES of the NORTHAMPTONSHIRE IRON ORES.‡

| —— | A. | B. | C. | D. | E. |
|---|---|---|---|---|---|
| Peroxide of iron - - - | 52·20 | — | 38·04 | 57·43 | 6·14 |
| Protoxide of iron - - | trace. | 33·29 | 10·54 | — | 40·93 |
| Bisulphide of iron - - | 0·03 | 0·13 | 0·13 | — | — |

* Geol. Rutland, p. 112. See also statistics quoted by Prof. Judd, p. 111.

† Jukes-Browne, Geol. S.W. Lincolnshire, p. 47; and H. B. Woodward, Memoir on the Lias of England and Wales, p. 307.

‡ Percy's Metallurgy; Iron and Steel, 1864, pp. 208, &c.; J. D. Kendall, Trans. N. of Eng. Inst. of Mining Engineers, vol. xxxv. p. 146; G. Maw, Quart. Journ. Geol. Soc., vol. xxiv. pp. 395–397; Judd, Geology of Rutland, &c., pp. 122, &c.; and Ussher, Geology of Lincoln, p. 37.

ANALYSES, &c.—*continued.*

| — | A. | B. | C. | D. | E. |
|---|---|---|---|---|---|
| Protoxide of manganese - - | 0·51 | 1·11 | 0·69 | 8·26 (with Alumina) | 0·16 |
| Alumina - - - - | 7·13 | 4·62 | 12·35 | | 8·08 |
| Lime - - - - | 7·13 | 0·50 | trace. | 0·56 | 3·47 |
| Magnesia - - - | 0·57 | 7·96 | 4·13 | 0·50 | 2·67* |
| Carbonic acid - - | 4·92 | 24·79 | 0·16 | 0·66 | 22·32 |
| Phosphoric acid - - - | 1·26 | 0·22 | 0·26 | 2·24 | 1·99 |
| Sulphuric acid - - - | — | trace. | trace. | 0·03 | trace. |
| Soluble silica - - | 1·60 | 1·99 | 1·96 | — | — |
| Insoluble residue (silica, &c.) - | 13·55 | 24·09 | 24·61 | 13·10 | 9·04 |
| Water - - - - | 11·37 | 0·54 | 6·92 | 15·74 (with Organic matter) | 4·92 |
| Organic matter - - - | — | 0·08 | 0·19 | | — |
| | 100·27 | 99·32 | 99·98 | 99·12 | 99·72 |
| Metallic iron - - - | 37·00 | 28·28 | 34·83 | 40·20 | — |

A. Wellingborough Iron-ore. Analysis by Mr. John Spiller.
B. Northamptonshire Iron-ore. Inner unweathered portion. Analysis by Mr. Allan B. Dick.
C. Northamptonshire Iron-ore. Outer weathered portion. Analysis by Mr. Dick.
D. Cottesmore Iron-ore. Analysis published by Mr. J. D. Kendall. The average yield of iron is 32 or 33 per cent.
E. Northamptonshire Iron-ore. Green patches in rock. Analysis by David Forbes.
An analysis of ore from Hardingstone, was also made by Mr. Dick.

### *Miscellaneous Iron-ores.*

I have elsewhere referred (p. 60) to the occurrence of ferruginous beds in the Inferior Oolite of Dorsetshire. They occur in the lower portion or "iron-shot beds." An analysis of brown rock from Symondsbury, near Bridport, has kindly been made by Mr. Dick, with the following result:—

| | |
|---|---|
| Peroxide of iron - - - - - - | 35·00 |
| Protoxide of manganese - - - - - | Trace. |
| Lime - - - - - - - | 19·00 |
| Magnesia - - - - - - - | 1·44 |
| Silica - - - - - - - | 10·60 |
| Alumina - - - - - - - | 9·50 |
| Potash - - - - - - - | Not determined. |
| Soda - - - - - - - | |
| Carbonic acid - - - - - - | 18·70 |
| Sulphuric acid - - - - - - | Trace. |
| Phosphoric acid - - - - - - | Trace. |
| Water (combined) - - - - - - | 4·00 |
| | 98·24 |

* Includes Potash, 0·19, and Soda, 0·27.

It may be reckoned that the rock would yield from 24 to 26 per cent. of metallic iron. The presence of so much carbonate of lime would not necessarily be injurious, as the material would act as a flux in the smelting process.

Prof. Judd mentions that at several localities in ancient times, and at Bottlebridge, near Overton Longville, in recent years, small quantities of ironstone have been obtained for smelting from the Great Oolite Clay: but the quantity of material that had to be removed and the small amount of ironstone led to the abandonment of the workings. He also states that in the neighbourhood of Lower Benefield near Oundle, and probably elsewhere, the ironstone-nodules at the base of the Upper Estuarine Series have in former times been dug for the purpose of smelting.* (See p. 416.)

*Ochre.*

Red ochre has been obtained from the Northampton Beds at Clipston, south-west of Market Harborough, and yellow ochre from the strata at Finedon (or Thingdon) near Wellingborough.

*Miscellaneous Minerals.*

The occurrence of detrital mineral fragments has been referred to on p. 10. Mention has also been made of the common occurrence of Selenite, Calcite, Aragonite, and Pyrites.

The following Minerals have also been found among the Lower Oolitic rocks :—

A silicate of alumina, allied to Allophane, was found by Dr. Charles Berrell in crevices of the Northampton Sand, at Northampton. This is probably due to the decomposition of mineral substances from the overlying strata. (W. D. Herman, Quart. Journ. Geol. Soc., vol. xxvii. p. 234.)

An aluminous mineral was recorded by Prof. Morris (as Websterite?) from a ferruginous band at the base of the Upper Estuarine Series at Corby in Lincolnshire (Quart. Journ. Geol. Soc., vol. ix. p. 328). Prof. Hull also notes the occurrence of a similar mineral in the Oolite at Lyneham Barrow, near Sarsden (Geol. Woodstock, p. 16).

*Barytes* (*Heavy Spar*).—Sulphate of Baryta, Inferior Oolite, Whatley, Somerset.

*Beekite.*—Annulated Chalcedony, Inferior Oolite (freestone), Dundry.

*Celestine.*—Sulphate of Strontian, "Oolite," Collier's Lane, near Bath. (T. M. Hall, Mineralogists' Directory, 1868, p. 67.)

*Calamine.*—Carbonate of Zinc, Inferior Oolite, near Nunney: no doubt detrital.

*Galena.*—Inferior Oolite, near Frome: detrital. (Lonsdale, Phil. Mag., ser. 2, vol. ii., p. 234; Rev. O. Fisher, Geologist, vol. vi. p. 29; C. Moore, Quart. Journ. Geol. Soc., vol. xxiii. p. 488.)

* Geol. Rutland, &c., pp. 194, 215; Porter, Geol. Peterborough, p. 92.

*Manganese Ore.*—Great Oolite, Bath. (R. Warrington, Jun., Quart. Journ. Chem. Soc., Ser. 2, vol. iii. p. 206.)

*Melanterite* (*Copperas*).—Hydrated sulphate of Iron, Fuller's Earth, Widcombe, near Bath. (T. M. Hall, *op. cit.*)

*Vanadium.*—Found by Riley in pig-iron of Northamptonshire. (J. A. Phillips, Elements of Metallurgy, Ed. 3, by H. Bauerman, 1891, p. 130.)

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# CHAPTER XVII.

## SPRINGS AND WATER SUPPLY.

The Oolitic limestones, by reason of their porous and jointed character, constitute important water-bearing strata; and the same may be said of the principal sandy strata. The water mostly is hard; but this hardness is of the "temporary kind," due to carbonate of lime. The water in the deeper wells is as a rule excellent for drinking-purposes: that in the shallow wells is often liable to pollution.*

Along the outcrop of these strata, springs of a more or less copious character mark their junction with underlying clays; and the presence of these springs and of the porous strata that readily furnished a supply of water from shallow wells, determined the positions of the majority of villages and towns. Nevertheless in many instances in the area to the north-east of Aylesbury, Bicester, and Banbury, the coverings of Drift clay and gravel have modified the sources of water from shallow wells.

In considering the water-bearing character of the Lower Oolites, it must be borne in mind that each great division varies in thickness and in lithological character, so that the yield of water in one locality, apart from other circumstances, is no guide to the water-bearing qualities of the same formation at a distance. Such remarks apply especially to the Great Oolite, when we compare the mass of limestones that occur near Bath and onwards to Minchinhampton and Tetbury, with the series of limestones, in which so many layers of marl become intercalated, in the Eastern Cotteswolds, in Oxfordshire, and in the country to the north-east.

Owing to the general easterly dip of the strata a good deal of the rain-water that falls on the escarpments flows away underground through the porous strata along the dip-slopes; while other portions escape here and there in the form of springs along the slopes of the escarpment, and thus enter distinct areas of drainage. This is the case with the "cliff" of Lincolnshire (see Fig. 60, p. 215), and with the Cotteswolds; although in the latter district the numerous faults, certain undulations in the strata, and the deep ramifying valleys, modify to some extent the ultimate direction of the waters and the outflow of springs.

### *Disappearance of streams—Swallet-holes.*

Springs or streams traversing the outcrop of successive strata, sometimes lose much in bulk when passing over porous rocks:

* See Sixth Report of the Rivers Pollution Commission, Domestic Water Supply, 1874, pp. 23, 81,97, 120.

the lost water may reappear in lower portions of the valley, or it may be lost to the drainage area.

In Wiltshire and Gloucestershire, in the Avon above Malmesbury, waters pass underground into absorbent beds of Great Oolite, and are imprisoned between the Fuller's Earth and Forest Marble clays; while again the Churn above Cirencester, loses about 2,000 gallons a minute.* These waters if pent up will naturally overflow, or they may uprise again in the lower courses of the river through fissures where the strata are faulted.

At West Cranmore in Somerset a pond is supplied by a spring that issues from the Inferior Oolite in a field south-east of the school: the spring is never known to fail, but in dry seasons the pond disappears and the water sinks underground.

Referring to the Midland Counties, Prof. Judd remarks that occasionally the whole volume of a stream thus disappears, and for a portion of its course, sometimes several miles in length, it becomes subterranean. Among the interesting examples of the disappearance of rivers, which thus leave their beds for a considerable distance quite dry, may be mentioned the River Witham, near Thistleton; the River Glen, between Little Bytham and Careby; and the brook which flows by the village of Benefield.† At Benefield, three miles west of Oundle, there are stated to be nine circular holes called the "Swallows," through which the land-floods flow and disappear.

Mr A. C. G. Cameron informs me that, in Bedfordshire, the Riseley brook flows down from the clay-lands about Knotting, until at Riseley it meets with the Oolite limestones cropping out beneath the Oxford Clay. The water then sinks into the Cornbrash, until arrested by the clays below, which throw it out again. In dry seasons the bed of the stream is often dry for a considerable distance.

Natural swallet or swallow-holes occur in some places, as along the scarp of Inferior Oolite and Midford Sand, that extends from Chelynch to Ingsdons Hill, north of Doulting. My attention was drawn in 1891, by Sir R. H. Paget, to one that had been recently developed on the south of Bodden, where a hole about 20 feet deep had suddenly been formed in the Liassic strata beneath the Oolitic scarp.

Prof. Judd observes that "the lines of junction of rocks like the Upper Estuarine Clays and the Lincolnshire Oolite are often marked by a series of these natural drains; in many cases a slight depression of the surface-level indicating their position. In some cases the volume of water carried off by means of a swallow-hole is very great, and the roar produced by it in descending is heard at some distance. In the case of the smaller swallow-holes, they may often be detected by placing the ear near the surface of the ground. These swallow-holes are well known to fox-hunters, for the long sinuous fissures worn by the constant passage of water

* J. H. Taunton, Proc. Cotteswold Club, vol. vi. pp. 304, &c.
† Geol. Rutland, p. 268.

through the jointed limestone rocks constitute retreats for foxes from which it is almost impossible to effect their dislodgment."

The drainage of the land is facilitated in places, and more especially in Northamptonshire and Lincolnshire by artificial swallow-holes or "dumb-wells" — excavations dug through clayey beds, such as the Upper Estuarine Series, into the Lincolnshire Limestone. Moreover, as Prof. Judd remarks, "when a tract of Boulder Clay overlapping limestone is drained, it is only necessary to carry the pipes to the outcrop of a thick bed of limestone and to allow them to terminate in an excavation in the latter."*

The distribution of the towns and villages is influenced in a marked way by the geological formations that appear at the surface, as on these depended the sources of water-supply which directly influenced the original settlements.

Hence we find most of the centres of population placed on permeable strata, on the slopes of escarpments or at the foot of hills, where shallow wells or natural springs afforded a ready supply of drinking water; while the larger portions of the wide vales are thinly populated, excepting where the clays are covered by gravel. Some of the earlier settlements were fixed according to the old fords, where the outcrop of strata caused shallows, and afforded ready means of crossing streams, as at Midford and Freshford, Telisford, Iford, and Bradford-on-Avon.†

### *Inferior Oolite Series.*

The Inferior Oolite and Midford Sand are essentially water-bearing strata, the water being supported by the Upper Lias clay, which throws out many springs along the escarpment and from isolated hills.

In South Dorsetshire the Inferior Oolite is thin, but the underlying Midford (or Bridport) Sands are capable of yielding plentiful supplies of water. I have no records, however, of well-borings in this area.

At Castleton, Sherborne, a well-boring that was carried into the Inferior Oolite (see p. 80), found water at a depth of 30 feet, and from 150 to 270 gallons per minute was the yield; this inflow was however probably connected with the river. H. W. Bristow noted that springs were again met with at depths of 123 to 143 feet, and the water then overflowed at the surface, the yield amounting to 170 gallons per minute.

At Yeovil, water is obtained from a boring, carried into the Midford (or Yeovil) Sands, on the hill to the south-east of the town.

A strong spring, known as the Seven Sisters, is thrown out of the Sands, near Corton Denham, north of Sherborne; another important spring issues from similar beds, north of Creech Hill, Milton Clevedon.

Wells sunk 30 or 40 feet in the Inferior Oolite between West Cranmore, Chelynch, and Doulting are apt to be low in dry weather, for the area is to some extent drained by springs; and at West Cranmore the Inferior Oolite probably rests directly on the Carboniferous Limestone (see p. 90).

There are many springs on Brent Knoll, which have been utilized for the local water-supply. Some of the springs issue from the Midford Sand, others from the Middle Lias.‡

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* Geol. Rutland, p. 267.

† Rev. J. Townsend, Character of Moses, pp. 189, 190.

‡ See "Notes of my Life," by Archdeacon G. A. Denison, Ed. 2. 1878, pp. 405–7.

North of the Mendips the Inferior Oolite furnishes limited supplies of water; and on some of the spurs, as at Tunley near Preston, the wells are deficient in times of drought. Over portions of this area the Midford Sands are very thin, and in some instances they are absent.

Near Bath, springs from the Midford Sands have yielded large supplies, amounting to as much as 430,000 gallons a day, but the water was very hard. Up to the year 1835 the city was supplied, first of all at an early date, by springs from Beechen Cliff and Beacon Hill, and later on (1769) from others thrown out by the Fuller's Earth on Bathwick Down (Sham Castle Springs).* In 1868 the Bathwick springs were found to yield 57,000 gallons per day. Of late years Bath has been supplied from other sources in the valleys near Charlcombe, Swainswick, and St. Catherines. Numerous springs are given out from the Great Oolite, and also from the Inferior Oolite and Midford Sands, but most of them are naturally affected in seasons of drought. It has been estimated however that an average supply of 800,000 gallons a day might be relied upon.† (See p. 507.) On the Castle estate at Midford there are springs from the Great Oolite, that yield 130,000 to 200,000 gallons daily.

The springs that issue from the top of the Upper Lias at Chalford and Brimscombe near Stroud, are copious, and their yield has been estimated at about 9,000,000 gallons a day. They come from the Inferior Oolite Series, chiefly on the south side of the valley and furnish some of the sources of the Frome. The highest spring, known as the "Bubbling Spring," is about 270 feet above sea-level. Their temperature is about 6° higher than that of the springs thrown out by the Fuller's Earth. At the works of the Stroud Water Company the yield is upwards of 1,000,000 gallons per day.‡

Here and there we find more or less noteworthy springs, as the Syreford spring near Cheltenham, which yields about 5 million gallons daily, and forms one of the head waters of the Coln; the Seven Wells, north of Cubberley; and springs at Cowley, which form the head of the river Churn. There are good springs near Leckhampton and elsewhere in the neighbourhood, which contribute to the supply of Cheltenham.

Borings have been made in the Inferior Oolite near Birdlip, to the east of Witcombe (see p. 123); and water was obtained in the basement-beds of the Inferior Oolite and underlying Midford (or Cotteswold) Sands.

On the eastern Cotteswolds there are good springs in places. The Windrush in its course above Bourton-on-the-Water, receives supplies amounting to about 25 or 30 millions of gallons daily from the Inferior Oolite and underlying Sands. These include the "Roaring Wells" of Eyeford,; a spring at Donnington Mill, north-west of Stow-on-the-Wold; springs higher up at Pope's Hole, west of Seizincote; Seven Wells, east of Snowshill; and springs again at Taddington, above Cutsdean. The Sherborne stream in its higher course, above Farmington, is very feeble in dry weather, much water being conveyed underground in the Sands on top of the Upper Lias clay. (See also account of boring near Fairford, p. 510.)

North of Stow-on-the-Wold, at Worcester Lodge, Batsford Park, a well was sunk 160 feet in the rock-beds of the Inferior Oolite, etc.

At Tite End, at the north of Chipping Norton, a copious spring is thrown out at the base of the Inferior Oolite, above the Upper Lias Clay.§

The Northampton Sand and the Lincolnshire Limestone hold good supplies of water, supported by the Upper Lias. Many springs are given

* All these springs are said to be polluted. Report, Domestic Water Supply, pp. 127, 128, 309.

† I am indebted to Mr. W. Topley for great part of the above information. See also Geol. East Somerset, &c., pp. 181, &c; and Winwood. Proc. Bath Nat. Hist. Club., vol. vii. p. 337.

‡ Report, Domestic Water Supply, p. 400; J. H. Taunton, Proc. Cotteswold Club, vol. ix. p. 52; Etheridge, *Ibid.*, vol. xi. p. 49.

§ Hudleston, Proc. Geol. Assoc., vol. v. p. 383

out at the junction; and the water is usually softer than that obtained from the Great Oolite.

The older wells of Northampton, St. John's well, and Becket's well, at one time of much repute, obtained their water from the Northampton Beds.* On the village green at Kingsthorpe there is a copious spring called the King's Well, which (according to Morton) has never been known either to fail or freeze. Water is obtained from a well in the Northampton Beds at Duston (p. 402.).

At the Kettering waterworks, south-west of Weekley church, water was obtained in the Northampton Beds at depths of 21 to 28 feet, from two shafts and galleries: the yield amounting to 480 gallons a minute.† South-east of Kingscliffe there is a spring called the Seven Wells.

A spring at Wothorpe, south-west of Stamford, is used for the supply of that town: it yields about 100,000 gallons per day and issues at the base of the Northampton Sand.

At Braceborough, the Lincolnshire Limestone yields an abundant supply of water. The river, above the Spa, is said to be studded with springs for a distance of about 2 miles. A well sunk to a depth of 28 feet through the Upper Estuarine Clays, yielded water at the rate of 420 gallons a minute, and this rose to 15 feet above the surface. At Wilsthorpe three borings were made to depths of 60 to 65 feet, and the total yield was 2,166,246 gallons per day.

At Well-head, near Bourn, in Lincolnshire, there are natural springs, which when gauged in 1874, yielded 4,600,000 million gallons per day.

At Bourn a well, sunk in 1856, to a depth of 92 feet yielded 567,000 gallons a day. In 1893 Messrs. Isler and Co. tapped springs at depths of 78 to 120 feet in the Lincolnshire Limestone, and these yielded 2,592,000 gallons a day, the water rising above ground. In other places in South Lincolnshire, good supplies have been obtained from the Lincolnshire Limestone, the water rising from 2 to 20 feet above the surface: as at Cawthorpe (depth 110 feet), Morton (93), Dunsby (105–112), Pointon (87), Billingborough (87–95), Horbling (87), and Sleaford (120). At Rippingdale (130 feet), and Swaton (200), the water did not rise above the surface; while at Graby (150), and Hanthorpe (168), no water was obtained. At Folkingham a well sunk through the Lincolnshire Limestone to a depth of 300 feet, obtained a "variable" amount of water.‡ No doubt the undulations in the rocks modify the underground flow of water.

Since the above records were published, I have obtained other accounts of wells in the district, from Messrs. T. Tilley and Sons. Thus in a boring at Sleaford, at a depth of 156 feet (in the Lincolnshire Limestone) a spring was struck, which rushed out of the bore-hole 3 feet above the surface, at the rate of 12,000 gallons per hour (see p. 426). In another boring, at Cross Key's Yard, Sleaford, water was obtained at a depth of 81 feet. Wells made at Osbournby (150 feet), Ruskington (120), and Aswarby (131), obtain their water from the Lincolnshire Limestone, and it rises above the surface during part of the year (see p. 426). A well at Ruskington Fen obtained water at a depth of 200 feet.

A well at Swaton, carried to a depth of 260 feet, gets water in the same formation; and I am informed by Mr. Jesse Clare that it flows above the surface all the year round, and is distributed by gravitation to the village. Another well-boring made by Messrs. Tilley and Sons, in 1892, at Heckington, was not so successful: water was found in the Lincolnshire Limestone at a depth of 400 feet, and it overflowed at the rate of about 6 gallons a minute. The water however contained about 127 grains per gallon of saline matter, chiefly chloride of sodium.

At Wilsford, near Sleaford, the Norcliff spring issues from the Lincolnshire Limestone; and at Horbling, east of Folkingham, there is a spring of some note. A spring at Stoke Rochford, near Colsterworth, south of Grantham, issuing from the Lincolnshire Limestone, is said to yield a very abundant supply of water.

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* Sharp, Quart. Journ. Geol. Soc., vol. xxvi. p. 368.

† De Rance, Rep. Brit. Assoc. for 1878, p. 36.

‡ J. Addy, Proc. Inst. C.E., vol. lxxiv. pp. 148, 151; J. Pilbrow, *Ibid.*, vol. lxxv. p. 245; J. C. Gill, *Ibid.*, vol. ci. p. 221; and Engineering, vol. lvi. p. 649.

Over the plain of Lincolnshire Limestone, east of Navenby, Waddington, and Bracebridge, there is a large area of the formation uncovered by Drift. Where the upper beds occur at Blankney and Metheringham, "very powerful springs occur," according to Mr. De Rance, and he remarks that "the line of permanent saturation occurs more than a mile west of the overhanging lip of impermeable rocks," at Great Spring Head, to the S.W. of Dunston. The wells that supply the district appear to be shallow. Estimating the thickness of the Lincolnshire Limestone at 65 feet, Mr. De Rance considers that about 26 feet of this is permanently saturated with water, and that a pumping station by the railway, south of Dunston Station, might be expected to produce, in dry years, the daily quantity of 700,000 gallons of water.* (See Fig. 60, p. 215.)

Lincoln is supplied from springs and rainfall collected from a gathering-ground of about 2,000 acres; and 700,000 gallons can be supplied daily.

At Sudbrook Holme, a well sunk through the Kellaways Beds and Great Oolite Series to the Lincolnshire Limestone, to a depth of 106 feet, yielded 7,000 gallons a day.†

Mr. De Rance states that a boring 106 feet deep, on the west side of Dunholme, was carried into the Lincolnshire Limestone, and water rose 5 feet above the surface, the yield being 20,000 gallons per day.

At Welton there are strong springs, one being marked on the map as the "Old Man's Head Spring." These springs, as stated by Mr. De Rance, show marked fluctuations according to the rainfall, proving the rapid circulation of water through fissures in the Lincolnshire Limestone. Thus the amount of water, as gauged by Mr. Teague, has varied from 105,000 gallons to 2,800,000 gallons (after heavy rainfall).‡

The danger arising from inattention to the drainage and the consequent pollution of well-waters, was shown some years ago at Winterton.§

*Great Oolite Series.*

On the Fuller's Earth clays there are comparatively few villages, though in Dorsetshire where the Upper Greensand rests on these beds, springs are thrown out and we find a number of small villages. More suitable situations were found on the Fuller's Earth Rock, as at Maperton, Purse Caundle, and Thornford; and water was formerly obtained from this formation in the lower part of Frome.

The Fuller's Earth is not always of an impervious character. Lycett remarks in reference to the Cotteswold area that "The experience of well-sinking fully illustrates the same fact, for it sometimes happens that after passing through the Great Oolite, when the clay is reached, the *pound* as it is termed by the operatives, destined to retain the water is permeable, rendering further sinking necessary until a more compact bed is attained, and it has occasionally been necessary to penetrate the marls 30 or 40 feet ere this has been accomplished."‖ In illustration of this, the following section of a well at Prior Park, Bath, recorded by De la Beche, may be quoted, as it "shows the water retained by clay beneath the great oolite limestone"¶ :—

| | | Ft. |
|---|---|---|
| Great Oolite. | Loose Rock | 20 |
| | Oolite | 20 |
| | Hard freestone | 20 |
| Fuller's Earth. | Clay | 40 |
| | Water | 100 |

* Proc. Yorksh. Geol. and Polyt. Soc., vol. xii. pp. 29–31.

† Geology of Lincoln, p. 196.

‡ Proc. Yorksh. Geol. and Polyt. Soc., vol. xii. p. 32.

§ See Report, Domestic Water Supply, p. 179.

‖ The Cotteswold Hills, p. 88. See also Witchell, Geol. Stroud, p. 70.

¶ Report on the state of Bristol, Bath, Frome, &c. (Health of Towns Commission), 1845, pp. 37, 49.

The Upper Estuarine Beds comprise sands that in places yield a small amount of water: but as a rule it would not be good in quality. Thus at Potter Hanworth Station water was said to be found at a depth of 49 feet in hard sand at the base of this series.* It is however likely that water from the underlying Lincolnshire Limestone was mingled with it.

The Great Oolite from Bath to Cirencester and Northleach is a good water-bearing formation: the water being held up by the Fuller's Earth clay and the overflow being thrown out in numerous springs. Thus many of the villages are built on the scarps or along the valleys. Near Bath, wells have been carried to depths (in feet) at Combe Down (80), Claverton Down (100), Winsley (110), Lansdown (100), East of Kings Down (110); and through the Forest Marble and Great Oolite at Wormwood House, near Atford (240), and at Upper Westwood, near Bradford-on-Avon (about 150 feet)†.

The Seven Springs at Charmy Down, together with those on Holts Down, north of Bath, are said to yield 116,000 gallons a day. (See p. 504.)

The Forest Marble is not calculated to yield any large amount of water, as the layers of limestone are usually interbedded with clays. In many localities from Dorsetshire to Wiltshire (see p. 355) supplies sufficient for a mansion or for several cottages have been obtained. There are fewer villages along its outcrop than along that of the Cornbrash.

Frome was formerly supplied from numerous springs and wells in the Forest Marble, but the waters were said to contain sulphate as well as carbonate of lime. Good supplies of fresh water have been obtained in certain localities in North Wilts, as at Malmesbury and Chippenham. At Malmesbury springs of an artesian character rise in the Abbey meadows from the Forest-marble.‡

At Chippenham, at Mr. Brotherhood's well, near the new church, the Cornbrash and Forest-marble were penetrated, and a good supply of water was obtained. The section was as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Cornbrash | Brash | 9 | 6 |
| Forest-marble | Hard Clay | 4 | 10 |
| | Blue Clay | 43 | 7 |
| | Rock | 5 | 0 |
| | Blue Clay | 3 | 0 |
| Great Oolite | Rock (blue oolitic limestone) | 33 | 9 |
| | | 99 | 8 |

Water gushed in from the south side of the well at the rate of 8,000 gallons an hour.§

Another record in the same town, was that of the Chippenham New Well (1874), the details of which were furnished by W. Bryan Wood, as follows:—

| | | Ft. | In. |
|---|---|---|---|
| | Sandy loam, and gravel (1 ft.) | 18 | 0 |
| | Cornbrash | 1 | 0 |
| Forest Marble and Great Oolite. | Hard blue rock, full of shells (a great quantity of water came in, probably from the river) | 4 | 0 |
| | Clay with thin layers of stone | 38 | 0 |
| | Hard rock, full of fissures (about 30,000 gallons of water per day) | 5 | 0 |
| | Hard stone (pounded by the borer) | 51 | 0 |
| | Stone (yielding 150,000 gallons a day) | 21 | 0 |
| | | 138 | 0 |

The water was pronounced to be very good by Dr. Voelcker.

* De Rance, Proc. Yorksh. Geol. and Polyt. Soc., vol. xii. p. 33.

† Geol. E. Somerset, &c., p. 181; Townsend, Character of Moses, &c., 1813, p. 128; H. H. Winwood, Proc. Geol. Assoc., vol. xiii., p. 134.

‡ J. H. Taunton, Proc. Cotteswold Club, vol. vi. p. 301.

§ From notes furnished by W. Bryan Wood, of Chippenham, to H. W. Bristow.

A spring known as Arthur's Well, by the road-side north-east of Ivy House, Chippenham, yielded 180 gallons an hour, and another spring known as Monkton spring by the river side east of the mill, yielded 900 gallons an hour.

The well-sinking at the Great Western railway-works at Swindon, encountered an abundant supply of very saline water at the base of the Forest Marble. (See p. 515.)

At Tetbury the Worwell and Magdalen Mead Springs issue at the junction of Forest Marble and Great Oolite north and north-east of the town. They uprise in the valley, where the Forest Marble has been denuded. Wells in the town sunk through the Forest Marble into the Great Oolite, have yielded limited supplies of water at depths of from 70 to 125 feet. That at Mr. Witchell's Brewery, in Church Street, 105 feet deep, yielded about 2,000 gallons a day at a depth of 97 feet, but the supply at times became exhausted. A bore-hole at Mr. Cook's Brewery, 125 feet deep, has yielded at the rate of 20,000 gallons a day.

The deep valleys that border the spur on which the town stands, tend to drain the water from the Great Oolite. During wet seasons, the valley near the Folly contains a copious brook, but during great part of the year the water is conveyed away underground, and this portion of the valley is dry. Where the water is sealed up beneath the Forest Marble, copious supplies of water have been obtained, as at Weston Birt, about 3 miles south-west of Tetbury.

A boring made at Blind Lane, on the north side of Tetbury, by Mr. T. Holloway, of Chippenham, (1892) proved the following strata, which I note from specimens kindly forwarded by him. The lithological descriptions must be considered as general, for single samples in some cases represented the strata 70 or 80 feet thick. The details are as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Forest Marble. | Oolitic shelly limestones | 8 | 0 |
| Great Oolite 160 feet. | Pale marly oolitic limestone | 20 | 0 |
| | Buff oolite | 14 | 0 |
| | Gritty marl | 0 | 6 |
| | Oolitic shelly limestones | 7 | 6 |
| | Oolite | 84 | 0 |
| | Grey earthy oolitic limestone | 13 | 0 |
| | Grey limestones | 21 | 0 |
| Fuller's Earth 84 feet. | Grey marl | 8 | 0 |
| | Grey limestone with *Ostrea* | 1 | 0 |
| | Hard grey marly bed | 75 | 0 |
| Inferior Oolite. | Hard grey limestones | 48 | 0 |
| | | 300 | 0 |

Water was tapped in a fissure at 147 feet, and it rose 28 feet (to 119 feet from the surface) and there stood: but the quantity was insufficient. At 300 feet (after the boring had been stopped for a time) pumping was again resorted to, and 2,964 gallons per hour were obtained. The pumping was continued for a fortnight without lowering the level of the water, which remained at 119 feet from the surface. The boring had been tubed to a depth of 250 feet, and with perforated tubes from 250 to 270 feet. The water then obtained was derived from the Inferior Oolite.

Near Stroud the yield of water from the Great Oolite is not nearly so great as that from the Inferior Oolite; it being estimated that the springs near Chalford yield about 500,000 gallons a day. (See p. 504.) There are also springs at Cherington, in the Nailsworth valley.

The Cerney or Boxwell spring rises (with a temperature of 52°) from the Great Oolite at South Cerney: the waters dive underground in a higher part of the valley and issue from a fault where the Forest Marble and Great Oolite on the north, are brought against the Oxford Clay on the south. The yield here has been estimated at 24 million gallons a day by

J. H. Taunton.* The Bitnell spring at Ewen, near Kemble, yields about one million gallons daily.

The Thames Head, near Trewsbury Castle, south-west of Cirencester, is a spring that issues from the Great Oolite: it is a bourne that varies in its outlet according to the level of saturation in the rocks. In the same neighbourhood there is a spring called the "Winterwell," described by John Bravender as intermittent, as "it only discharges at certain seasons when there is a large body of water descending the plane of the stratification of the Fuller's Earth, when it rises higher in the bed of the Oolite than the surface it discharges, but whenever the water falls below that point the spring ceases to flow." Bravender also states that at the pumping-station south of Thames Head bridge, there is a well "64 feet deep, and for months together the engine throws up more than 3,000,000 gallons into the summit level of the Thames and Severn canal every day."† He mentioned that in March 1864, when pumping had been going on for two years, with cessations of only a few hours at a time, there were 26 feet of water in the wells, and the engine was making no impression on it. Subsequently in a very dry season, he found there were 9 feet of water in the well, and the engine was producing no effect on the level, although the country was dry and there was scarcely any water in any of the rivers or brooks. He considered that the water held up by the Fuller's Earth in the neighbourhood of Thames Head would not reach the surface in summer time. Prof. Allen Harker has stated that the Thames rose in Trewsbury Mead before the Canal Company put in their pumping-machine; now it rises half a mile or more lower down its course.

A well-boring at Tarlton, to the north-west, was carried to a depth of 100 feet (in 1893) without finding water.

At the Trewsbury new well, 54 feet deep, the water (as stated by Prof. Harker) varies with the seasons.

In the area between Cirencester, Fairford, and Northleach, there are several important springs, which issue from the Great Oolite, and these were gauged by Bravender. The Seven Springs, west of Northleach, yield about half-a-million gallons daily. Other springs occur at Rendcomb, Winson ($1\frac{1}{2}$ million gallons daily), Ablington (2 million gallons), Bibury (12 million gallons), and Ampney Crucis (12 million gallons).‡

Shallow wells at Cirencester carried into the Great Oolite have yielded water at depths of 20 to 65 feet: that at the market-place (about 20 feet deep) has, according to Bravender, never been known to be entirely dry. A well at the Bacon Factory, 89 feet deep, yields about 20,000 gallons a day from the Great Oolite, as stated by Prof. Harker.

The strata at Cirencester are however faulted in places, and consequently some wells have been sunk from 80 to nearly 180 feet before reaching a sufficient supply of water in the Great Oolite. A boring for Earl Bathurst, at the Barton, was carried to a depth of 148 feet: the water rose above the surface at the rate of 18 gallons per minute. A boring for the Cirencester Water Works Company, at Lewis Lane, described by Prof. Harker, showed the following section:—

| | Ft. | In. |
|---|---|---|
| Made ground | 7 | 0 |
| Valley gravel | 12 | 0 |
| Kellaways sand and clay | 26 | 4 |
| Cornbrash | 13 | 8 |
| Forest Marble | 65 | 9 |
| Great Oolite | 52 | 9 |
| | 177 | 6 |

At a depth of 130 feet water was obtained at the rate of about 40,000 gallons per day of 10 hours; the boring was continued for the purpose of getting an increased supply.

* Proc. Cotteswold Club, vol. ix. p. 70.

† Report, Domestic Water Supply, p. 468.

‡ Report, Domestic Water Supply, pp. 298, 467.

At the Farm of the Royal Agricultural College, a well was sunk 140 feet deep through Great Oolite into Fuller's Earth. Another well at Further Barton was about 120 feet deep, and has never been dry.*

At Hatherop Castle near Fairford, a boring was made by the Aqueous Works and Diamond Rock-boring Company, to a depth of 114 feet, and the water then rose 4 feet above the surface of the ground. The section was as follows:—

| | | Ft. | In. |
|---|---|---|---|
| Valley Gravel. | Light loam | 5 | 0 |
| | Gravel | 6 | 0 |
| Forest Marble. | Clay | 3 | 0 |
| Great Oolite. | Limestone | 39 | 3 |
| | Yellow sandy clay | 7 | 6 |
| | Blue clay | 1 | 0 |
| | Grey limestone | 1 | 5 |
| | Blue clay | 4 | 10 |
| | Blue limestone | 1 | 7 |
| Fuller's Earth. | Blue clay | 44 | 5 |
| | | 114 | 0 |

The quantity of water was "very large," and its quality excellent. Although the Inferior Oolite rock was not recorded, it seems most likely that it was reached, and that the artesian water escaped from it.

In the Great Oolite near Notgrove, and again in that exposed between Chipping Norton and Hook Norton, we find a considerable proportion of its mass of an impervious character, amounting indeed to about $\frac{1}{3}$ at Notgrove, and $\frac{2}{5}$ at the other locality, hence the water would be found at different levels and would be of variable quantity. The Great Oolite may be said to possess these characters from the neighbourhood of Burford and in its course to the north-east. In confirmation of this I may quote the Rev. J. Clutterbuck, who says," It often happens that in one locality there are several distinct beds of water, either to be traced in wells, or to be seen, as indicated by springs issuing from the hill-sides. Such, for instance, is the case at Stonesfield, in Oxfordshire, where three distinct beds of water are found at various levels, at about 15, 50, and 100 feet from the surface respectively; none, except the lowest, which rests on the lias clay, yielding a large amount of water, but each sufficient for ordinary domestic purposes."† My own observations at Stonesfield bear out this statement, as in one of the shafts sunk for working the "slate," copious springs were met with after heavy rains at two levels. (See p. 311.)

Gagingwell east of Enstone has a spring that is said never to fail, and this is one of the sources of the Glyme.

Over much of the area immediately north of Woodstock, near Wootton; again at Minster Lovel and Witney, the uppermost beds of the Great Oolite consist mainly of limestones to a depth of 25 or even 30 feet, and they yield supplies of water sufficient for local purposes. Thus small springs are thrown out on the north side of the valley below Wootton village, the dip of the strata being (at a low angle) in a south-easterly direction. Fair Rosamond's well, adjoining Blenheim Lake, is another example, and there is a spring called the Ruddy Well, north of Stonesfield, that issues from the Great Oolite: these "never fail."

At Tackley, north-east of Woodstock, a boring was made (in 1888) apparently through Forest Marble and Great Oolite, to a depth of 54 feet. A good supply of water was tapped in a bed of "sandstone," reached at 46 feet.

* Proc. Cotteswold Club, vol. x. p. 180; see also J. H. Taunton, *Ibid.*, vol. ix. p. 52; and J. Lucas, Trans. Inst. Surveyors, vol. xiii. pp. 170, 179, and plate.

† Journn. Roy. Agric. Soc., ser. 2, vol. i. p. 286.

At Witney, wells sunk to depths of 50 or 60 feet, through Cornbrash and Forest Marble as the case may be, find water in the upper beds of the Great Oolite, the yield being from 500 to 600 gallons per hour. (See p. 319.)

In Buckinghamshire and Bedfordshire, the Great Oolite Limestone may yield supplies of water; but large tracts of the country are covered by Drift, and percolation is thereby arrested. A boring made at Stony Stratford by Messrs. Le Grand and Sutcliff, yielded 60,000 gallons of water per day of 10 hours at a depth of 120 feet. (See also pp. 391, 393.)

At Bedford a well 30 feet deep was carried into the Great Oolite Limestone, and with headings driven in two directions 150 and 75 feet long. About a quarter of a million gallons is pumped daily.*

The Great Oolite Limestone of Northamptonshire and Lincolnshire is not calculated to store any great amount of water, and northwards it diminishes in thickness, so that only limited local supplies could be expected.

A spring called the Seven Wells, issues from the Great Oolite Limestone at Barnwell, south of Oundle; and the occurrence of powerful springs near Stoke Doyle, has been noticed (p. 410.)

Water was obtained in abundance from the Great Oolite Limestone at Helpstone, but the quality was not good (see p. 416.)

Numerous villages are found along the outcrop of the Cornbrash, throughout the country. Supplies of water for domestic purposes may be obtained, but no very large amount could be expected.

### *Reservoirs and Ornamental Waters.*†

I know of no large reservoirs on the Lower Oolites, but there are ornamental waters in a number of parks in the area. Of these it will be sufficient to mention those in Sherborne Park, Dorset (Fuller's Earth Rock and Clay); Orchardleigh, north of Frome (Forest Marble); Ledgemore Pond, south-west of Avening (Fuller's Earth Clay); Blenheim Lake, Woodstock, covering an area of 250 acres; also small lakes at Glympton, near Woodstock, and at Stowe, near Buckingham (Great Oolite); at Blatherwycke, near King's Cliffe (Northampton Sand and Upper Lias); and at Grimsthorpe, north-west of Bourn (Upper Estuarine Series).

## *Springs.*

The underground waters, springs, and river-waters of the Oolitic districts ordinarily contain from 6 to 30 grains per gallon (average about 20 grains) of mineral matter, chiefly carbonate of lime, with minor quantities of sulphates of lime and magnesia, chloride of sodium, &c. In highly cultivated districts the presence of nitrates of lime and soda is noticeable in the surface waters.‡ The temperature of the springs varies from 45° to 52°.

### *Holy Wells.*

Some of the more prominent springs have already been mentioned, and it is curious to note the number of "Seven Wells" or "Seven Springs" that occur. Other springs have, through legendary virtues or associations, been designated Holy Wells or named after some Saint. They are generally copious and constant. There is a Holy Well S.E. of Biddestone and N. of Corsham: it issues from the Cornbrash.

At Holywell Farm, east of Tadmarton Camp, S.W. of Banbury, there is a Holy Well known as the Sugar Well. The spring issues from the Inferior Oolite, and yields between 200,000 and 300,000 gallons per diem. An analysis by Mr. T. Beesley showed 14 grains of mineral matter per imperial

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* Report, Domestic Water Supply, p. 311.

† See also Report Roy. Comm. on Water Supply, 1893, p. 30; Minutes of Evidence, pp. 325, 343; and Appendices, pp. 371, 413, 418, 425, 426.

‡ See Report, Domestic Water Supply, pp. 50, 80, 96, 118, 291.

gallon, including 9 of carbonate of lime, together with small quantities of salts of magnesia, sodium, &c.*

There is a village of Holywell, north of Stamford; a Holy Well, at Fulbeck, between Grantham and Lincoln, a strong spring that issues from the base of the Inferior Oolite; and at Ancaster there is the Lady Well, that comes from the Inferior Oolite.

At Doulting, east of Shepton Mallet, there is a spring known as St. Aldhelm's Well, which issues from the Inferior Oolite.

### *Petrifying Springs.*

Springs of a "Petrifying" nature, depositing carbonate of lime on objects placed within their influence, and sometimes, as at Dursley forming important accumulations of tufa, have been met with in a number of localities where springs issue from the limestones of the Great and Inferior Oolite Series.

Such springs occur at the junction of the Inferior Oolite Series and Lias clays at Chalford near Stroud; at Dursley (Broadwell); Chedworth; North Aston and Somerton, south-east of Deddington; at Old (or Wold) near Maidwell, south-west of Rothwell; at Brixworth, and Pytchley.

Issuing from the Great Oolite Series are the Magdalen Mead well north of Tetbury, and springs at Northleach, and at Raunds, north-east of Higham Ferrers. The waters that flow over the weir from Blenheim Lake, deposit tufaceous coatings on twigs, leaves and other objects.

### *Chalybeate Springs.*

Chalybeate Springs frequently issue from the ferruginous strata; some of them are locally known as "Red Wells," and others formerly had some reputation as "Spas."

The following may be noted in reference to the formations from which they issue:—

#### *Northampton Sand.*

Farthingho, north-west of Brackley.
Floore (or Flower), between Daventry and Northampton, at Nobottle (Newbottle) Grove.
East Haddon, north-west of Northampton.
Eydon, south-west of Daventry.
Wellingborough.
Burghley Park, near Stamford.
Whittering Spa, Northamptonshire.
Neville Holt Spa, Medbourne, Leicestershire (saline chalybeate).

#### *Inferior Oolite and Midford Sand.*

Goathill (opposite side of stream south of church), south of Milborne Port.
Lyncombe Spa, Bath (saline chalybeate).
Middle Hill Spa, north-west of Box.
Stow-on-the-Wold.

#### *Lincolnshire Limestone.*

Stamford.
Tolthorpe Spa, between Little Casterton and Ryhall.

* A. Beesley, History of Banbury, p. 12.

*Cornbrash, &c.*

Road, north-east of Frome (saline chalybeate).
Chippenham (saline chalybeate).
North Leigh, north-east of Witney.
King's Cliffe, Northamptonshire (saline chalybeate).
Billingborough, east of Folkingham.
Sempringham, east-south-east of Folkingham.

## *Saline Springs.*

Saline waters have been proved in a number of localities in the Oolitic strata, as follows:—

*Inferior Oolite.*

East Chinnock, south-west of Yeovil. Salt-house, between East and Middle Chinnock, where common salt was formerly obtained in quantity.
Chadlington, near Chipping Norton.
Woodhall Spa, near Horncastle. (See p. 515.)

*Great Oolite Series.*

Melksham Spa, near Bower House, south-east of Melksham. (See p. 514.)
Trowbridge (well-boring). (See p. 514.)
Swindon (well-sinking). (See p. 515.)
Braceborough Spa, south of Bourn, and north of Braceborough Station (contains carbonate and sulphate of lime, sulphate of soda, and chloride of sodium).
Aunsby, south-west of Sleaford (160 grains of salts per gallon).
Heckington (well-boring), south-west of Sleaford (127 grains per gallon, chiefly chloride of sodium).

Other mineral springs have been recorded from the Inferior Oolite and Great Oolite Series at the following localities:—

Hyde, north of Temple Guiting, Gloucestershire; Kingsthorpe; Stanwick; Higham Ferrers; near Oundle (Drumming Well); Warmington, north-east of Oundle (Chadwell); Weedon Lois, west of Towcester (St. Loy's Mineral Spring), in Northamptonshire; and Spital-in-the-Street (Spa), Lincolnshire.

At Blatherwycke, north-west of Oundle, a spring containing sulphuretted hydrogen was discovered in sinking a well through the Northampton Sands, &c. to the Upper Lias Clays.

Carbonic acid gas is given off from the waters at Woodhall Spa: and the same gas together with Nitrogen, Oxygen, and Chlorine, are said to be evolved from the waters at Braceborough Spa.*

The mineral water at St. Clement's, Oxford, was found in sinking an Artesian well in 1832. The well was carried through 265 feet of Oxford Clay and to a further depth 155 feet in rock (Lower Oolites, &c.).

Buckland remarked that when the bore-hole was first made, the water rose 3 or 4 feet above the surface in a considerable volume.† It was found on subsequent analysis to yield (per gallon) 748 grains of chloride of sodium, 357 grains of sulphate of soda, 135 of sulphate of lime, together with small quantities of chloride of magnesium and carbonate of lime, bringing the total to 1,277 grains per gallon. This water rose when the clay was passed through, from a depth of 280 feet; afterwards when the boring was carried lower the water was not so strongly charged with sulphuric salts.‡ This last fact is important.

* Judd, Geology of Rutland, &c., p. 102.
† Buckland, Proc. Geol. Soc., 1835, p. 204.
‡ Daubeny, Trans. Geol. Soc., ser. 2, vol. v. p. 263.

In reference to this saline water, Prof. Prestwich has expressed the opinion that it "has its origin in the New Red Sandstone, and not in the Oolitic or Liassic Strata, as would otherwise, from the depth of the boring, be the natural inference. If the water were from the Oolitic strata we should expect to find it much purer, and its solid matter to consist chiefly of carbonate of lime: if from the Marlstone or Lias, to be more ferruginous and calcareous."*

At Holt, between Melksham and Trowbridge, saline waters were discovered towards the close of the 17th century in sinking a well. An account was published by H. Eyre,† who states that the water contained "mixed salts," in the proportion of 3 drachms, 1 scruple, and 19 grains in 1½ gallons of water (= about 146 grains per gallon); no particular analysis, however, was given. The details of the strata passed through were noted by the Rev. J. Lewis as follows:—

[Oxford Clay.]

"After they had passed the upper turf they came to a blue Clay, which held about 3 foot; then they met with a yellow, brittle Clay, very much like ochre, used by painters, about 2 foot in thickness; and next with a loam of a looser texture, which sparkled with a kind of talc, called by the naturalists Selenites, and was intermixed with yellow ochre. . . .

"Below this, at about 10 foot deep, they came to a bed of stones, of a large size, and very hard texture [Septaria] . . .

Kellaways [Rock?]

"Here the springs come in, and below this the Clay was darker coloured, and interlaid with small shells of the Oyster, Escallop and Muscle kind, and with a few Belemnites curiously shaped. Here they met with stones of a very close texture, which when washed seemed to be nothing but a mass of shells jumbled and embodyed together."‡

In connection with this subject it is interesting to note that saline or brackish water was also met with in a well made at Trowbridge (1870). The well was sunk 160 feet and bored 40 feet "into Lias." The water was found to contain the following ingredients:—

| | |
|---|---|
| Total solid impurity (in parts per 100,000) - | 144·34 |
| Chlorine - - | 36·70 |

The following appears to be the only account of this well at present published:—"In sinking the shaft a salt spring was tapped and afterwards stopped out, but we were informed that some water came in at about 20 feet from the surface. Our analysis * * * shows the water to be excessively hard, and to contain a considerable proportion of common salt (6 lbs. in 1,000 gallons, 3 oz. in this volume of water being about the usual proportion in good potable water), besides a rather large proportion of organic elements."§ No details of the strata are given. The well was probably commenced in the Cornbrash (if not Oxford Clay), and if carried into the Lias, it shows a great diminution in thickness of the Lower Oolitic strata. It is very likely, however, that the term "Lias" was that used by the well-sinker, and the well was simply carried through the Forest Marble into the Great Oolite.

The Melksham Spa derives its saline waters from a well sunk (1815–16) through the Oxford Clay, Kellaways Beds, and Cornbrash into the Forest Marble, the depth being 351 ft. 6 in. It contains 552 grains of saline matter, chiefly chloride of sodium, in the gallon.

Saline waters were met with at Swindon in a well-sinking made by the Great Western Railway Company at their works (1883–85).|| The formations proved were as follows:—

* Prestwich, Ashmolean Soc., 1876. Analysis by W. F. Donkin.

† A brief Account of the Holt Waters in Wiltshire. 12mo. 1731.

‡ Phil. Trans. vol. xxxv. p. 489 (1728).

§ Sixth Report of the Rivers Pollution Commission, pp. 105, 405.

|| H. B. W., Quart. Journ. Geol. Soc., vol. xlii. p. 287; and Taunton, Proc. Cotteswold Club, vol. ix. p. 61.

| | Ft. | In. |
|---|---|---|
| Made ground - - - - | 8 | 0 |
| Kimeridge Clay - - - - | 64 | 1 |
| Corallian beds - - - - | 40 | 1 |
| Oxford Clay and Kellaways Rock - - | 572 | 9 |
| Cornbrash - - - - - | 18 | 3 |
| Forest Marble - - - - | 33 | 0 |
| | 736 | 2 |

The Corallian beds, which occur between the depths of 72 and 112 feet, yielded the first supply of water, which issued at the rate of about 1,000 gallons per hour; but neither in quality nor in quantity was it deemed satisfactory. It contained 144 grains of saline matter per imperial gallon.

Water again was met with at a depth of 730 to 736 feet, rising from the Forest Marble at the rate of about 2,000 gallons per hour, and having a temperature of 64° F. This water, unfortunately, proved to be much more saline, containing 2,131 grains per imperial gallon, and was therefore utterly unfit for use in the locomotive and stationary engines.

The following analysis was made by Mr. F. W. Harris:—

| | grains per gallon. |
|---|---|
| Sodium chloride - - - | 1,824·37 |
| Potassium chloride - - - | 16·56 |
| Calcium chloride - - - | 191·11 |
| Calcium sulphate - - - | 1·25 |
| Magnesium chloride - - - | 88·47 |
| Magnesium carbonate - - - | 8·71 |
| Silica, Ferric oxide, and alumina - | 0·39 |
| Ammonia - - - - | 0·99 |
| | 2,131·85 |

The influx of water put a stop to further sinking. For a time it was pumped away, but after Christmas 1885 the pumping was discontinued, and the water, which had been kept at 253 feet from the surface (or 483 feet from the bottom of the well), rose eventually, on February 4, 1886, to within 25 feet of the ground-level, or about 304 feet above Ordnance datum. Although pumping had been resorted to for many months the quality of the water remained much the same.

The Woodhall Spa, near Horncastle in Lincolnshire, was discovered in boring for coal in 1819. According to Mr. Jukes-Browne the strata penetrated were probably the following:—

| | Feet. |
|---|---|
| Gravel and Boulder Clay - - - | 10 |
| Kimeridge and Oxford Clays - - - | 350 |
| Kellaways Beds, Cornbrash, and Great Oolite Series - - - - - - | 140 |
| Lincolnshire Limestone and Northampton Sand - - - - - - | 140 |
| Lias - - - - - - | 380 |
| | 1,020 |

The saline water issues at a depth of 530 feet, and would therefore appear to be situated in the Inferior Oolite.

The water, which formerly overflowed, stands at 50 feet from the surface, or at 330 feet from the surface when the pump is at work. 1,000 gallons an hour can be raised without draining the well. Analysis shows 1,215 grains of chloride of sodium, 105 of chloride of calcium, 86 of chloride of magnesium, 45 of bicarbonate of soda, 30 of sulphate of soda, &c., altogether about 1,500 grains of mineral matter per gallon. Small quantities of iodide and bromide of sodium occur, and the Spa is known as the Woodhall Iodine Spa.*

It is interesting to find that, not far from the church at Woodhall, at a depth of 33 feet, "a spring of salt water was tapped, resembling that of Woodhall Spa, but it gradually became less salt, and was finally replaced by a supply of fresh water."†

In connection with this subject, it is useful to bear in mind that at Northampton, saline waters were encountered beneath the Lias, at a depth of 650 feet. At Gayton at a depth of 994 feet, below the Lias, saline waters were found, and they yielded 1,500 grains per gallon; at Kettering saline water, amounting to 200,000 gallons a day, with 1,200 grains per gallon, was encountered between the Lias and Lower Carboniferous Rocks.‡ At Rugby saline-waters were met with in the New Red rocks.

The occurrence of saline waters is to some extent connected with the underground damming up of waters, whereby the saline matters, derived in great part from the rocks themselves, become concentrated. Hence pumping may in certain cases reduce the amount of the ingredients. The occasional outbreak at the surface of such springs may sometimes be connected with lines of fault, especially in clayey tracts, although it may be difficult to prove the existence of these disturbances.

In others cases the supply of saline matter may be distant and become diffused among the Oolitic rocks from deep-seated Palæozoic strata, where the newer rocks abut against them: the saline ingredients being derived in a measure from the percolation of sea-water, or to the descent of water to considerable depths among folded Palæozoic strata where increased temperature would lead to increased solution of materials. Synclinal troughs among the older strata may receive a considerable amount of saline water from the sea, and it may rise as artesian springs among the overlying strata. The saline waters may also be distributed locally by means of faults and fissures. To some such cause, the saline waters of Swindon and the Bath thermal waters may be attributed.

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* A. Strahan, in Geology of Lincoln, p. 208; see also A. B. Granville, Spas of England, vol. ii. Midland Spas, p. 104.

† A. Strahan, in Geol. Lincoln, p. 205.

‡ De Rance, 16th Report on Underground Waters, Rep. Brit. Assoc. for 1890, p. 374; H. J. Eunson, Quart. Journ. Geol. Soc., vol. xl. p. 482.

# APPENDIX.

## CATALOGUE OF FOSSILS

FROM THE

## LOWER OOLITIC ROCKS OF ENGLAND.

General remarks on the preparation of the lists of Fossils were made in the Memoir on the Lias. The same general plan is now adopted. Species whose occurrence or identification is doubtful, are either omitted, or they are inserted with a query.

The species in the Museum of Practical Geology (excepting where the horizon is doubtful) are recorded. I have received much assistance in noting them from Mr. H. A. Allen. Many specimens obtained by Mr. J. Rhodes and myself during the progress of the work have been named by Messrs. Sharman and Newton. Species recorded in the volumes of the Palæontographical Society, and in the later Geological Survey Memoirs, are included; as well as species from other publications, a list of which will be given in the final volume.

In addition to the British Museum of Natural History, the Woodwardian Museum at Cambridge, and the University Museum at Oxford, there are Museums at Dorchester, Sherborne (Grammar School), Bath, Bristol, Gloucester, Devizes, Cirencester (Royal Agricultural College), and Northampton, where many Oolitic fossils are preserved. A few specimens are to be seen in the smaller Museums at Bridport, Peterborough, and Stamford.

Of private collections, in addition to those mentioned in the Memoir on the Lias (pp. 327, 328) there are those of Mr. S. S. Buckman at Oxlynch, Stonehouse; of the late E. Witchell, at Stroud; of Mr. W. C. Lucy, at Brookthorpe, Gloucester; of the Rev. T. W. Norwood, at Wrenbury, Cheshire; Mr. W. H. Hudleston, London (including the collection of the Rev. A. W. Griesbach); Mr. James Parker, at Oxford; Mr. F. W. Crick, at Bedford; and Mr. Thomas Jesson, at Great Houghton, Northampton. The collection formed by the late Dr. J. Lycett is preserved partly in the Woodwardian Museum and partly in the Museum of Practical Geology; that of William Walton of Bath, in the Woodwardian Museum, Cambridge; that of J. C. Pearce is in the possession of his son, Dr. J. C. Pearce, of Ramsgate; that of Dr. H. Porter, of Peterborough, was purchased by S. Sharp, and the principal portion of the Sharp collection was acquired by the British Museum; that of the Marquis of Northampton is in the Northampton Museum; and that of Mr. H. Monk, of Yeovil, is in the Woodwardian Museum.

So far as this list is concerned, it may be regarded as representing our general knowledge of the Fauna and Flora of the Lower Oolitic Rocks. Some authorities would subdivide our genera and species much more than is done in this list; but such a splitting up is seldom of service to the stratigraphical geologist, and indeed generally renders the determination of the so-called species, and their use in the identification of strata, of value only to the specialist.

The *Ammonites* are indexed under this generic name: and a list of the sub-genera is given for convenience of reference.

Great assistance in the matter of nomenclature, has been derived from the British Museum Catalogues of Fossil Vertebrata, by Mr. R. Lydekker and Mr. A. Smith Woodward; from the Catalogue of British Fossil Vertebrata, by Messrs. A. S. Woodward and C. D. Sherborn; and the Catalogue of British Jurassic Gasteropoda, by Messrs W. H. Hudleston and E. Wilson.

For figures of British Lower Oolitic Fossils, the student may consult Sowerby's "Mineral Conchology," the works of the Palæontographical Society, Lycett's "Cotteswold Hills," Phillips' "Geology of Oxford and the valley of the Thames," Witchell's "Geology of Stroud," and Prestwich's "Geology," vol. ii.

REFERENCES TO LOCALITIES.

| | | | |
|---|---|---|---|
| D. | Dorsetshire. | H. | Huntingdonshire. |
| S. | Somersetshire. | N. | Northamptonshire. |
| W. | Wiltshire. | R. | Rutlandshire. |
| G. | Gloucestershire. | L. | Lincolnshire. |
| O. | Oxfordshire. | Y. | Yorkshire (the references are to the species noted from other countries, that occur also in Yorkshire). |
| Bk. | Buckinghamshire. | | |
| Lond. | London area (borings). | | |
| Sy. | Surrey (borings). | | |
| Be. | Bedfordshire. | | |

The grouping of the subdivisions is arranged, in ascending order, as follows :—

1. Zone of *Ammonities jurensis.*
2. Zone of *A. opalinus.*
3. Zone of *A. Murchisonæ;* including Collyweston Slate and Lincolnshire Limestone.
4. Zone of *A. humphriesianus.*
5. Zone of *A. Parkinsoni.*
6. Fuller's Earth Clay and Rock, (Fullonian) ; including Upper Estuarine Series.
7. Great Oolite and Stonesfield Slate ; including Great Oolite Limestone.
8. Forest Marble and Bradford Clay ; including Great Oolite Clay.
9. Zone of *A. macrocephalus ;* Cornbrash.

× Occurs in the Lias, or in higher beds of the Oolitic Series, according to the column.

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. | | Inferior Oolite. | | | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. jurensis. | Am. opalinus. | Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | | | | | | | |
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| MAMMALIA. | | | | | | | | | | | | | |
| *Marsupialia.* | | | | | | | | | | | | | |
| Amphilestes Broderipi, Owen. | | | | | | | | 7 | | | | O. - - | *Amphitherium.* |
| Amphitherium Prevosti, Blainv. | | | | | | | | 7 | | | | O. - - | *Didelyhys, Thylacotherium.* |
| Amphitylus Oweni, Osborn | | | | | | | | 7 | | | | O. | |
| Phascolotherium Bucklandi, Brod. | | | | | | | | 7 | | | | O. - - | *Didelphys, Thylacotherium.* |
| *Insectivora.* | | | | | | | | | | | | | |
| Stereognathus ooliticus, Charlesw. | | | | | | | | 7 | | | | O. | |
| REPTILIA. | | | | | | | | | | | | | |
| *Ornithosauria.* | | | | | | | | | | | | | |
| Rhamphocephalus Bucklandi, von Meyer. | | | | | | | | 7 | | | | O. - - | *Pterodactylus Kiddi,* Owen. *Rhamphorhynchus.* |
| —— depressirostris, Huxley | | | | | | | | 7 | | | | O. - - | *Pterodactylus Aclandi,* Owen. |
| —— Prestwichi, Seeley - | | | | | | | | 7 | | | | G. | |
| *Dinosauria.* | | | | | | | | | | | | | |
| Bothriospondyhus robustus, Owen. | | | | | | | | | 8 | | | W. | |
| Cardiodon rugulosus, Owen | | | | | | | | 7 | 8 | | | G. W. | |
| Cetiosaurus glymptonensis, Phil. | | | | | | | | 7 | 8 | | | O. N. | |
| —— oxoniensis, Phil. - | | | | | | | | 7 | 8 | | | G. O. Bk. N. | *C. longus,* Owen, (pars.) *C. medius ?,* Owen. |
| Megalosaurus Bucklandi, von Meyer. | | | | | | 5 | | 7 | 8 | 9 | × | D. S. G. W. O. N. | *Poikilopleuron.* |
| *Crocodilia.* | | | | | | | | | | | | | |
| Goniopholis carinata, Owen | | | | | | | | 7 | | | | G. | |
| Marmarosaurus obtusus, Owen. | | | | | | | | | 8 | | | W. | |
| Oolithes bathonicæ, Buckm. | | | | | | | | 7 | | | | S. W. G. O. - | Reptilian (Teleosaurian) Eggs. |
| —— sphæricus, Carr. - | | | | | | | | 7 | | | | | |
| Steneosaurus Boutilieri, Desl. | | | | | | | | 7 | | 9 | ? | O. | |
| —— brevidens, Phil. - | | | | | | | | 7 | | | | G. O. N. - | *Teleosaurus.* |
| —— ? Geoffroyi, Owen - | | | | | | | | 7 | | | | O. | |
| —— ? laticeps, Owen - | | | | | | | | 7 | | | | O. | |
| —— latifrons, Owen - | | | | | | | | 7 | | | | N. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. | | Inferior Oolite. | | | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. jurensis. | Am. opalinus. | Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | | | | | | | |
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Reptilia—*cont.* | | | | | | | | | | | | | |
| *Crocodilia*—cont. | | | | | | | | | | | | | |
| Steneosaurus megistorhynchus, Desl. | | | | | | 5 | | | | | | G. - - | Gryphite Grit. |
| —— Stephani, Hulke - | | | | | | | | | | 9 | | S. | |
| —— temporalis, Owen - | | | | | | | | 7 | | | | S. | |
| Teleosaurus brevirostris, Owen. | | | | | | | | 7 | | | | O. | |
| —— eadomensis, Geoff. - | | | | | | | | 7 | | | | O. - - | Doubtful. |
| —— Geoffroyi, Desl. - | | | | | | | | 7 | | | | O. | |
| —— subulidens, Phil. - | | | | | | | | 7 | | 9 | | G. O. | |
| *Ichthyopterygia* (*Ichthyosauria*). | | | | | | | | | | | | | |
| Ichthyosaurus advena, Phil. | | | | | | | | 7 | | | | O. | |
| —— sp. - - - | | 1 | | | | | | | | 9 | | G. H. | |
| *Sauropterygia* (*Plesiosauria*). | | | | | | | | | | | | | |
| Cimoliosaurus brevior, Lyd. | | | | | | | | | | 9 | × | H. | |
| erraticus, Phil. - | | | | | | | | 7 | | | | O - - | *Plesiosaurus.* |
| *Chelonia.* | | | | | | | | | | | | | |
| Protochelys Stricklandi, Phil. | | | | | | | | 7 | | | | O - - | *Testudo.* *Chelys? Blakei*, Mackie. |
| Pisces. | | | | | | | | | | | | | |
| *Ganoidei.* | | | | | | | | | | | | | |
| Aspidorhynchus crassus, A. S. Woodw. | | | | | | | | 7 | | | | O. N. | |
| Belonostomus? leptosteus, Ag. | | | | | | | | 7 | | | | O. | |
| Caturus pleiodus, Ag. - | | | | | | | | 7 | | | | O. | |
| Ctenolepis cyclus, Ag. - | | | | | | | | 7 | | | | O. | |
| *Gyrodus.* See Mesodon. | | | | | | | | | | | | | |
| *Gyronchus.* See Mesodon. | | | | | | | | | | | | | |
| Lepidotus minor, Ag. - | | | | | | | | 7 | | | × | O. | |
| —— tuberculatus, Ag. - | | | | | | | | 7 | | | | O. | |
| —— unguiculatus, Ag. - | | | | | | | | 7 | | | | O. N. | |
| Leptolepis disjecta, A. S. Woodw. | | | | | | | | 7 | | | | O. | |
| Macrosemius brevirostris, A. S. Woodw. | | | | | | | | 7 | | | | O. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Passage Beds, Midford Sands. Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Inferior Oolite. Am. humphriesianus. | Inferior Oolite. Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| PISCES—*cont.* | | | | | | | | | | | | | |
| *Ganoidei*—cont. | | | | | | | | | | | | | |
| Mesodon biserialis, Ag. | | | | | | | | 7 | | | | O. N. | *Pycnodus.* |
| —— Bucklandi, Ag. | | | | | | | | 7 | | 9 | × | O. H. | *P. ovalis*, Ag. *P. obtusus*, Ag. *P. didymus*, Ag. *Gyrodus perlatus*, Ag. |
| —— ? discoides, Ag. | | | | | | | | 7 | | | | O. | |
| —— oblongus, Ag. | | | | | | | | 7 | | | | O. | *Gyronchus.* |
| —— rugulosus, Ag. | | | | | | | | 7 | | | | O. N. | *P. parvus*, Ag. |
| —— tenuidens, A. S. Woodw. | | | | | | | | 7 | | | | O. | |
| —— trigonus, Ag. | | | | | | | | 7 | | | | O. | *Gyrodus.* *P. latirostris*, Ag. |
| —— umbonatus, Ag. | | | | | | | | | 8 | | | O. | |
| Microdon radiatus, Ag. | | | | | | | | 7 | | | × | O. | |
| Ophiopsis Flesheri, Ag. | | | | 3 | | | | | | | | N. | |
| Pholidophorus minor, Ag. | | | | | | | | 7 | | | | O. | |
| *Pycnodus.* See Mesodon. | | | | | | | | | | | | | |
| Sauropsis mordax, Ag. | | | | | | | | 7 | | | | O. | |
| Scaphodus heteromorphus, (Ag.) A. S. Woodw. | | | | | | | | 7 | | | | O. | |
| *Sphærodus.* See Lepidotus. | | | | | | | | | | | | | |
| Undina? | | | | | | | | 7 | | | | O. | |
| *Dipnoi.* | | | | | | | | | | | | | |
| Ceratodus Phillipsi, Ag. | | | | | | | | 7 | | | | O. N. | |
| *Elasmobranchii.* | | | | | | | | | | | | | |
| (*Selachii.*) | | | | | | | | | | | | | |
| Acrodus leiodus, A. S. Woodw. | | | | | | | | 7 | 8 | | | S. G. W. O. | |
| —— leiopleurus, Ag. | | | | | | | | 7 | | | | W. G. | |
| Asteracanthus acutus, Ag. | | | | | | | | 7 | ? | 9 | × | D. G. O. Be. N. | |
| —— ornatissimus, Ag. | | | | 3 | | | | 7 | | 9 | × | W. H. N. | *Strophodus subreticulatus*, Ag. |
| —— semisulcatus, Ag. | | | | | | | | 7 | | | | O. | *A. tenuistriatus*, Phil. |
| —— verrucosus, Ag. | | | | | | | | | | 9 | × | H. | |
| Hybodus apicalis, Ag. | | | | | | | | 7 | | | | O. | |
| —— crassus, Ag. | | | | 3 | | | | | | | | N R. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. | | Inferior Oolite. | | | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. jurensis. | Am. opalinus. | Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | | | | | | | |
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Pisces—*cont.* | | | | | | | | | | | | | |
| *Elasmobranchii*—cont. | | | | | | | | | | | | | |
| Hybodus dorsalis, Ag. - | | | | | | | | 7 | | | | O. | |
| —— grossiconus, Ag. - | | | | | | | | 7 | 8 | | | S. W. G. O. N. | |
| —— levis, A. S. Woodw. - | | | | | | | | 7 | | | | O. | |
| —— marginalis, Ag. - | | | | | | | | 7 | | | | O. | |
| —— polyprion, Ag. - - | | | | | | | | 7 | | | | S. G. O. - | *H. jugosus*, Phil. |
| Leptacanthus semistriatus, Ag. | | | | | | | | 7 | | | | O. - - | ? *Ganodus*. |
| —— serratus, Ag. - - | | | | | | | | 7 | | | | O. - - | ? *Ganodus*. |
| Nemacanthus brevis, Phil. | | | | | | | | 7 | | | | O. - - | *N. brevispinus*, Ag. |
| Pristacanthus securis, Ag. - | | | | | | | | 7 | | | | O. | |
| Strophodus lingualis, Phil. | | | | | | | | 7 | 8 | | | G. W. O. N. L. | |
| —— magnus, Ag. - - | | | | 3 | | | | 7 | 8 | 9 | | S. to Y. - | *S. favosus*, Ag. |
| —— tenuis, Ag. - - | | | | | | | | 7 | 8 | 9 | | S. to L. - | Inf. Ool. |
| —— see also Asteracanthus. | | | | | | | | | | | | | |
| *Holocephali.* | | | | | | | | | | | | | |
| Ganodus curvidens, Eg. - | | | | | | | | 7 | | | | O. - - | *Chimæra*. |
| —— dentatus, Eg. - - | | | | | | | | 7 | | | | O. | |
| —— falcatus, Eg. - - | | | | | | | | 7 | | | | O. - - | ? = *G. Oweni*. |
| —— neglectus, Eg. - - | | | | | | | | 7 | | | | O. - - | ? = *G. Oweni*. *Ischyodus*. |
| —— Oweni, Ag. - - | | | | | | | | 7 | | | | O. - - | *Chimæra*. |
| —— psittacinus, Eg. - | | | | | | | | 7 | | | | O. - - | ? = *G. Oweni*. |
| —— rugulosus, Eg. - - | | | | | | | | 7 | | | | O. - - | *Chimæra*. ? = *G. curvidens*. |
| —— see also Ischyodus. | | | | | | | | | | | | | |
| Ischyodus Bucklandi, Eg. - | | | | | | | | 7 | | | | O. - - | *Ganodus*. |
| —— Colei, Ag. - - | | | | | | | | 7 | | | | O. | |
| —— emarginatus, Eg. - | | | | | | | | 7 | | | | G. O. - | *Ganodus*. |

## Index to Sub-Generic Names of Ammonites.

Amaltheus.
Cadoceras.
Catulloceras.
Cœloceras.
Cosmoceras.
Dorsetensia.
Dumortieria.
Grammoceras.
Hammatoceras.
Haploceras.
Haplopleuroceras.
Harpoceras.
Haugia.
Hildoceras.
Hudlestonia.
Hyperlioceras.
Lillia.
Lioceras.
Lissoceras.
Ludwigia.
Lytoceras.
Macrocephalites.
Morphoceras.
Œcotraustes.
Oppelia.
Oxynoticeras.
Parkinsonia.
Perisphinctes.
Pleuroceras.
Poecilomorphus.
Polymorphites.
Polyplectus.
Pseudolioceras.
Sonninia.
Sphæroceras.
Stephanoceras.
Tmetoceras.
Witchellia.
Zurcheria.

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. | | Inferior Oolite. | | | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. jurensis. | Am. opalinus. | Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | | | | | | | |
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| **Mollusca.** | | | | | | | | | | | | | |
| *Cephalopoda.* | | | | | | | | | | | | | |
| Ammonites aalensis, Ziet. - | | | 2 | | | | | | | | | D. S. G. Y. - | *Harp., Gramm.* |
| —— —— var. Moorei, Lyc.- | | | 2 | | | | | | | | | D. S. G. - | *Dum.* |
| —— —— var. regularis, Ziet. | | | | | | | | | | | | D. G. - | Inf. Ool. |
| —— acanthodes, S. Buckm. | | | | 3 | | | | | | | | D. - - | *Sonninia.* |
| —— adricus, Waag. - | | | | 3 | 4 | | | | | | | D. S. - | *Harp., Sonn.* |
| —— affinis, Seeb. - - | | 1 | 2 | | | | | | | | | G. Y. - | *Hudl.* |
| —— alternatus, S. Buckm. | | | | 3 | | | | | | | | D. - - | *Sonn.* |
| —— amaltheiformis, Vacek. | | | | 3 | | | | | | | | D. - - | *Hamm.* |
| —— ambiguus, S. Buckm. - | | | | 3 | | | | | | | | D. - - | *Lioc.* |
| —— —— var. costatus, S. Buckm. | | | | 3 | | | | | | | | G. | |
| —— amplectens, S. Buckm. | | | | 3 | | | | | | | | D. - - | *Hamm.* |
| —— apertus, S. Buckm. - | | | | | | | | | | | | D. - - | *Lioc.* |
| —— aratus, S. Buckm. - | | 1 | 2 | | | | | | | | | G. - - | *Dum., Catull.* |
| —— arbustigerus, d'Orb. - | | | | | | | 6 | 7 | | | | S. G. O. N. | |
| —— arenatus, Quenst. - | | | | 3 | | | | | | | | D. S. - | *Sonn.* |
| —— aspidoides, Oppel. - | | | | | | | | | | | | D. - - | ?Inf. Ool. *Oppelia.* |
| —— Bakeriæ, Sow. - | | | | | | | | | | 9 | × | L. | |
| —— Beyrichi, Schloen. - | | | 2 | | | | | | | | | G. - - | *Pseudolioc.* |
| —— bicarinatus, Münst. - | | 1 | | | | | | | | | | G. - - | *Harp.* |
| —— biflexuosus, d'Orb. - | | | | | | | | 7 | | | | G. | |
| —— bifrons, Brug. - - | × | 1 | | | | | | | | | | G. N. - | *Harp., Hild.* |
| —— Blagdeni, Sow. - | | | | | 4 | | | | | | | D. S. L. Y. - | *Steph. Cœl.* |
| —— Boweri, S. Buckm. - | | | | 3 | 4 | | | | | | | D. S. - | *Harp., Sonn.* |
| —— —— bradfordensis, S. Buckm. | | | | 3 | | | | | | | | D. S. | *Lioc.* |
| —— —— var. giganteus, S. Buckm. | | | | 3 | | | | | | | | D. | |
| —— Braikenridgei, Sow. - | | | | 3 | 4 | | | | | | | D. S. G. Y. - | *Steph.* |
| —— braunianus, d'Orb. - | × | 1 | | | | | | | | | | G. - - | *Steph.* |
| —— brevispinatus, S. Buckm. | | | | 3 | | | | | | | | D. - - | *Sonn.* |
| —— Brocchii, Sow. - - | | | | | 4 | 5 | | | | | | D. S. G. Y. - | *Sphær.* |
| —— Brongniarti, Sow - | | | | | 4 | | | | | | | D. S. - | *Sphær.* |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. | | Inferior Oolite. | | | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. jurensis. | Am. opalinus. | Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | | | | | | | |
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| MOLLUSCA—*cont.* | | | | | | | | | | | | | |
| *Cephalopoda*—cont. | | | | | | | | | | | | | |
| Ammonites Browni, Sow. - | | | | 3 | | | | | | | | D. S. - | *Sonn.*, var. of *A. Sowerbyi.* |
| —— bullatus, d'Orb. - | | | | | | | 6 | 7 | | 9 | | D. G. O. N. L. | *Sphær.* |
| —— cadomensis, Defr. - | | | | 3 | 4 | | | | | | | D. | |
| —— *candidus*, d'Orb. See A. aalensis. | | | | | | | | | | | | | |
| —— Caumonti, d'Orb. - | | | | | | | | | | | | D. S. - | *Cosm.*, Inf. Ool. |
| —— climacomphalus, Vacek | | | | 3 | | | | | | | | D. - - | *Hamm.* |
| —— comensis, von Buch. - | | 1 | | | | | | | | | | G. Y. - | Near to *A. striatulus.* |
| —— compactilis, Simps. - | | 1 | | | | | | | | | | G. Y. - | *Pseudolioc.* |
| —— complanatus, S. Buckm. | | | | | 4 | | | | | | | D. - - | *Dors.* |
| —— concavus, Sow. - - | | | | 3 | | | | | | | | D. S. G. - | *Harp., Lioc.* |
| —— —— var. formosus, S. Buckm. | | | | 3 | | | | | | | | D. | |
| —— —— var. pinguis, S. Buckm. | | | | 3 | | | | | | | | D. | |
| —— —— var. v. scriptus, S. Buckm. | | | | 3 | | | | | | | | D. | |
| —— confusus, S. Buckm. - | | | | 3 | | | | | | | | D. - - | *Lyt.* |
| —— conjungens, K. Mayer | | | | | | | | | | | | D. - - | Inf. Ool. |
| —— *contractus*, Sow. See A. Sauzei. | | | | | | | | | | | | | |
| —— convolutus, Schloth. - | | | | | | | | | | | | D. - - | Inf. Ool. |
| —— cornu, S. Buckm. - | | | | 3 | | | | | | | | D. - - | *Harp., Ludw.* |
| —— corrugatus, Sow. - | | | | 3 | | | | | | | | D. S. G. O. N. | *Sonn.* ? var. of *A. Murchisonæ.* |
| —— costatus, S. Buckm. - | | | | 3 | | | | | | | | D. - - | *Sonn.* |
| —— costosus, Quenst. - | | | 2 | | | | | | | | | D. - - | *Ludw.* |
| —— costula, Rein. - - | | 1 | 2 | | | | | | | | | G. Y. ? - | *Harp., Dum.* ? *A. costulatus*, Ziet. |
| —— cotteswoldiæ, S. Buckm. | | 1 | | | | | | | | | | G. - - | *Gramm.* |
| —— crassispinatus, S. Buckm. | | | | 3 | | | | | | | | D. | |
| —— cycloides, d'Orb. - | | | | | 4 | | | | | | | D. - - | *Harp., Poecil.* |
| —— cymatera, S. Buckm. - | | | | 3 | | | | | | | | D. - - | *Sonn.* |
| —— Davidsoni, S. Buckm. | | | | | 4 | | | | | | | D. - - | *Perisph.* |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Passage Beds, Midford Sands. Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Inferior Oolite. Am. humphriesianus. | Inferior Oolite. Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| MOLLUSCA—*cont.* | | | | | | | | | | | | | |
| *Cephalopoda*—cont. | | | | | | | | | | | | | |
| Ammonites decipiens, S. Buckm. | | | | 3 | | | | | | | | D? - - | *Lioc.* {non *A. decipiens*, Sow. |
| —— —— var. intermedius, S. Buckm. | | | | 3 | | | | | | | | D. | |
| —— —— var. similis, S. Buckm. | | | | | | | | | | | | Loc. unknown. | Inf. Ool. |
| —— Defrancei, d'Orb. - | | | | | | | | | | | | S. - - | Inf. Ool. |
| —— Deslongchampsi, Defr. | | | | | 4 | | | | | | | D. - - | *Steph.* |
| —— Desori, Moesch - | | | | 3 | | | | | | | | D. - - | *Hyper.* |
| —— dimorphus, d'Orb. - | | | | | 4 | 5 | | | | | | D. - - | *Sphær.* |
| —— discites, Waag. - | | | | 3 | 4 | | | | | | | D. G. - | *Hyper.* |
| —— discoides, Ziet. - | | 1 | 2 | 3 | | | | | | | | S. G. - | *Harp., Polypl.* |
| —— discoideus, Quenst. - | | | | 3 | 4 | | | | | | | D. G. - | *Hyper.* |
| —— discus, Sow. - - | | | | | | | | 7 | 8 | 9 | | D. to N. | |
| —— dispansus, Lyc. - | | 1 | | | | | | | | | | D. S. G. L. | *Gramm.* ? var. of *A. variabilis.* |
| —— distans, S. Buckm. - | | | 2 | | | | | | | | | G. - - | *Gramm.* |
| —— doerntensis, Denckm. | | 1 | | | | | | | | | | G. - - | *Gramm.* |
| —— dolium, S. Buckm. - | | | | 3 | | | | | | | | D. - - | *Hamm.* |
| —— dominans, S. Buckm. - | | | | 3 | | | | | | | | D. - - | *Sonn.* |
| —— Dumortieri, S. Buckm. | | 1 | | | | | | | | | | G. - - | *Haugia.* |
| —— Dumortieri, Thioll. - | | 1 | 2 | | | | | | | | | D. S. - | *Catull.* |
| —— edouardianus, d'Orb. - | | ? | | 3 | 4 | | | | | | | D. S. - | *Harp., Dors.* |
| —— Eseri, Oppel - - | | 1 | | | | | | | | | | D. G. - | *Haugia.* |
| —— Etheridgei, S. Buckm. | | | | 3 | | | | | | | | D. S. - | *Hapl., Lissoceras.* |
| —— eudesianus, d'Orb. - | | | | | | 5 | | | | | | D. G. - | *Lyt.* |
| —— fallaciosus, Bayle - | | 1 | | | | | | | | | | S. G. - | *Gramm.* |
| —— fallax, S. Buckm. - | | | | 3 | | | | | | | | D. - - | *Lioc.* |
| —— fissilobatus, Waag. - | | | | | | | | | | | | D. S. - | *Harp.*, Inf. Ool. |
| —— fluitans, Dum. - | | | 2 | | | | | | | | | G. - - | *Gramm.* |
| —— fuscus, Quenst. - | | | | 3 | | 5 | | | | | | D. O. - | *Oppelia.* |
| —— garantianus, d'Orb. - | | | | | 4 | 5 | | | | | | D. G. - | *Cosm., Park.* |
| —— Gervillei, Sow. - - | | | | | 4 | | | | | | | D. S. Y. - | *Sphær.* |
| —— gracilis, J. Buckm. - | | | | | | | 6 | 7 | | | | G. O. N. L. | |
| —— grammoceroides, Haug. | | | 2 | 3 | | | | | | | | D. S. - | *Dum.* |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. | | Inferior Oolite. | | | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. jurensis. | Am. opalinus. | Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | | | | | | | |
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| MOLLUSCA—*cont.* | | | | | | | | | | | | | |
| *Cephalopoda*—cont. | | | | | | | | | | | | | |
| Ammonites *Herveyi* Sow. See A. macrocephalus. | | | | | | | | | | | | | |
| —— hircinus, Schloth. - | | 1 | 2 | 3 | | | | | | | | D. G. Y. - | *Lyt.* |
| —— hollandæ, S. Buckm. - | | | | 3 | | | | | | | | D. - - | *Cosm., Tmet.* |
| —— humphriesianus, Sow. | | | | | 4 | 5 | | | | | | D. S. G. Y. - | *Steph., Cœl.* |
| —— illustris, Denckm. - | | 1 | | | | | | | | | | G. - - | *Haugia.* |
| —— inconstans, S. Buckm. | | | | 3 | | | | | | | | D. - - | *Zurch.* |
| —— insignis, Schübl. - | × | 1 | 2 | | | | | | | | | D. S. G. N. Y. | *Harp., Hamm.* |
| —— insignisimilis, Brauns. | | 1 | 2 | | | | | | | | | G. - - | *Catull.* |
| —— irregularis, S. Buckm. | | | | 3 | | | | | | | | D. - - | *Sonn.* |
| —— jugifera, Waag. - | | | | 3 | | | | | | | | S. - - | *Witc.* |
| —— jugosus, Sow. - - | | 1 | | | | | | | | | | D. G. - | *Haugia.* |
| —— jurensis, Ziet. - - | | 1 | | | | | | | | | | D. S. G. N. Y. | *Lyt.* |
| —— læviusculus, Sow. - | | | | 3 | | | | | | | | D. S. O. L. | *Witc.*, near to *A. Murchisonæ.* |
| —— *Leckenbyi*, Lyc. See A. hircinus. | | | | | | | | | | | | | |
| —— Leesbergi, Branco - | | 1 | 2 | | | | | | | | | G. - - | *Catull.* |
| —— leurum, S. Buckm. - | | | 2 | | | | | | | | | G. - - | *Gramm.* |
| —— Levesquei, d'Orb. - | | 1 | 2 | | | | | | | | | D. S. G. - | *Harp., Dum.* |
| —— linguiferus, d'Orb. - | | | | | | | | | | | | D. - - | *Steph.*, Inf. Ool. |
| —— liostraca, S. Buckm. - | | | | | 4 | | | | | | | D. - - | *Dors.* |
| —— lotharingicus, Branco. | | | 2 | | | | | | | | | G. - - | *Gramm.* |
| —— Lucyi, S. Buckm. - | | | | 3 | | | | | | | | D. - - | *Ludw.* |
| —— lympharum, Dum. - | × | 1 | | | | | | | | | | N. - - | *Harp.* |
| —— macer, S. Buckm. - | | | | | 4 | | | | | | | D. S. - | *Pœcil.* |
| —— macrocephalus, Schloth. | | | | | | | | | | 9 | × | D. to Y. - | *A. Herveyi*, Sow. *Macroc.* |
| —— mactra, Dum. - - | | | 2 | | | | | | | | | D. G. - | *Gramm.* |
| —— magnispinatus, S. Buckm. | | | | 3 | 4 | | | | | | | D. - - | *Sonn.* |
| —— Manseli, J. Buckm. - | | | | | | | | | | | | D. - - | *Sphær.* |
| —— marginatus, S. Buckm. | | | | 3 | | | | | | | | D. - - | *Sonn.* |
| —— Martinsi, d'Orb. - | | | | | 4 | 5 | | | | | | D. S. G. - | *Perisph.* |
| —— meniscus, Waag. - | | | | | | | | | | | | D.? - - | *Sphær.*, Inf. Ool. |
| —— mesacanthus, Waag. - | | | | | | | | | | | | D.? - - | Inf. Ool. |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. jurensis. | Am. opalinus. | Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | | | | | | | |
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Mollusca—*cont.* | | | | | | | | | | | | | |
| *Cephalopoda*—cont. | | | | | | | | | | | | | |
| Ammonites metallarius, Dum. | | 1 | | | | | | | | | | G. - - | *Gramm.* |
| —— modestus, S. Buckm. - | | | | 3 | | | | | | | | D. - - | *Sonn.* |
| —— modiolaris, Lhwyd. - | | | | | | | | | | 9 | × | H. - - | *Cadoc.* |
| —— *Moorei.* See A. aalensis. | | | | | | | | | | | | | |
| —— *Morrisi*, Oppel. See A. viator. | | | | | | | | | | | | | |
| —— Muelleri, Denckm. - | | 1 | | | | | | | | | | G. - - | *Gramm.* |
| —— multispinatus, S. Buckm. | | | | 3 | | | | | | | | D. - - | *Sonn.* |
| —— mundus, S. Buckm. - | | | | 3 | | | | | | | | D. - - | *Haplopl.* |
| —— Murchisonæ, Sow. - | | | | 3 | | | | | | | | D. S. G. O. - | *Harp., Ludw.* |
| —— —— var. Baylei, S. Buckm. | | | | | | | | | | | | Loc. doubtful. | Inf. Ool. |
| —— —— var. obtusa, Quenst. | | | | 3 | | | | | | | | D. | |
| —— nannodes, S. Buckm. - | | | | 3 | | | | | | | | D. - - | *Gramm.* |
| —— *niortensis*, d'Orb. See A. subfurcatus. | | | | | | | | | | | | | ? var. of *A. Parkinsoni.* |
| —— obtusiformis, S. Buckm. | | | | 3 | | | | | | | | D. - - | *Sonn.* |
| —— occidentalis, Haug. - | | 1 | | | | | | | | | | G. - - | *Haugia.* |
| —— oolithicus, d'Orb. - | | | 2 | | | | | | | | | D. - - | *Hapl.* |
| —— opalinus, Rein. - | | | 2 | | | | | | | | | D. S. G. O. N. | *Harp., Lioc.* *A. primordialis,* Schloth. |
| —— —— var. comptus, Rein. | | | 2 | | | | | | | | | D. S. G. N. | |
| —— Orbignyi, S. Buckm. - | | 1 | 2 | | | | | | | | | G. Y. - | *Gramm.* |
| —— Parkinsoni, Sow. - | | | | | | 5 | | | | | | D. S. G. O. - | *Cosm., Park.* |
| —— —— var. dorsetensis, Wright. | | | | | | 5 | | | | | | D. O. | |
| —— parvicostatus, S. Buckm. | | | | 3 | | | | | | | | D. - - | *Sonn.* |
| —— parvispinatus, S. Buckm. | | | | 3 | | | | | | | | D. - - | *Zurch.* |
| —— *patella*, Waag. See A. corrugatus. | | | | | | | | | | | | | |
| —— perexpansus, S. Buckm. | | | | | 4 | | | | | | | D. - - | *Sphær.* |
| —— perlævis, Denckm. - | | 1 | | | | | | | | | | G. | |
| —— pertinax, Vacek. - | | | | 3 | | | | | | | | D. - - | *Zurch.* |
| —— phylliciuctus, Quenst. | | 1 | | | | | | | | | | D. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Passage Beds, Midford Sands. Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Inferior Oolite. Am. humphriesianus. | Inferior Oolite. Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Mollusca—*cont.* | | | | | | | | | | | | | |
| *Cephalopoda*—cont. | | | | | | | | | | | | | |
| Ammonites polyacanthus, Waag. | | | | 3 | | | | | | | | D. L. | |
| —— polymorphus, d'Orb. - | | | | 3 | | 5 | | | | | | D. S. - | *Sphær, Morph.* |
| —— præradiatus, Douvillé. | | | | | 4 | | | | | | | S. - - | *Liss.* |
| —— priscus, S. Buckm. - | | 1 | 2 | | | | | | | | | S. - - | *Dum.* |
| —— propinquans, Bayle. - | | | | 3 | | | | | | | | D. S. - | *Sonn.* |
| ——pseudo-radiosus, Branco. | | 1 | 2 | | | | | | | | | D. G. - | *Dum.* |
| —— ptycta, S. Buckm. - | | | | 3 | | | | | | | | D. - - | *Sonn.* |
| —— pulcher, S. Buckm. - | | | | | 4 | | | | | | | D. - - | *Dors.* Unique. |
| —— pygmæus, d'Orb. - | | | | 3 | | | | | | | | D. | |
| —— quadratus, Haug. - | | 1 | | | | | | | | | | G. - - | *Gramm.* |
| —— radians, Rein. - - | | 1 | 2 | | | | | | | | | D. S. G. - | *Harp., Gramm., Dum.* |
| —— —— var. exiguus, S. Buckm. | | | 2 | | | | | | | | | G. | |
| —— radiosus, Seeb. - | | 1 | 2 | | | | | | | | | G. - - | *Dum.* |
| —— —— var. gundershofensis, Haug. | | | 2 | | | | | | | | | D. G. | |
| —— revirescens, S. Buckm. | | | | 3 | | | | | | | | D. - - | *Sonn.* |
| —— rudis, S. Buckm. - | | | 2 | | | | | | | | | D. S. - | *Ludw.* |
| —— Sæmanni, Dum. - | | 1 | | | | | | | | | | G. - - | *Gramm.* |
| —— Sauzei, d'Orb. - - | | | | 3 | 4 | | | | | | | D. S. - | *Sphær.* |
| — scissus, Benecke - | | | 2 | 3 | | | | | | | | D. S. G. - | *Tmet.* |
| —— semispinatus, S. Buckm. | | | | 3 | | | | | | | | D. - - | *Sonn.* |
| —— senescens, S. Buckm. - | | | 2 | | | | | | | | | G. - - | *Polym.* |
| —— serrodens, Quenst. - | | 1 | | | | | | | | | | G. - - | *Hudl.* |
| —— sigaloen, S. Buckm. - | | 1 | | | | | | | | | | S. - - | *Lyt.* |
| —— simplex, S. Buckm. - | | | | 3 | | | | | | | | D. - - | *Sonn.* |
| —— Sowerbyi, Miller - | | | | 3 | | | | | | | | D. S. G. L. - | *Sonn.* |
| —— —— var. gingensis, Waag. | | | | 3 | | | | | | | | D. | |
| —— sparsicosta, Haug. - | | | 2 | | | | | | | | | G. - - | *Dum.* |
| —— spinicostatus, S. Buckm. | | | | 3 | | | | | | | | D. - - | *Sonn.* |
| —— spinifer, S. Buckm. - | | | | 3 | | | | | | | | D. - - | *Sonn.* |
| —— spinigera, S. Buckm. - | | | | 3 | | | | | | | | D. - - | *Sonn.* |
| —— Stephani, S. Buckm. - | | | | 3 | | | | | | | | D. - - | *Amal.?* |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Mollusca—*cont.* | | | | | | | | | | | | | |
| *Cephalopoda*—cont. | | | | | | | | | | | | | |
| Ammonites striatulo-costatus, Quenst. | | 1 | 2 | | | | | | | | | S. G. - | *Dum.* |
| —— striatulus, Sow. - | × | 1 | | | | | | | | | | D. S. G. Y. - | *Harp., Gramm.* |
| —— subcomptus, Branco - | | | 2 | | | | | | | | | G. - - | *Gramm.* |
| —— subconcavus, Y. & B. - | × | 1 | | | | | | | | | | G. Y. - | *Harp.* |
| —— subcontractus, Mor. & Lyc. | | | | | | 5 | 6 | 7 | | | | D. S. G. - | { *A. modiolaris*, W. Smith (*non Lhwyd.*). |
| —— subcostatus, S. Buckm. | | | | 3 | | | | | | | | D. - - | *Sonn.* |
| —— subdiscoideus, S. Buckm. | | | | 3 | | | | | | | | D. - - | *Hyper.* |
| —— subfurcatus, Schloth. | | | | | 4 | | | | | | | D. - - | { *Cosm., Park.* *A. niortensis*, d'Orb. |
| —— subinsignis, Oppel. - | | | 2 | | | | | | | | | D. G. | *Hamm.* |
| —— sublineatus, Oppel. - | | 1 | | | | | | | | | | G. - - | *Lyt.* |
| —— submarginatus, S. Buckm. | | | | 3 | | | | | | | | D. - - | *Sonn.* |
| —— subplanatus, Oppel. - | × | 1 | | | | | | | | | | D. N. L. - | *A. complanatus*, d'Orb. |
| —— subquadratus, S. Buckm. | | 1 | 2 | | | | | | | | | G. - - | *Gramm.* |
| —— subradiatus, Sow. - | | | | | | 5 | | | | | | D. S. L. - | *Oppelia.* |
| —— subserrodens, Branco - | | | 2 | | | | | | | | | G. - - | *Gramm.* |
| —— subspinatus, S. Buckm. | | | | 3 | | | | | | | | D. - - | *Amal., Haplopl.* |
| —— substriatus, S. Buckm. | | | | 3 | | | | | | | | D. - - | *Sonn.* |
| —— subtectus, S. Buckm. - | | | | | 4 | | | | | | | D. - - | *Dors.* |
| —— subtrigonatus, S. Buckm. | | | | 3 | | | | | | | | D. - - | *Sonn.* |
| —— subundulatus, Branco | | | 2 | | | | | | | | | S. - - | *Dum.* |
| —— sulcatus, S. Buckm. - | | | | | 4 | | | | | | | D. - - | *Lillia.* |
| —— Sutneri, Branco - | | | | 3 | | | | | | | | S. - - | *Witc.* |
| —— tectus, S. Buckm. - | | | | | 4 | | | | | | | D. - - | *Dors.* |
| —— *terebratus*, Phil. See A. macrocephalus. | | | | | | | | | | | | | |
| —— tessonianus, d'Orb. - | | | | | 4 | | | | | | | D. S. G. | |
| —— toarcensis, d'Orb. - | | 1 | 2 | 3 | | | | | | | | D. S. G Y. - | { *Gramm.* near to *A. striatulus.* *A. thouarsensis.* |
| —— torulosus, Schübl. - | | | 2 | | | | | | | | | D. G. - | *Lyt.* |
| —— trapeza, Quenst. - | | | | 3 | | | | | | | | D. | |
| —— Truellei, d'Orb. - | | | | | | 5 | | | | | | D. - - | *Oppelia, Amal.* |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Passage Beds, Midford Sands. Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Inferior Oolite. Am. humphriesianus. | Inferior Oolite. Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mollusca—*cont.* | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| *Cephalopoda*—cont. | | | | | | | | | | | | | |
| Ammonites variabilis, d'Orb. | × | 1 | | | | | | | | | | D. G. O. Y. | *Harp., Haugia.* |
| —— viator, d'Orb. | | | | | | | 6 | 7 | | | | S. G. | *A. Morrisi,* Oppel. |
| —— Walkeri, S. Buckm. | | | | 3 | 4 | | | | | | | D. G. | *Hyper.* |
| —— Waterhousei, Mor. & Lyc. | | | | | | | | 7 | | | | D. G. O. | |
| —— Wrighti, S. Buckm. | | 1 | 2 | | 4 | | | | | | | D. S. G. | *Sphær., Lyt.; A. jurensis* of some authors. |
| —— zigzag, d'Orb. | | | | | | 5 | | | | | | D. S. | *Steph.* |
| Aptychus or Trigonellites | × | | | | | 5 | | 7 | | | × | S. O. | |
| Ancyloceras annulatum, Desh. | | | | | 4 | | | | | | | D. | |
| —— Waltoni, Morris | | | | | | | | | | | | D. | Inf. Ool. |
| Belemnites aalensis, Voltz. | | | 2 | 3 | | 5 | | | | | | D. G. O. N. Y. | *B. giganteus,* Schloth. *Megateuthis.* |
| —— abbreviatus, Sow. | | 1 | 2 | 3 | 4 | 5 | | | | | × | D. S. G. | |
| —— acuarius, Schloth. | | | 2 | | | | | | | | | G. | *B. tubularis,* Y. & B. |
| —— apiconus, Blainv. | | | | | 4 | | | | | | | D. | |
| —— aripistillum, Lhwyd. | | | | | | | 6 | 7 | | | | S. G. O. | *B. fusiformis,* Park. |
| —— bessinus, d'Orb. | | | | 3 | | 5 | | 7 | | | | D. S. G. O. N. L. | |
| —— Blainvillei, Voltz. | | | | 3 | 4 | | | | | | × | D. S. N. L. | |
| —— breviformis, Voltz. | × | 1 | 2 | 3 | | | | | | | | G. | |
| —— canaliculatus, Schloth. | | | | | 4 | 5 | | | | | | D. S. G. | |
| —— compressus, Stahl. | × | 1 | 2 | 3 | | | | | | | | S. G. | |
| —— cylindricus, Simps. | × | | 2 | | | | | | | | | G. | |
| —— ellipticus, Mill. | | | | 3 | 4 | | | | | | | D. S. O. | |
| —— *giganteus,* Schloth. See B. aalensis. | | | | | | | | | | | | | |
| —— gingensis, Oppel. | | | | | 4 | | | | | | | D. S. G. | |
| —— inornatus, Phil. | | | 2 | | | | | | | | | G. Y. | |
| —— insculptus, Phil. | | | | | 4 | | | | | | | S. G. | |
| —— irregularis, Schloth. | | 1 | 2 | 3 | | | | | | | | S. G. N. Y. | |
| —— parallelus, Phil. | | | | | | | 6 | | | | | D. S. | |
| —— quadricanaliculatus, Quenst. | × | | 2 | 3 | | | | | | | | D. | |
| —— quinquesulcatus, Blainv. | | | | 3 | | | | | | | | D. Y. | |
| —— spinatus, Quenst. | | | | | | | | | | | | G. | |

| SPECIES. | Lower Beds of Lias. | Passage Beds, Midford Sands. | | Inferior Oolite. | | | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | LOCALITIES. | REMARKS. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. jurensis. | Am. opalinus. | Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | | | | | | | |
| MOLLUSCA—*cont.* | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| *Cephalopoda*—cont. | | | | | | | | | | | | | |
| Belemnites sulci-stylus, Phil. | | | 2 | | | | | | | | | G. | |
| — terminalis, Phil. - | | | | | 4 | | | | | | | D. | |
| — tripartitus, Schloth. - | × | 1 | | | | | | | | | | G. O. | |
| — Voltzi, Phil. - - | × | | 2 | | | | | | | | | G. - - | *B. ventralis*, Phil. |
| — vulgaris, Y. & B. - | × | 1 | | | | | | | | | | G. | |
| — sp. - - - | | | | | | | | | | 9 | | D. | |
| Nautilus Baberi, Mor. & Lyc. | | | | | | | | 7 | ? | ? | | G. O. Be. N. L. | |
| — burtonensis, Foord & Crick. | | | | | | | | | | | | D. - - | Inf. Ool. |
| — clausus, d'Orb. - | | | | 3 | | | | | | | | D. S. G. | |
| — dispansus, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| — excavatus, Sow. - | | | | 3 | | | | | | | | D. S. | |
| — glaber, Foord & Crick - | | | | | | | | | | | | S. - - | Inf. Ool. |
| — hexagonus, Sow. - | | | | | | | | 7 | | | × | O. | |
| — inornatus, d'Orb. - | | | | 3 | | | | | | | | D. G. | |
| — jurensis, Quenst. - | | 1 | 2 | | | | | | | | | N. Y. | |
| — latidorsatus, d'Orb. - | × | | 2 | 3 | | | | | | | | D. G. - | *N. toarcensis*, d'Orb. |
| — lineatus, Sow. - - | | | | 3 | 4 | 5 | | | | | | D. S. G. Y. | |
| — lineolatus, Foord & Crick. | | | | | | | | | | | | D. S. - | Inf. Ool. |
| — multiseptatus, Foord & Crick. | | | 2 | | | | | | | | | N. - - | North. Sand. |
| — obesus, Sow. - - | | | 2 | | | | | 7 | | | | D. S. G. N. | |
| — ornatus, Foord & Crick | | | | | | | | ? | | | | D. S. W. G. | Inf. Ool. |
| — perinflatus, Foord & Crick. | | | | | | | | | | | | D. S. - | Inf. Ool. |
| — polygonalis, Sow. - | | | | 3 | 4 | | | | | | | D. S. L. | |
| — pseudolineatus, Foord & Crick. | | | | | | | | | | | | D. S. - | Inf. Ool. |
| — sinuatus ? Sow. - | | | | 3 | | | | | | | | D. | |
| — Smithi, Foord & Crick | | | | | | | | | | | | D. - - | Inf. Ool. |
| — striatus, Sow. - - | × | 1 | | | 4 | | | | | | | D. S. | |
| — subtruncatus, Mor. & Lyc. | | | | | | | | 7 | | | | G. N. L. | |
| — truncatus ? d'Orb. - | × | | | 3 | 4 | | | | | | | D. G. | |
| Rhyncholites - - | | 1 | | | | 5 | | | | 9 | | D. S. - | Mandibles of *Nautilus*. |
| Toxoceras Orbignyi, Baug. & Sauzé. | | | | | 4 | | | | | | | D. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. | | Inferior Oolite. | | | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. jurensis. | Am. opalinus. | Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | | | | | | | |
| Mollusca—*cont.* | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| *Gasteropoda.* | | | | | | | | | | | | | |
| Actæon bathonicus, Lyc. - | | | | | | | | 7 | | | | S. | |
| —— phasianoides, Lyc. - | | | | | | | | 7 | | | | G. | |
| —— pullus, Koch & Dunker | | | | | | | | | | | | O. G. N. Y. | Inf. Ool. |
| —— Sedgvici, Phil. - - | | | | 3 | | | | 7 | | | × | G. Y. | |
| Actæonina antiqua, Lyc. - | | | | | | 5 | | | | | | G. | |
| —— brevis, Mor. & Lyc. - | | | | ? | | | | 7 | 8 | | | W. G. O. L. | *Cylindrites.* |
| —— bulimoides, Mor. & Lyc. | | | | | | | | 7 | | | | G. O. | |
| —— canaliculata, Lyc. - | | | | | | | | 7 | | | | O. | |
| —— convoluta, Lyc. - | | | | | | | | | | | | G. - - | Inf. Ool. |
| —— fasciata, Lyc. - - | | | | | | | | | 8 | | | W | |
| —— glabra, Phil. - - | | | | 3 | | | | | | | | G. N. L. Y. | |
| —— kirtlingtonensis, Lyc. | | | | | | | | 7 | 8 | | | O. | |
| —— Luidi, Mor. - - | | | | | | | | 7 | 8 | 9 | | W. O. | |
| —— olivæformis, Dunk. - | | | | | | | | 7 | 8 | | | W. G. O. | |
| —— scalaris, Lyc. - - | | | | | | | | 7 | | | | G. O. | |
| —— scarburgensis, Lyc. - | | | | | | | | | | 9 | | N. Y. | |
| —— Suessea, Lyc. - - | | | | | | | | | 8 | | | S. W. | |
| —— tumidula, Mor. & Lyc. | | | | 3 | | | | | | | | G. N. Y. | |
| —— wiltonensis, Lyc. - | | | | | | | | | 8 | | | W. | |
| —— see also Ceritella. | | | | | | | | | | | | | |
| Alaria angusta, Hudl. - | | | | | | | | | | | | Loc. unknown. | Inf. Ool. |
| —— armata, Mor. & Lyc. - | | | | | | ? | | 7 | | | | G. N. L. Y. | |
| —— *atractoides*, Desl. See Aporrhais. | | | | | | | | | | | | | |
| —— cirrus, Desl. - - | | | | | | | | 7 | | | | G. | |
| —— Doublieri, d'Orb. - | | | | | | 5 | | | | | | D. S. | |
| —— dundriensis, Tawn. - | | | | | | | | | | | | S. - - | Inf. Ool. |
| —— fusca, Hudl. - - | | | | | 4 | | | | | | | D. | |
| —— *gracilis*, Lyc. See A. Lorieri. | | | | | | | | | | | | | |
| —— hamoides, Hudl. - | | | | 3 | | | | | | | | L. | |
| —— hamulus, Desl. - | | | | ? | | | | | | | × | G. L. | |
| —— hamus, Mor. & Lyc. - | | | | | | | | 7 | | | | G. - - | *Rostellaria.* |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Passage Beds, Midford Sands. Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Inferior Oolite. Am. humphriesianus. | Inferior Oolite. Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| MOLLUSCA—*cont.* | | | | | | | | | | | | | |
| *Gasteropoda*—cont. | | | | | | | | | | | | | |
| Alaria hamus, Desl. | | | | 3 | | 5 | | | | | | D. S. | |
| —— —— var. nodosa, Hudl. | | | | | | | | | | | | D. S. | Inf. Ool. |
| —— —— var. Phillipsi, d'Orb. | | | | 3 | 4 | | | | | | | D. S. N. Y. | *A. composita*, Sow. |
| —— hexagona, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— hortonensis, Hudl. | | | | | | 5 | | | | | | G. | Unique. |
| —— ignobilis, Mor. & Lyc. | | | | | | | | 7 | | | | G. | *Pterocera.* |
| —— lævigata, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— Lorieri, d'Orb. | | | | 3 | | 5 | | | | | | D. G. | |
| —— —— var. gracilis, Lyc. | | | | 3 | | | | | | | | D. G. | |
| —— lotharinga, Schlum. | | | | | | | | | | | | S. | Inf. Ool. |
| —— myurus, Desl. | | | | | | 5 | | ? | | | | S. G. Y. | *Rostellaria.* |
| —— pagoda, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— *paradoxa*, Desl. See Diartema. | | | | | | | | | | | | | |
| —— parvula, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— pinguis, Hudl. | | | | | | 5 | | | | | | D. S. | |
| —— pontonis, Hudl. | | | | 3 | | | | | | | | L. | |
| —— —— var. spinifera, Hudl. | | | | 3 | | | | | | | | L. | |
| —— prælonga, Hudl. | | | | 3 | | | | | | | | D. | |
| —— primigenia, Hudl. | | | | | | 5 | | | | | | D. | |
| —— (cf.) rarispina, Schlum. | | | | 3 | | | | | | | | D. | |
| —— Roubaleti, Schlum. | | | | 3 | | | | | | | | D. | |
| —— —— var. dorsetensis, Hudl. | | | | 3 | | | | | | | | D. | |
| —— solida, Lyc. | | | | 3 | | | | | | | | G. | *Rostellaria* |
| —— spinigera, Lyc. | | | | 3 | | | | | | | | G. | *Rostellaria.* |
| —— sublævigata, Hudl. | | | | 3 | | | | | | | | D. Y. | |
| —— subpunctata ? Münst. | | | | 3 | | | | | | | | L. | |
| —— *rinitatis*, Tawn. See Spinigera. | | | | | | | | | | | | | |
| —— unicarinata, Hudl. | | | | 3 | | | | | | | | Y. | North. Sand. ? |
| —— unicornis, Lyc. | | | | 3 | | | | | | | | D. G. | |
| —— —— var. bradfordiensis, Hudl. | | | | 3 | | | | | | | | D. | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| MOLLUSCA—*cont.* | | | | | | | | | | | | | |
| *Gasteropoda*—cont. | | | | | | | | | | | | | |
| *Alaria varcifera*, Hudl. See Diartema. | | | | | | | | | | | | | |
| Amberleya biserta, Phil. | | | 2 | 3 | | | | | | | | D. S. Y. | *Trochus.* |
| —— capitanea, Goldf. | × | 1 | 2 | 3 | | ? | | ? | 8 | | | D. S. W. G. | *Turbo.* |
| —— cygnea, Hudl. | | | | 3 | | | | | | | | L. | |
| —— densinodosa, Hudl. | | | | 3 | | | | | | | | D. S. | |
| —— ? dundriensis, Tawn. | | | | 3 | | | | | | | | S. | *Turbo.* |
| —— elongata, Hudl. | | | | 3 | | | | | | | | D. S. | |
| —— gemmata, Lyc. | | | | 3 | | | | | | | | O. G. N. L. | |
| —— (cf.) generalis, Münst. | | | | | 4 | | | | | | | S. | |
| —— goniata, Desl. | | | | | | 5 | | | | | | D. S. | |
| —— jurassi, Lyc. | | | | | | | | 7 | | | | G. | |
| —— (cf.) Meriani, Goldf. | | | | 3 | | | | | | | | N. L. Y. | |
| —— Milleri, Wright | | | | 3 | | | | | | | | D. | |
| —— monilifera, Lyc. | | | | | | | | | 8 | | | W. | |
| —— Murchisoni, Münst. | | | | | 4 | | | | | | | D. | |
| —— nodosa, J. Buckm. | | | | | | | | 7 | 8 | | | W. G. O. | *Pagodus.* |
| —— obornensis, Hudl. | | | | | 4 | | | | | | | D. | |
| —— orbignyana, Hudl. | | | | | 4 | 5 | | | | | | D. S. | |
| —— ornata, Sow. | | | | 3 | | | | | | | | D. S. G. O. L. | *Turbo, Littorina.* |
| —— —— var. horrida, Hudl. | | | | 3 | | | | | | | | D. | |
| —— pagodiformis, Hudl. | | | | 3 | | | | | | | | D. | |
| —— pinguis, Desl. | | | | | | 5 | | | | | | S. | |
| —— plicata, d'Arch. | | | | | | | | 7 | | | | G. | |
| —— *spinulosa*, Münst. See A. ornata. | | | | | | | | | | | | | |
| —— Stoddarti, Tawn. | | | | 3 | | | | | | | | S. | *Turbo.* |
| —— tricincta, Lyc. | | | | | | | | | 8 | | | W. | |
| —— turbinoides, Hudl. | | | | 3 | | | | | | | | D. S. | |
| Aporrhais atractoides, Desl. | | | | | | | | 7 | | | | G. | |
| Aptyxiella subconica, Hudl. | | | | | | 5 | | | | | | G. | |
| Ataphrus Acmon, d'Orb. | | | | | | | | | | | | S. | Inf. Ool., *Trochus.* |
| —— Belus, d'Orb. | | | | 3 | | | | | | | | L. | |
| —— comma, Lyc. | | | | | | | | | 8 | | | W. S. | |

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| | | Am. jurensis. | Am. opalinus. | Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | | | | | | | |
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| MOLLUSCA—*cont.* | | | | | | | | | | | | | |
| *Gasteropoda*—cont. | | | | | | | | | | | | | |
| Ataphrus discoideus, Mor. & Lyc. | | | | 3 | | | | 7 | 8 | | | O. G. L. | |
| —— heliciformis, Mor. & Lyc. | | | | | | | | 7 | | | | O. G. - | Inf. Ool.? |
| —— Labadyei, d'Arch. - | | | | | | ? | | 7 | | | | S. G. W. O. | Inf. Ool.? |
| —— lævigatus, Sow. - | | | | 3 | | | | | | | | D. S. G. L. Y. | *Monodonta.* |
| —— Waltoni, Lyc. - - | | | | | | | | | 8 | | | W. S. | |
| Bourguetia conica, Mor. & Lyc. | | | | | | | | 7 | | | | G. - - | *Phasianella.* |
| —— conoidea, Witc. - | | | | | | | | 7 | | | | G. | |
| —— elegans, Mor. & Lyc. - | | | | 3 | | | | 7 | | | | G. O. L. | |
| —— latiuscula, Mor. & Lyc. | | | | 3 | | | | | | | | N. L. Y. | |
| —— Leymeriei, d'Arch. - | | | | | | | | 7 | | | × | G. O. | |
| —— —— var. lindonensis, Hudl. | | | | 3 | | | | | | | | L. | |
| —— nuciformis, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— parvula, Mor. & Lyc. - | | | | | | | | 7 | | | | G. | |
| —— pontonis, Lyc. - - | | | | 3 | | | | | | | | L. | |
| —— striata, Sow. - - | | | | 3 | 4 | | | | | | × | D. S. G. O. Y. | *Melania.* *Phasianella Sæmanni*, Oppel. |
| —— —— var. costata, Witc. | | | | | | 5 | | | | | | G. | |
| —— —— var. multistriata, Hudl. | | | | 3 | | | | | | | | D. | |
| —— subglobosa, Mor. & Lyc. | | | | | | | | 7 | | | | G. - - | *Eulima.* |
| —— (cf.) subumbilicata, d'Arch. | | | | 3 | | | | | | | | N. | |
| —— tumidula, Mor. & Lyc. | | | | 3 | | | | 7 | | | | G. L. | |
| —— variata, Lyc. - - | | | | | | | | 7 | 8 | | | W. O. | |
| Brachytrema binodosum, Hudl. | | | | 3 | | | | | | | | L. | |
| —— buccinoideum, Lyc. - | | | | | | | | 7 | | | | G. | |
| —— Buvignieri, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— pygmæum, Mor. & Lyc. | | | | | | | | 7 | | | | G. - - | *Turbo.* |
| —— subnodulosum, d'Orb. | | | | | | | | 7 | | | | G. - - | *Fusus.* |
| —— subvaricosum, Hudl. - | | | | 3 | | | | | | | | N. L. | |
| —— turbiniforme, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— varicosum, Lyc. - | | | | | | | | 7 | | | | G. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. | | Inferior Oolite. | | | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. jurensis. | Am. opalinus. | Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | | | | | | | |
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Mollusca—*cont.* | | | | | | | | | | | | | |
| *Gasteropoda.* | | | | | | | | | | | | | |
| Brachytrema Wrighti, Cott. var. despecta, Hudl. | | | | | | 5 | | | | | | D. | |
| *Buccinum.* See Ceritella. | | | | | | | | | | | | | |
| Bulla doliolum, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— Favrei, Lyc. - - | | | | | | | | | | | | G. - - | Inf. Ool. |
| —— undulata, Bean - | | | | | | | | 7 | | 9 | | D. W. G. Y. | |
| Ceritella acuta, Mor. & Lyc. | | | | | | | | 7 | 8 | | | G. L. - | Inf. Ool.? |
| —— conica, Mor. & Lyc. - | | | | | | | | 7 | | | | G. | |
| —— fusiformis, Lyc. - | | | | | | | | 7 | | | | G. | |
| —— gibbosa, Mor. & Lyc. - | | | | | | | | 7 | | | | G. | |
| —— lindonensis, Hudl. - | | | | 3 | | | | | | | | N. L. | |
| —— Lycettea, Buv. - - | | | | | | | | 7 | | | | G. - - | |
| —— minutissima, Lyc. - | | | | | | | | 7 | | | | G. | |
| —— mitralis, Mor. & Lyc. - | | | | | | | | 7 | | | | G. | |
| —— Morrisea, Buv. - - | | | | | | | | 7 | 8 | | | G. O. - | *Pleurotoma longiscata,* Mor. & Lyc. (non Buv.). |
| —— parvula, Roem. - | | | | | | | | 7 | | | | G. O. - | *Actæonina.* |
| —— planata Mor. & Lyc. - | | | | | | | | 7 | | | | G. | |
| —— *rissoides,* Buv. See C. Lycettea. | | | | | | | | | | | | | |
| —— Sowerbyi, Mor. & Lyc. | | | | 3 | | | | 7 | | | | G. N. L. | |
| —— unilineata, Sow. - | | | | | | | | 7 | | | | W. G. | |
| Cerithinella bajocensis, Hudl. | | | | 3 | | | | | | | | D. | |
| —— —— var. drosera, Hudl. | | | | 3 | | | | | | | | D. | |
| —— —— var. melitta, Hudl. | | | | 3 | | | | | | | | D. | |
| —— Brodiei, Hudl. - - | | | | | | | | | | | | G. - | Inf. Ool. |
| Cerithium abbas, Hudl. - | | | | 3 | | | | | | | | D. | |
| —— armatum, Goldf. - | × | 1 | | | | | | | | | | G. | |
| —— attritum, Hudl. - | | | | 3 | | | | | | | | N. L. | |
| —— bathonicum, Lyc. - | | | | | | | | 7 | | | | S. | |
| —— Beani, Mor. & Lyc. - | | | | 3 | | | | | | | | G. N. L. Y. | |
| —— —— var. weldonis, Hudl. | | | | 3 | | | | | | | | N. | |
| —— bulimoides, Desl. - | | | | | | | | 7 | | | | G. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Passage Beds, Midford Sands. Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Inferior Oolite. Am. humphriesianus. | Inferior Oolite. Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mollusca—*cont.* | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| *Gasteropoda*—cont. | | | | | | | | | | | | | |
| Cerithium bussagensis, Witc. | | | | | | | | 7 | | | | G. | |
| —— circe, d'Orb. | | | | | | 5 | | | | | | D. | |
| —— clypeatum, Witc. | | | | | | 5 | | | | | | G. | *Nerinæa.* |
| —— clypeus, Hudl. | | | | | | 5 | | | | | | G. | |
| —— comma, Münst. | | | | | 4 | | | | | | | D. | |
| —— *compositum,* Lyc. See C. portuliferum. | | | | | | | | | | | | | |
| —— *comptonense,* Hudl. See Exelissa. | | | | | | | | | | | | | |
| —— costigerum, Piette | | | | | | | | 7 | 8 | | | D. W. O. L. | Inf. Ool. ? |
| —— cotteswoldiense, Witc. | | | | | | | | 7 | | | | G. | |
| —— exscalptum, Lyc. | | | | | | | | 7 | | | | G. O. | ? Inf. Ool. |
| —— gemmatum, Mor. & Lyc. | | | | 3 | | | | | | | | L. Y. | |
| —— ? geniculatum, Terq. & Jourdy. | | | | | | | | | | | | G. | Inf. Ool. |
| —— Georgei, Hudl. | | | | 3 | | | | | | | | N. | |
| —— hemicinctum, Lyc. | | | | | | | | | 8 | | | W. | |
| —— latisulcatum, Hudl. | | | | 3 | | | | | | | | N. | |
| —— leckhamptonense, Hudl. | | | | | | | | | | | | G. | Inf. Ool. |
| —— limæforme, Roem. | | | | | | | | 7 | | | × | G. | |
| —— —— var. pontonis, Hudl. | | | | 3 | | | | | | | | L. | |
| —— multiforme, Piette | | | | | | | | 7 | | | | O. | |
| —— neglectum, Lyc. | | | | | | | | 7 | | | | G. | |
| —— obesum, Hudl. | | | | | | 5 | | | | | | D. | |
| —— obornense, Hudl. | | | | | 4 | | | | | | | D. | |
| —— pentagonum, d'Arch. | | | | | | | | 7 | | | | G. | |
| —— pergradatum, Hudl. | | | 2 | | | | | | | | | S. | |
| —— pisoliticum, Hudl. | | | ? | 3 | | | | | | | | G. | |
| —— poculum, Lyc. | | | | | | | | 7 | | | | G. | |
| —— polystrophum, Hudl. | | | | 3 | | | | | | | | N. | |
| —— portuliferum, Piette | | | | | | | | 7 | | | | G. | |
| —— *pulchrum,* Lyc. See Exelissa. | | | | | | | | | | | | | |
| —— quadricinctum, Goldf. | | | | 3 | | | | 7 | 8 | | | G. O. L. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. | | Inferior Oolite. | | | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. jurensis. | Am. opalinus. | Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | | | | | | | |
| Mollusca—*cont.* | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| *Gasteropoda*—cont. | | | | | | | | | | | | | |
| Cerithium *Roissyi*, d'Arch. See Fibula. | | | | | | | | | | | | | |
| —— ? sexcostatum, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— *spiculum*, Lyc. See Exelissa. | | | | | | | | | | | | | |
| —— *strangulatum*, d'Arch. See Exelissa. | | | | | | | | | | | | | |
| —— subabbreviatum, d'Orb. | | | | | | 5 | | | | | | D. | |
| —— subcostigerum, Hudl. | | | | 3 | | | | | | | | N. | |
| —— subglabrum, Hudl. - | | | | 3 | | | | | | | | D. | |
| —— subscalariforme, d'Orb. | | | | | 4 | 5 | | | | | | D. S. | |
| —— —— var. spinicostata, Wr. | | | | 3 | | | | | | | | D. O. | |
| —— Tennanti, Mor. & Lyc. | | | | | | | | 7 | | | | W. | |
| —— undulatum, Desl. - | | | | | | | | 7 | | | | G. | |
| —— variabile, Mor. & Lyc. | | | | | | | | 7 | | 9 | | G. O. | |
| —— vetustum, Phil. - | | | | 3 | | 5 | | | | | | D. to Y. - | { *Melania scalariformis*, Desl. *Chemnitzia.* |
| —— —— var. seminuda, Hudl. | | 1 | | | | | | | | | | N. Y. | |
| —— Waltoni, Lyc. - - | | | | | | | | | 8 | | | W. | |
| —— wansfordiæ, Hudl. - | | | | 3 | | | | | | | | N. | |
| —— Witchelli, Lyc. - | | | | | | | | 7 | | | | G. | |
| —— See also Fibula and Turritella. | | | | | | | | | | | | | |
| Chemnitzia *bicarinata*, Wr. See Pseudomelania. | | | | | | | | | | | | | |
| —— ? constricta, Lyc. - | | | | | | | | 7 | | | | W. G. | |
| —— ? hamptonensis, Mor. & Lyc. | | | | | | | | 7 | | | | G. O. | |
| —— *Leckenbyi*, Mor. & Lyc. | | | | | | | | | | | | | |
| —— *lineata*, Sow. - - | | | | | | | | | | | | | |
| —— *Lonsdalei*, Mor. & Lyc. | | | | | | | | | | | | | |
| —— *phasianoides*, Mor. & Lyc. | } See Pseudomelania. | | | | | | | | | | | | |
| —— *procera*, Desl. - - | | | | | | | | | | | | | |
| —— *scarburgensis*, Mor. & Lyc. | | | | | | | | | | | | | |
| —— *simplex*, Mor. & Lyc. - | | | | | | | | | | | | | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Passage Beds, Midford Sands. Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Inferior Oolite. Am. humphriesianus. | Inferior Oolite. Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Mollusca—*cont.* | | | | | | | | | | | | | |
| *Gasteropoda*—cont. | | | | | | | | | | | | | |
| Chemnitzia ? sparsilineata, Witc. | | | | | | | | 7 | | | | G. | |
| —— *turris*, Desl. See Pseudomelania coarctata. | | | | | | | | | | | | | |
| —— *variabilis*, Mor. & Lyc. See Cerithium. | | | | | | | | | | | | | |
| —— *vittata*, Phil. See Pseudomelania. | | | | | | | | | | | | | |
| —— ? Wetherelli, Mor. & Lyc. | | | | 3 | | | | 7 | | | | G. L. | |
| —— sp. | | | | | | | 6 | | | | | D. | |
| —— See also Nerinæa. | | | | | | | | | | | | | |
| Cirrus Calisto, d'Orb. | | | | 3 | | | | | | | | S. G. | |
| —— Etheridgei, Lyc. | | | | | 4 | | | | | | | G. | |
| —— gradatus, Hudl. | | | | 3 | | | | | | | | D. S. | Inf. Ool. |
| —— ? intermedius, J. Buckm. | | | | | | | | | | | | D. | Inf. Ool. |
| —— Leachii, Sow. | | | | 3 | | | | | | | | D. S. | |
| —— nodosus, Sow. | | | | 3 | | | | | | | | D. S. G. | |
| —— pyramidalis, Tawn. | | | | | | | | | | | | S. G. | Inf. Ool. |
| —— varicosus, Hudl. | | | | 3 | | | | | | | | G. | |
| Cloughtonia cincta, Phil. | | | | 3 | | | | | | | | N. Y. | *Phasianella.* |
| *Conus.* See Cylindrites. | | | | | | | | | | | | | |
| Crossostoma ? Pratti, Mor. & Lyc. | | | | ? | | 5 | | ? | | | | S. G. O. L. | |
| —— See also Delphinula and Monodonta. | | | | | | | | | | | | | |
| Cryptaulax contorta, Desl. | | | | | 4 | 5 | | | | | | D. S. G. | *Cerithium.* |
| —— papillosa, Desl. | | | | | | 5 | | | | | | S. | |
| —— scobina, Desl. | × | 1 | 2 | | | | | | | | | D. G. | |
| —— tortilis, Heb. and Desl. | | | | | | 5 | | | | | | D. S. G. | |
| —— (cf.) undulata, Quenst. | × | | | | | 5 | | | | | | D. | |
| Cylindrites acutus, Sow. | | | | ? | | | | 7 | 8 | | | W. G. O. L. | *Actæon.* |
| —— altus, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— angulatus, Mor. & Lyc. | | | | | | | | 7 | | | | G. O. | |
| —— *brevis*, Mor. & Lyc. See Actæonina. | | | | | | | | | | | | | |
| —— bullatus, Mor. & Lyc. | | | | ? | | | | 7 | | | | G. L. | *Conus minimus.* |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Mollusca—*cont.* | | | | | | | | | | | | | |
| *Gasteropoda*—cont. | | | | | | | | | | | | | |
| Cylindrites cuspidatus, Sow. | | | | | | | | 7 | | | | W. G. | |
| —— cylindricus, Mor. & Lyc. | | | | ? | | | | 7 | | | | G. N. L. | |
| —— excavatus, Mor. & Lyc. | | | | | | | | 7 | 8 | 9 | | G. O. Lond.? | |
| —— exiguus, Lyc. | | | | | | | | 7 | | | | G. | |
| —— mammillaris, Lyc. | | | | 3 | | | | | | | | G. | |
| —— pyriformis, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— tabulatus, Lyc. | | | | 3 | | | | | | | | G. N. | |
| —— Thorenti, Buv. | | | | | | | | 7 | | 9 | | D. G. | |
| —— turriculatus, Lyc. | | | | 3 | | | | 7 | | | | G. L. | |
| Delphinula alta, Mor. & Lyc. | | | | 3 | | | | 7 | | | | G. N. | |
| —— ? Buckmani, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— coronata, Sow. | | | | | | | | 7 | | | | W. G. | |
| —— ? funata, Goldf. | | | | 3 | | | | | | | | G. | |
| —— *Pratti*, Mor. & Lyc. See Crossostoma. | | | | | | | | | | | | | |
| —— See also Ataphrus and Monodonta. | | | | | | | | | | | | | |
| Deslongchampsia Eugenei, McCoy. | | | | | | | | 7 | | | | G. | |
| Diartema paradoxum, Desl. | | | | | | | | 7 | | | | G. | *Alaria.* |
| —— ? variciferum, Hudl. | | | | 3 | | | | | | | | L. | |
| Discohelix cotteswoldiæ, Lyc. | | | | 3 | | | | | | | | G. | *Solarium.* |
| —— spinosus, Hudl. | | | | 3 | | | | | | | | D. | |
| —— Waltoni, Lyc. | | | | | | | | 7 | | | | S. | |
| *Ditremaria.* See Trochotoma. | | | | | | | | | | | | | |
| Emarginula alta, Lyc. | | | | 3 | | | | | | | | G. | |
| —— scalaris, Sow. | | | | 3 | | | | 7 | 8 | | | G. W. O. | |
| —— *tricarinata*, Sow. See Rimula. | | | | | | | | | | | | | |
| Eucycloidea bianor, d'Orb. | | | | 3 | | | | | | | | D. | *Purpurina, Turbo.* |
| —— carino-crenata, Lyc. | | | | | | | | | | | | G. | Inf. Ool. |
| *Eulima.* See Bourguetia and Pseudomelania. | | | | | | | | | | | | | |
| *Euomphalus.* See Straparollus. | | | | | | | | | | | | | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Mollusca—*cont.* | | | | | | | | | | | | | |
| *Gasteropoda*—cont. | | | | | | | | | | | | | |
| *Euspira.* See Cloughtonia and Natica. | | | | | | | | | | | | | |
| Exelissa *constricta,* Lyc. See Chemnitzia. | | | | | | | | | | | | | |
| —— formosa, Lyc. | | | | | | | | 7 | | | | W. G. | *Kilvertia.* |
| —— normanniana, d'Orb. | | | | | | 5 | | | | | | D. S. | *Cerithium.* |
| —— pulchra, Lyc. | | | | 3 | | | | 7 | 8 | | | W. L. | *Kilvertia.* |
| —— spicula, Lyc. | | | | | | | | 7 | | | | G. | *Kilvertia.* |
| —— strangulata, d'Arch. | | | | ? | | | | 7 | | | | W. G. | *Cerithium.* |
| —— —— var. ovalis, Hudl. | | | | 3 | | | | | | | | N. | |
| —— —— var. pisolitica, Hudl. | | | | 3 | | | | | | | | G. | |
| —— weldonis, Hudl. | | | | 3 | | | | | | | | N. Y. | *Cerithium comptonense,* Hudl. |
| Fibula angustivoluta, Hudl. | | | | 3 | | | | | | | | N. | |
| —— eulimoides, Whit. | | | | | | | | 7 | | | | G. O. | *Chemnitzia.* |
| —— phasianoides, Mor. & Lyc. | | | | | | | | 7 | | | | G. | *Chemnitzia.* |
| —— ? Roissyi, d'Arch. | | | | | | | | 7 | | | | G. O. | *Cerithium.* |
| —— variata, Lyc. | | | | | | | | 7 | | | | G. O. | |
| Fissurella acuta, Desl. | | | | 3 | | | | 7 | | | | G. | *Rimula.* |
| Fusus ? *carinatus,* Roem. | | | | | | | | | | | | - - - | Doubtful. |
| —— ? *carino-crenatus,* Lyc. See Eucycloidea. | | | | | | | | | | | | | |
| —— ? coronatus, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— ? multicostatus, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— See also Brachytrema. | | | | | | | | | | | | | |
| Hamusina (cf.) *Bertheloti,* d'Orb. See H. oppelensis. | | | | | | | | | | | | | |
| —— Damesi, Gemm. var. babylonica, Hudl. | | | | 3 | | | | | | | | D. S. | |
| —— oppelensis, Lyc. | | | | 3 | | | | | | | | S. G. L. | *Turbo.* |
| Harpagodes Wrighti, Mor. & Lyc. | | | | | | | | 7 | | | | G. | *Pterocera.* |
| *Kilvertia.* See Exelissa. | | | | | | | | | | | | | |
| Littorina ædilis, Münst. | | | | 3 | | | | | | | | D. S. L. | |
| —— *biserta,* Phil. See Amberleya. | | | | | | | | | | | | | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Passage Beds, Midford Sands. Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Inferior Oolite. Am. humphriesianus. | Inferior Oolite. Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mollusca—*cont.* | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| *Gasteropoda*—cont. | | | | | | | | | | | | | |
| Littorina dorsetensis, Hudl. | | | | 3 | | | | | | | | D. G. - | ? var. of *L. ædilis* (Hudleston). |
| —— *ornata*, Sow. See Amberleya. | | | | | | | | | | | | | |
| —— Phillipsi, Mor. & Lyc. | | | | 3 | 4 | 5 | | | 8 | | | D. to Y. | |
| —— pisolitica, Hudl. - | | | | 3 | | | | | | | | G. | |
| —— polytimeta, Hudl. - | | | | 3 | | | | | | | | L. | |
| —— prætor, Goldf. - - | | | | 3 | | | | | | | | D. S. | |
| —— recteplanata, Tawn. - | | | | 3 | | | | | | | | S. G. | |
| —— (cf.) sulcata, Héb. & Desl. | | | | | | 5 | | | | | | D. | |
| —— triarmata, Héb. & Desl. | | | | ? | | | | | | | | D. | |
| —— weldonis, Hudl. - | | | | 3 | | | | | | | | L. | |
| —— sp. - - - | | | | | | | | | | 9 | | D. | |
| Lobostoma involutum, Lyc. | | | | | | | | 7 | | | | O. - - | *Nerita.* |
| —— texatum, Lyc. - - | | | | | | | | 7 | 8 | | | S. O. W. - | *Natica.* |
| Malaptera Bentleyi, Mor. & Lyc. | | | | 3 | | | | | | | | N. L. - | *Pterocera.* |
| —— —— var. neglecta, Hudl. | | | | 3 | | | | | | | | N. L. | |
| —— ? ignobilis, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| *Mathilda.* See Turritella. | | | | | | | | | | | | | |
| *Melania.* See Cerithium and Pseudomelania. | | | | | | | | | | | | | |
| Monodonta arata, Lyc. - | | | | | | | | | 8 | | | W. | |
| —— *comma*, Lyc. See Ataphrus. | | | | | | | | | | | | | |
| —— composita, Lyc. - | | | | | | | | 7 | | | | G. | |
| —— *decussata*, Mor. & Lyc. See Turbo obtusus. | | | | | | | | | | | | | |
| —— *discoidea*, Mor. & Lyc. See Ataphrus. | | | | | | | | | | | | | |
| —— ? exigua, Lyc. - - | | | | | | | | 7 | | | | G. | |
| —— formosa, Mor. & Lyc. - | | | | | | | | 7 | | | | G. O. - | Inf. Ool. |
| —— *heliciformis*, Lyc. See Ataphrus. | | | | | | | | | | | | | |
| —— imbricata, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— *Labadyei*, d'Arch. } See Ataphrus. | | | | | | | | | | | | | |
| —— *lævigata*, Sow. } See Ataphrus. | | | | | | | | | | | | | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. | | Inferior Oolite. | | | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. jurensis. | Am. opalinus. | Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | | | | | | | |
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Mollusca—*cont.* | | | | | | | | | | | | | |
| *Gasteropoda*—cont. | | | | | | | | | | | | | |
| Monodonta Lycetti, Whit. | | | | | | | | | 8 | | | O. | |
| —— Lyelli, d'Arch. - | | | | 3 | | | | 7 | | | | G. L. | |
| —— ? sparsistriata, Lyc. - | | | | | | | | 7 | | | | G. | |
| —— tegulata, Lyc. - - | | | | | | | | | 8 | | | W. | |
| —— *Waltoni*, Lyc. See Ataphrus. | | | | | | | | | | | | | |
| Narica arata, Lyc. - - | | | | | | | | 7 | | | | G. - - | *Natica.* |
| Natica adducta, Phil. - | | | 2 | 3 | 4 | 5 | | | | | | G. L. Y. | |
| —— —— var. globata, Hudl. | | | | 3 | ? | | | | | | | D. G. | |
| —— —— var. oppelensis, Lyc. | | | 2 | | | | | | | | | G. | |
| —— alta, Lyc. - - | | | | | | | | 7 | 8 | | | G. W. - | *Euspira.* |
| —— ambigua, Mor. & Lyc. | | | | | | | | 7 | | | | G. - - | Inf. Ool. |
| —— *arata*, Mor. & Lyc. See Narica. | | | | | | | | | | | | | |
| —— bajocensis, d'Orb. - | | | | | 4 | 5 | | | | | | D. S. G. - | *Euspira.* |
| —— canaliculata, Mor. & Lyc. | | | | 3 | | 5 | | ? | | | | G. O. N. L. Y. | *Euspira.* |
| —— cincta, Phil. - - | | | | 3 | | | | | | | | G. to Y. | |
| —— ? coronata, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— dundriensis, Tawn. - | | | | | 4 | | | | | | | D. S. O. ? - | *Euspira.* |
| —— formosa, Mor. & Lyc. - | | | | | | | | 7 | | | | G. | |
| —— globosa, Roem. - | | | | | | | | 7 | | | | G. O. N. | |
| —— grandis, Goldf. - | | | | | | | | 7 | | | | G. N. | |
| —— hulliana, Lyc. - - | | | | | | 5 | | 7 | | | | S. G. O. | |
| —— insignis, Lyc. - - | | | | | | | | 7 | | | | G. Y. | |
| —— intermedia, Mor. & Lyc. | | | | | | | | 7 | 8 | | | G. O. N. | |
| —— *leckhamptonensis*, Lyc. See N. cincta. | | | | | | | | | | | | | |
| —— (cf.) Lorieri, d'Orb. - | | | | | | | | | | | | D. G. O. - | Inf. Ool. |
| —— —— var. canina, Hudl. | | | | 3 | | | | | | | | N. ? Y. | |
| —— Michelini, d'Arch. - | | | | 3 | | | | 7 | | | | G. O. N. | |
| —— minchinhamptonensis, De Lor. | | | | | | | | 7 | | | | G. O. - | ? var. of *N. Michelini.* |
| —— neritoidea, Mor. & Lyc. | | | | | | | | 7 | | | | G. N. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. | | Inferior Oolite. | | | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. jurensis. | Am. opalinus. | Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | | | | | | | |
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Mollusca—*cont.* | | | | | | | | | | | | | |
| *Gasteropoda*—cont. | | | | | | | | | | | | | |
| Natica *oppelensis*, Lyc. See N. adducta. | | | | | | | | | | | | | |
| —— ? protracta, Hudl. - | | | | | | 5 | | | | | | D. - - | *Euspira.* |
| —— punctura, Bean - | | | | 3 | | | | | | | × | L. Y. | *Littorina.* |
| —— pyramidata, Mor. & Lyc. | | | | | | | 6 | 7 | | | | G. O. N. | |
| —— Sharpei, Mor. & Lyc. - | | | | | | | | 7 | 8 | | | S. G. N. | |
| —— Stricklandi, Mor. & Lyc. | | | | | | 5 | | 7 | | | | G. O. | |
| —— subcanaliculata, Mor. & Lyc. | | | | | | | | 7 | | | | G. - - | *Euspira.* |
| —— subelegans, Hudl. - | | | | | | 5 | | | | | | D. G. | |
| —— Tancredi, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— *texata*, Lyc. See Lobostoma. | | | | | | | | | | | | | |
| —— Verneuili, d'Arch. - | | | | | | | | 7 | | | | G. O. N. | |
| —— ? zelima, d'Orb. - | | | | | | | | | | | | S. - - | Inf. Ool. |
| —— See also Nerita. | | | | | | | | | | | | | |
| Neridomus hemisphæricus, Roem. | | | | | | | | 7 | 8 | | | S. G. W. O. N. | *Nerita.* Inf. Ool.? |
| —— minutus, Sow. - - | | | | | | | | 7 | 8 | | | S. W. G. O. | |
| —— —— var. tumidula, Phil. | | | | 3 | | | | | | | | G. Y. | |
| Nerinæa altivoluta, Witc. | | | | 3 | | | | | | | | G. N. | |
| —— attenuata, Witc. - | | | | 3 | | | | | | | | G. R. | |
| —— bacillus, d'Orb. - | | | | | | 5 | | | | | | S. G. L. - | *Ptygmatis.* |
| —— —— var. carnicotensis, Hudl. | | | | | | 5 | | | | | | S. | |
| —— —— var. cervicula, Hudl. | | | | 3 | | | | | | | | G. N. | |
| —— —— var. crassicincta, Hudl. | | | | 3 | | | | | | | | G. | |
| —— brevivoluta, Hudl. - | | | | 3 | | 5 | | | | | | S. G. N. | |
| —— calcarea, Witc. - | | | | | | | | 7 | | | | G. - - | *N. simplex.* |
| —— campana, Hudl. - | | | | 3 | | | | | | | | R. - - | *Ptygmatis.* |
| —— cingenda, Phil. - | | | | 3 | | | | | | | | G. to Y. | |
| —— *clypeata*, Witc. See Cerithium. | | | | | | | | | | | | | |
| —— complicata, Witc. - | | | | | | | | 7 | | | | G. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Passage Beds, Midford Sands. Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Inferior Oolite. Am. humphriesianus. | Inferior Oolite. Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Mollusca—*cont.* | | | | | | | | | | | | | |
| *Gasteropoda*—cont. | | | | | | | | | | | | | |
| Nerinæa conoidea, Hudl. - | | | | 3 | | | | | | | | G. | |
| —— consobrina, Witc. - | | | | 3 | | | | | | | | G. - - | *Ptygmatis.* |
| —— cotteswoldiæ, Lyc. - | | | | 3 | | | | | | | | G. L. R. - | *Ptygmatis.* |
| —— —— var. conica, Witc. | | | | 3 | | | | | | | | G. to L. | |
| —— deducta, Hudl. - | | | | 3 | | | | | | | | G. | |
| —— Dufrenoyi, d'Arch. - | | | | | | | | 7 | | | | G. O. | |
| —— (cf.) elegantula, d'Orb. | | | | 3 | | | | | | | | L. | |
| —— Eudesi, Mor. & Lyc. - | | | | 3 | | 5 | | 7 | 8 | | | G. to L. Sy. | |
| —— expansa, Hudl. - | | | | 3 | | | | | | | | G. N. L. - | |
| —— funiculus, Desl. - | | | | | | | | 7 | | | | G. O. - | Inf. Ool. ? |
| —— gracilis, Lyc. - - | | | | 3 | | | | | | | | G. N. - | *Chemnitzia. Nerinella.* |
| —— Guisei, Witc. - - | | | | | | 5 | | | | | | S. G. | |
| —— hudlestoniana, Witc. - | | | | 3 | | | | | | | | G. | |
| —— intermedia, Witc. - | | | | | | | | 7 | | | | G. | |
| —— Jonesi, Lyc. - - | | | | 3 | | | | | | | | G. O. N. L. | *Ptygmatis.* |
| —— longfordensis, Hudl. - | | | | 3 | | | | | | | | G. | |
| —— oolitica, Witc. - | | | | 3 | | | | | | | | G. | |
| —— oppelensis, Lyc. - | | | | 3 | | | | | | | | G. - - | *Ptygmatis.* |
| —— parva, Witc. - - | | | | 3 | | | | | | | | G. N. | |
| —— pisolitica, Witc. - | | | | 3 | | | | | | | | G. O. N. - | *Ptygmatis.* |
| —— producta, Witc. - | | | | 3 | | | | | | | | G. - - | *Ptygmatis.* |
| —— pseudocylindrica, d'Orb. | | | | 3 | | | | | | | | G. N. L. | |
| —— pseudopunctata, Cossm. | | | | 3 | | | | 7 | | | | G. L. N. | |
| —— punctata, Voltz - | | | | | | | | 7 | | | | G. O. - | Inf. Ool. |
| —— santonis, Hudl. - | | | | 3 | | | | | | | | G. L. - - | *Ptygmatis.* |
| —— striata, Buckm. - | | | | | | | | 7 | | | | G. | |
| —— Stricklandi, Mor. & Lyc. | | | | ? | | | | 7 | | | | G. O. N. L. | |
| —— stroudiensis, Witc. - | | | | 3 | | | | | | | | G. - | *Ptygmatis.* |
| —— subcingenda, Hudl. - | | | | 3 | | | | | | | | N. L. | |
| —— subglabra, Hudl. - | | | | 3 | | | | | | | | L. | |
| —— velox, Witc. - - | | | | 3 | | | | | | | | G. - - | *Ptygmatis.* |
| —— Voltzi, Desl. - - | | | | | | | | 7 | | | | G. O. N. L. - | Inf. Ool. ? |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Passage Beds, Midford Sands. Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Inferior Oolite. Am. humphriesianus. | Inferior Oolite. Am Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mollusca—*cont.* | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| *Gasteropoda*—cont. | | | | | | | | | | | | | |
| Nerinæa weldonis, Hudl. - | | | | 3 | | | | | | | | N. | |
| —— xenos, Hudl. - - | | | | 3 | | | | | | | | G. - - | *Ptygmatis.* |
| —— zonophora, Hudl. - | | | | 3 | | | | | | | | N. | |
| —— sp. - - - | | | | | | | 6 | | | | | G. | |
| *Nerinella.* See Nerinæa. | | | | | | | | | | | | | |
| Nerita Buvignieri, Mor. & Lyc. | | | | | | | | 7 | 8 | | | D. S. G. W. O. | *Stomatia.* |
| —— cancellata, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— clavatula, Lyc. - | | | | | | | | 7 | | | | G. | |
| —— costulata, Desh. - | | | | 3 | | | | 7 | | | | W. S. O. N. Y. | *N. costata,* Sow. of Inf. Ool. |
| —— *hemisphærica,* Roem. See Neridomus. | | | | | | | | | | | | | |
| —— *involuta,* Lyc. See Lobostoma. | | | | | | | | 7 | | | | O. | |
| —— *minuta,* Sow. See Neridomus. | | | | | | | | | | | | | |
| —— pseudocostata, d'Orb. - | | | | 3 | | | | | | | | G. Y. | |
| —— rugosa, Mor. & Lyc. - | | | | | | | | 7 | 8 | | | D. to O. - | Chipping Norton Limest. |
| Neritopsis bajocensis, d'Orb. | | | | 3 | | | | | | | | S. Y.? | |
| —— *canaliculata,* d'Arch. See Lobostoma. | | | | | | | | | | | | | |
| —— lævigata, Phil. - - | | | | 3 | | | | | | | | S. Y. - | *Nerita.* |
| —— striata, Mor. & Lyc. - | | | | | | | | 7 | | | | G. O. | |
| —— sulcosa, d'Arch. - | | | | | | | | 7 | | | | G. - - | Inf. Ool. |
| —— varicosa, Mor. & Lyc. - | | | | 3 | | | | 7 | | | | G. | |
| Onustus burtonensis, Lyc. | | | | | | | | 7 | 8 | | | D. G. | |
| —— ornatissimus, d'Orb. - | | | | 3 | | | | | | | | D. to Y. - | *Trochus.* |
| —— pyramidatus, Phil. - | | | 2 | 3 | | | | | | | | D. G. Y. - | *Trochus.* |
| *Pagodus.* See Amberleya. | | | | | | | | | | | | | |
| Paludina, sp. - - | | | | | | | 6 | | | | | L. | |
| Patella arachnoidea, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— aubentonensis, d'Arch. | | | | | | | | 7 | | | | G. | |
| —— —— ? var. suprajurensis, Buv. | | | | | | | | 7 | | | | G. | |
| —— cingulata, Goldf. - | | | | | | | | 7 | 8 | 9 | | W. G. O. - | Inf. Ool. |
| —— hamptonensis, Mor. & Lyc. | | | | | | | | 7 | | | | G. - - | *Umbrella?* |

| SPECIES. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | LOCALITIES. | REMARKS. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| MOLLUSCA—*cont.* | | | | | | | | | | | | | |
| *Gasteropoda*—cont. | | | | | | | | | | | | | |
| Patella inornata, Lyc. | | | | 3 | | | | 7 | | | | G. L. | |
| —— lata, Sow. | | | | | | | | 7 | | | | G. O. | |
| —— nana, Sow. | | | | | | | | 7 | | | | W. G. | |
| —— nitida, Desl. | | | | 3 | | | | | | | | G. | |
| —— paradoxa, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— Roemeri, Mor. & Lyc. | | | | | | | | 7 | | | | G. O. | |
| —— rugosa, Sow. | | | | 3 | | | | 7 | | | | W. G. O. L. | |
| —— striatula, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— sulcata, Desl. | | | | | | | | 7 | | | | G. | |
| *Phasianella.* See Bourguetia. | | | | | | | | | | | | | |
| Pileolus lævis, G. B. Sow. | | | | 3 | | | | 7 | | | | S. W. G. | |
| —— plicatus, Sow. | | | | 3 | | | | 7 | | | | W. G. | |
| Pleurotomaria abbreviata, Sow. | | | | | | | | | | | | S. | Inf. Ool. |
| —— Actæa, d'Orb. | | | | 3 | | | | | | | | D. S. | |
| —— actinomphala, Desl. | | | | 3 | | | | | | | | D. S. | |
| —— agatha, d'Orb. | | | | | | | | | | | | D. S. | Inf. Ool. |
| —— Allica, d'Orb. | | | | | | | | | | | | S. | Inf. Ool. |
| —— Amyntas, d'Orb. | | | | | | | | | | | | D. S. | Inf. Ool. |
| —— armata, Münst. | | | | 3 | | | | | | | | D. S. L. | |
| —— bathonica, Lyc. | | | | | | | | | 8 | | | W. | |
| —— Baugieri, d'Orb. | | | | | | | | | | | | D. | Inf. Ool. |
| —— bessina, d'Orb. | | | | 3 | | | | | | | | D. S. | |
| —— blandina, d'Orb. | | | | | | | | | 8 | | | D. | |
| —— burtonensis, Lyc. | | | | | | | | | 8 | | | D. | |
| —— ? clathrata, Goldf. | | | | | | | | 7 | | | | G. | |
| —— composita, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— conoidea, Desh. | | | | 3 | | | | | | | | D. | |
| —— Defrancei, Hudl. & Wils. | | | | | | | | | | | | D. | Inf. Ool. |
| —— discoidea, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— distinguenda, Tawn. | | | | | | | | | | | | S. | Inf. Ool. |
| —— elongata, Sow. | | | | | 4 | | | | | | | D. S. G. | |
| —— fasciata, Sow. | | | | 3 | 4 | 5 | | | | | | D. S. G. L. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. | | Inferior Oolite. | | | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
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| | | Am. jurensis. | Am. opalinus. | Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | | | | | | | |
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Mollusca—*cont.* | | | | | | | | | | | | | |
| *Gasteropoda*—cont. | | | | | | | | | | | | | |
| Pleurotomaria granulata, Sow. | | | | | 4 | | | | | | | D. S. G. - | *Trochus.* |
| —— granulata, Lyc. - | | | | | | | | | | 9 | | H. Y. | |
| —— gyrocycla, Desl. var. saccata, Desl. | | | | 3 | | | | | | | | S. | |
| —— Lycetti, d'Orb. - | | | | | | | | 7 | | | | G. | |
| —— monticulus, Desl. - | | | | | | | | | | | | D. S. - | Inf. Ool. |
| —— *obconica*, Tawn. See P. sulcata. | | | | | | | | | | | | | |
| —— obesa, Desl. - - | | | | | | | | 7 | | | | G. | |
| —— ornata, Sow. - - | | | | 3 | 4 | | | | | | | D. to L. | |
| —— *pagodus*, Desl. See Turbo depauperatus. | | | | | | | | | | | | | |
| —— Palæmon, d'Orb. - | | | | | | | | | | | | D. S. - | Inf. Ool. |
| —— *pallium*, Sow. See P. ornata. | | | | | | | | | | | | | |
| —— phyospira, Desl. - | | | | 3 | | | | | | | | D. S. | |
| —— proteus ?, Desl. - | | | | | 4 | 5 | | | | | | S. | |
| —— punctata, Sow. - | | | | | 4 | | | | | | | D. S. G. | |
| —— recondita, Lyc. - | | | | | | | | 7 | | | | G. | |
| —— *reticulata*, Desl. See P. subreticulata. | | | | | | | | | | | | | |
| —— Sandersi, Tawn. - | | | | | | | | | | | | S. - - | Inf. Ool. |
| —— *scalaris*, Mor. & Lyc. See P. Lycetti. | | | | | | | | | | | | | |
| —— *Stoddarti*, Tawn. See P. gyrocycla. | | | | | | | | | | | | | |
| —— subreticulata, d'Orb. - | | | | 3 | | | | | | | | D. S. L. | |
| —— sulcata, Sow. | | | | 3 | | | | | | | | D. S. G. L. | |
| —— Thiarella, Desl. - | | | | | | | | | 8 | | | W. | |
| —— yeovilensis, Tawn. - | | | | | | | | | | | | D. - - | Inf. Ool. |
| Pseudalaria Etheridgei, Tawn. | | | | 3 | | | | | | | | D. S. | |
| —— —— var. granosa, Hudl. | | | | | | | | | | | | D. - - | Inf. Ool. |
| Pseudomelania astonensis, Hudl. | | | | 3 | | 5 | | | | | | G. L. | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Mollusca—*cont.* | | | | | | | | | | | | | |
| *Gasteropoda*—cont. | | | | | | | | | | | | | |
| Pseudomelania bicarinata, (Wr. MS.) Hudl. | | | | 3 | 4 | | | | | | | D. G. | |
| —— burtonensis, Hudl. - | | | | | | 5 | | | | | | D. | |
| —— coarctata, Desl. - | | | | | 4 | 5 | | | | | | D. G. - | *Melania turris*, Desl. *Chemnitzia.* |
| —— communis, Mor. & Lyc. | | | | | | | | 7 | 8 | | | D. G. O. - | *Eulima.* |
| —— heterocycla, E. Desl. - | | | | 3 | | | | | | | | D. S. G. - | *Chemnitzia.* |
| —— ? Leckenbyi, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— lineata, Sow. - - | | | | | 4 | 5 | | | | | | D. S. - | *Melania. Chemnitzia.* |
| —— Lonsdalei, Mor. & Lyc. | | | | | | | | 7 | | | | G. Y. (Inf. Ool.) | *Chemnitzia.* |
| —— phasianoides, Mor. & Lyc. | | | | | | | | 7 | | | | G. - - | *Chemnitzia.* |
| —— procera, Desl. - - | | | 2 | 3 | 4 | | | | | | | D. S. G. L. Y. | *Melania lineata*, Sow. *Chemnitzia.* |
| —— —— var. minor, Hudl. | | | | | | 5 | | | | | | D. | |
| —— —— var. pinguis, Hudl. | | | | 3 | | | | | | | | S. | |
| —— robusta, Hudl. - | | | 2 | | | | | | | | | G. - - | Unique. |
| —— scarburgensis, Mor. & Lyc. | | | | | | | | | | | | D. Y. - | Inf. Ool. |
| —— simplex, Mor. & Lyc. - | | | | 3 | | | | 7 | | 9 | | G. H. - | *Chemnitzia.* |
| —— vagans, Mor. & Lyc. - | | | | | | | | 7 | | | | G. - - | *Eulima pygmæa*, Mor. & Lyc. |
| —— vittata, Phil. - - | | | | 3 | | | | | | 9 | | S. N. H. Y. | *Chemnitzia.* |
| *Pterocera.* See Harpagodes and Malaptera. | | | | | | | | | | | | | |
| *Ptygmatis.* See Nerinæa. | | | | | | | | | | | | | |
| Purpurina aspera, Hudl. - | | | | 3 | | | | | | | | D. | |
| —— bellona, d'Orb. - | | | | | 4 | 5 | | | | | | D. S. G. | |
| —— —— var. pagoda, Hudl. | | | | | 4 | 5 | | | | | | D. S. | |
| —— *bianor*, d'Orb. See Eucycloidea. | | | | | | | | | | | | | |
| —— calcar, Hudl. - - | | | | 3 | | | | | | | | D. | |
| —— cancellata, Hudl. | | | | 3 | | | | | | | | D. S. | |
| —— *carino-crenata*, Lyc. See Eucycloidea. | | | | | | | | | | | | | |
| —— curta, Hudl. - - | | | | | 4 | | | | | | | D. S. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Mollusca—*cont.* | | | | | | | | | | | | | |
| *Gasteropoda*—cont. | | | | | | | | | | | | | |
| Purpurina elaborata, Lyc. - | | | | 3 | | | | 7 | | | | D. G. L. Y. | *Turbo.* |
| —— —— var. aperta, Hudl. | | | | 3 | | | | | | | | G. | |
| —— inflata, Tawn. - - | | | | | 4 | 5 | | | | | | D. S. G. | |
| —— parcicosta, Hudl. - | | | | | | | | | | | | D. - - | Inf. Ool. |
| —— rotunda, Hudl. - | | | | 3 | | | | | | | | D. S. | |
| —— (cf.) Sowerbyi, Waag. | | | | 3 | | | | | | | | D. | |
| —— tabulata, Hudl. - | | | | 3 | | | | | | | | D. S. | |
| Purpuroidea glabra, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— insignis, Lyc. - - | | | | | | | | 7 | | | | G. | |
| —— Lycettea, Hudl. & Wils. | | | | | | | | 7 | | | | G. | |
| —— Morrisea, Buv. - | | | | | | | | 7 | | | | G. - - | *P. moreausea*, Mor. & Lyc. *Purpurina.* |
| —— *nodulata*, Y. & B. See P. Lycettea. | | | | | | | | | | | | | |
| *Ranella.* See Spinigera. | | | | | | | | | | | | | |
| Rimula Bloti, Desl. - | | | | 3 | | | | 7 | | | | W. G. L. - | *Emarginula.* |
| —— clathrata, Sow. - | | | | 3 | | | | 7 | | | | W. G. L. | |
| —— tricarinata, Sow. - | | | | 3 | | | | 7 | | | | W. G. - | *Emarginula.* |
| —— See also Emarginula and Fissurella. | | | | | | | | | | | | | |
| Rissoa? exigua, Lyc. - | | | | | | | | 7 | | | | G. | |
| —— lævis, Sow. - - | | | | ? | | | | 7 | 8 | | | W. G. O. | |
| —— See also Rissoina. | | | | | | | | | | | | | |
| Rissoina acuta, Sow. - | | | | | | | | 7 | | | | W. G. O. - | *Rissoa.* |
| —— cancellata, Mor. & Lyc. | | | | ? | | | | 7 | | | | G. L. | |
| —— duplicata, Sow. - | | | | | | | | 7 | 8 | | | W. G. O. | |
| —— gymnoides, Hudl. - | | | | 3 | | | | | | | | N. | |
| —— Milleri, Lyc. - - | | | | | | | | 7 | | | | G. | |
| —— obliquata, Sow. - | | | | 3 | | | | 7 | | | | W. G. N. L. | *Rissoa.* |
| —— —— var. parcicostata, Hudl. | | | | 3 | | | | | | | | N. | |
| —— obtusa, Lyc. - - | | | | 3 | | | | | | | | G. | |
| —— subulata, Lyc. - | | | | | | | | | 8 | | | W. | |
| —— tricarinata, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— tumidula, Lyc. - | | | | | | | | 7 | | | | G. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. | | Inferior Oolite. | | | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. jurensis. | Am. opalinus. | Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | | | | | | | |
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Mollusca—*cont.* | | | | | | | | | | | | | |
| *Gastercpoda*—cont. | | | | | | | | | | | | | |
| Rissoina Witchelli, Lyc. - | | | | | | | | 7 | | | | G. | |
| *Rostellaria*. See Alaria. | | | | | | | | | | | | | |
| *Scalaria*. See Chemnitzia. | | | | | | | | | | | | | |
| Solarium *bathonicum*, Lyc. See Straparollus. | | | | | | | | | | | | | |
| —— *cotswoldiæ*, Lyc. See Discohelix. | | | | | | | | | | | | | |
| —— diadema, Hudl. - | | | | 3 | | | | | | | | G. | |
| —— *disculum*, Mor. & Lyc. See Straparollus. | | | | | | | | | | | | | |
| —— pisoliticum, Hudl. - | | | | 3 | | | | | | | | G. | |
| —— polygonium, d'Arch. - | | | | | | | | 7 | | | | G. | |
| —— polygonoides, Hudl. - | | | | | | 5 | | | | | | O. | |
| —— turbiniforme, Lyc. - | | | | | | | | 7 | | | | S. W. | |
| —— varicosum, Mor. & Lyc. | | | | | | | | 7 | | | | G. O. | |
| —— *Waltoni*, Lyc. See Discohelix. | | | | | | | | | | | | | |
| —— subvaricosum, Hudl. | | | | | | 5 | | | | | | D. S. G. | |
| Spinigera crassa, Hudl. - | | | | | 4 | | | | | | | D. | |
| —— didactyla, Hudl. - | | | | 3 | | | | | | | | D. | |
| —— longispina, Desl. - | | | | | 4 | | | | | | | D. S. - | *Ranella*. |
| —— recurva, Hudl. - | | | | | | 5 | | | | | ? | D. | |
| —— trinitatis, Tawn. - | | | | 3 | | | | | | | | D. S. - | *Alaria*. |
| *Stomatia*. See Nerita. | | | | | | | | | | | | | |
| Straparollus (cf.) altus, d'Orb. | | | | | | | | | | | | D. - - | Inf. Ool. |
| —— bathonicus, Lyc. - | | | | | | | | 7 | | | | S. G. - | *Solarium*. |
| —— disculum, Mor. & Lyc. | | | | | | 5 | | 7 | | | | G. | |
| —— dundriensis, Tawn. - | | | | 3 | | | | | | | | S. | |
| —— exsertus, Hudl. - | | | | 3 | | | | | | | | D. S. | |
| —— pulchrior, Hudl. - | | | | 3 | | | | | | | | D. S. | |
| —— tuberculosus (dexter), Thorent. | | | | 3 | | 5 | | | | | | D. S. L. | |
| *Tornatella*. See Actæonina. | | | | | | | | | | | | | |
| Trochotoma acuminata, Desl. | | | | | | | | 7 | | | | G. | |
| —— calix, Phil. - - | | | 2 | 3 | 4 | | | | | | | D. G. L. Y. - | *Solarium*. |

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| | | Am. jurensis. | Am. opalinus. | Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | | | | | | | |
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Mollusca—*cont.* | | | | | | | | | | | | | |
| *Gasteropoda*—cont. | | | | | | | | | | | | | |
| Trochotoma carinata, Lyc. | | | | 3 | | 5 | | | | | | G. | |
| —— conuloides, Desl. - | | | | | | | | 7 | | | | G. | |
| —— *discoidea*, Roem. See T. tornata. | | | | | | | | | | | | | |
| —— extensa, Mor. & Lyc. - | | | | 3 | | | | 7 | | | | G. L. | |
| —— gradus, Desl. - | | | | | | | | | | | | S. ? - - | Inf. Ool. |
| —— obtusa, Mor. & Lyc. - | | | | | | | | 7 | | | | G. | |
| —— tabulata, Mor. & Lyc. - | | | | | | | | 7 | | | | G. | |
| —— tornata, Phil. - - | | | | | | | | 7 | | | × | G. | |
| Trochus acis, d'Orb. - | | | | 3 | | | | | | | | L. | |
| —— ? anceus, Goldf. - | | | | | | | | 7 | | | | G. | |
| —— angulatus, Sow. - | | | | | | | | | | | | G. - - | Inf. Ool. |
| —— *Belus*, d'Orb. See Ataphrus. | | | | | | | | | | | | | |
| —— biarmatus, Münst. - | | | | | | | | | | | | D. S. - | Inf. Ool. |
| —— bicingendus, Lyc. - | | | | 3 | | | | | | | | G. | |
| —— *bijugatus*, Quenst. See Turbo. | | | | | | | | | | | | | |
| —— Bunburyi, Mor. & Lyc. | | | | | | | | 7 | | 9 | | G. | |
| —— burtonensis, Lyc. - | | | | | | | | 7 | 8 | | | D. L. | |
| —— ? clypeatus, Witc. - | | | | | | 5 | | | | | | G. | |
| —— dimidiatus, Sow. - | | | | | | | | | | | | G. - - | Inf. Ool. |
| —— Dunkeri, Mor. & Lyc. - | | | | 3 | | | | 7 | | | | G. L. | |
| —— duplicatus, Sow. - | | 1 | | 3 | | | | | | | | D. S. G. L. | |
| —— Guisei, Lyc. - - | | | | | | | | 7 | | | | G. | |
| —— Ibbetsoni, Mor. & Lyc. | | | | 3 | | | | 7 | 8 | | | G. O. L. | |
| —— ? Leckenbyi, Mor. & Lyc. | | | | 3 | | | | | | | | L. Y. | |
| —— monilitectus, Phil. - | | | | 3 | | 5 | | | | | | G. O. L. Y. | |
| —— niortensis, d'Orb. - | × | | | | | | | | | | | S. - - | Inf. Ool. |
| —— obsoletus, Roem. - | | | | | | | | 7 | | | × | G. | |
| —— *pileolus*, Mor. & Lyc. See Turbo obtusus. | | | | | | | | | | | | | |
| —— *plicatus*, d'Arch. See Amberleya. | | | | | | | | | | | | | |
| —— Sandersi, Tawn. - | | | | | | | | | | | | S. - - | Inf. Ool. |

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| | | Am. jurensis. | Am. opalinus. | Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | | | | | | | |
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| MOLLUSCA—*cont.* | | | | | | | | | | | | | |
| *Gasteropoda*—*cont.* | | | | | | | | | | | | | |
| Trochus spiratus, d'Arch. - | | | | 3 | | | | 7 | 8 | | | G. O. N. L. | |
| —— squamiger, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— subduplicatus, d'Orb. - | | | | | | | | | | | | D. S. - | *Turbo.* Inf. Ool. |
| —— Winwoodi, Tawn. - | | | | | | | | | | | | S. - - | Inf. Ool. |
| —— Zetes, d'Orb. - - | | | | | 4 | | | | | | | D. S. | |
| —— See also Littorina, Onustus, and Turbo. | | | | | | | | | | | | | |
| Turbo ? bijugatus, Quenst. | | | | 3 | | | | | | | | L. | |
| —— burtonensis, Lyc. - | | | | | | | | 7 | 8 | | | D. W. | |
| —— depauperatus, Lyc. - | | | | | | | | 7 | 8 | | | W. G. - | *Trochus.* *Pleurotomaria pagodus* var. (of M. & L.). |
| —— *dundriensis*, Tawn. See Amberleya. | | | | | | | | | | | | | |
| —— *elaboratus*, Lyc. See Purpurina | | | | | | | | | | | | | |
| —— *Etheridgei*, Lyc. See Cirrus. | | | | | | | | | | | | | |
| —— *gemmatus*, Lyc. See Amberleya. | | | | | | | | | | | | | |
| —— Gomondei, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— hamptonensis, Mor. & Lyc. | | | | | | | | 7 | | | | G. O. - | Inf. Ool. |
| —— *lævigatus.* See Ataphrus and Neritopsis. | | | | | | | | | | | | | |
| —— obtusus, Sow. - - | | | | | | | | 7 | 8 | | | W. G. - | *T. pileolus*, M. & L. |
| —— *oppelensis*, Lyc. See Hamusina. | | | | | | | | | | | | | |
| —— *Phillipsi*, Mor. & Lyc. See Littorina. | | | | | | | | | | | | | |
| —— *princeps*, Roem. See Amberleya. | | | | | | | | | | | | | |
| —— Shaleri, Tawn. - - | | | | 3 | | | | | | | | D. S. | |
| —— Sharpei, Mor. & Lyc. - | | | | | | | | 7 | | | | G. | |
| —— Stoddarti, Tawn. - | | | | | | | | | | | | S. - - | Inf. Ool. |
| —— subtexatus, Lyc. - | | | | | | | | | 8 | | | S. - - | *Trochus.* |
| Turritella abbas, Hudl. - | | | | 3 | | | | | | | | D. G. - | *Mathilda.* |
| —— (cf.) binaria, Héb. & Desl. | | | | 3 | | | | | | | | D. | |

LIBRARY OF THE UNIVERSITY

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. | | Inferior Oolite. | | | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. jurensis. | Am. opalinus. | Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | | | | | | | |
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Mollusca—*cont.* | | | | | | | | | | | | | |
| *Gasteropoda*—cont. | | | | | | | | | | | | | |
| Turritella dorsetensis, Hudl. | | | | 3 | | | | | | | | D. G. | |
| —— opalina, Quenst. - | | | 2 | 3 | | | | | | | | D. Y. ? - | *Mathilda.* |
| —— —— var. canina, Hudl. | | | | 3 | | | | | | | | D. Y | |
| —— quadrivittata, Phil. - | | | | 3 | | | | | | | | D. N. Y. - | *Cerithium, Mathilda.* |
| —— (cf.) Schlumbergeri, E. Desl. | | | | 3 | | | | | | | | D. | |
| —— strangulata, Hudl. - | | | | 3 | | | | | | | | D. - - | *Mathilda.* |
| *Umbrella.* See Patella. | | | | | | | | | | | | | |
| *Scaphopoda.* | | | | | | | | | | | | | |
| Dentalium entaloides, Desl. | | | | | | 5 | | | | | | O. Y. - | *D. Parkinsoni*, Quenst. |
| *Lamellibranchiata.* | | | | | | | | | | | | | |
| *Alectryonia.* See Ostrea. | | | | | | | | | | | | | |
| *Amphidesma.* See Myacites. | | | | | | | | | | | | | |
| Anatina pinguis, Ag. - | | | | | | | | | | | | G. - - | Inf. Ool. |
| —— plicatella, Mor. & Lyc. | | | | | | | 6 | 7 | | 9 | | D. to Y. | |
| —— siliqua, Ag. - - | | | | | | | 6 | 7 | | 9 | × | D. S. G. Y. - | { *A. undulata*, Sow. Inf. Ool. |
| *Anomia.* See Placunopsis. | | | | | | | | | | | | | |
| Arca æmula, Phil. - - | | | | 3 | | | | 7 | | 9 | × | G. O. L. | |
| —— —— var. transversa, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— æquata, Whidb. - | | | | 3 | | | | | | | | G. | |
| —— carinata, K. & D. - | | | | | | | | | | | | G. - - | Inf. Ool. |
| —— culmotecta, Whidb. - | | | | | | | | | | | | S. G. - | Inf. Ool. |
| —— Eudesi, Mor. & Lyc. - | | | | 3 | | | | | | | | G. O. N. L. | |
| —— Kilverti, Mor. & Lyc. - | | | | | | | | 7 | | | | G. | |
| —— lata, Dunk. - - | | | | 3 | | | 6 | | | | | G. | |
| —— minuta, Sow. - - | | | | | | 5 | | 7 | 8 | | | W. G. O. | |
| —— oblonga, Goldf. - | | | | | | | | | | | | S. L. - | Inf. Ool. |
| —— Pratti, Mor. & Lyc. - | | | | 3 | | 5 | 6 | 7 | | | | D. W. G. O. L. | |
| —— pulchra, Sow. - - | | | | 3 | | 5 | | 7 | | | | W. G. O. L. | |
| —— rudis, Sow. - - | | | | 3 | | | | 7 | | | | D. W. G. | |
| —— rugosa, Mor. & Lyc. - | | | | | | | 6 | 7 | | 9 | | G. O. L. - | ? var. of *A. Pratti.* |
| —— tenuitexta, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Mollusca—*cont.* | | | | | | | | | | | | | |
| *Lamellibranchiata*—cont. | | | | | | | | | | | | | |
| *Arcomya.* See Myacites. | | | | | | | | | | | | | |
| Astarte aliena, Phil. | | | | | | | | | | 9 | × | O. | |
| —— anatiformis, Whidb. | | | | | | | | | | | | G. | Inf. Ool. |
| —— angulata, Mor. & Lyc. | | | | | | | | 7 | | | | D. G. O. L. | Inf. Ool. |
| —— aytonensis, Lyc. | | | | | | | | 7 | | | × | S. | |
| —— bathonica, Lyc. | | | | | | 5 | | 7 | | | | S. O. | |
| —— bullata, Lyc. | | | | 3 | | | | | | | | G. | |
| —— clypeata, Witc. | | | | | | 5 | | | | | | G. | |
| —— crassitesta, Roem. | | | | | 4 | 5 | | | | | | D. | *A. Manseli*, J. Buckm. |
| —— depressa, Goldf. | | | 2 | 3 | | 5 | | 7 | | 9 | × | D. to L. | |
| —— —— var. depressior, Witc. | | | | | | 5 | | | | | | G. | |
| —— —— var. rodborensis, Witc. | | | | | | 5 | | | | | | G. | |
| —— detrita, Goldf. | | | 2 | | 4 | | | | | | | G. | |
| —— elegans, Sow. | | | | 3 | 4 | 5 | | | | 9 | | D. to Y. | |
| —— —— var. munda, Whidb. | | | | | | | | | | | | S. | Inf. Ool. |
| —— elongata, S. Buckm. | | | | 3 | | 5 | | | | | | D. | |
| —— excavata, Sow. | | | 2 | 3 | 4 | 5 | | | | | | D. to Y. | *A. complanata*, Roem. |
| —— —— var. compressiuscula, Mor. & Lyc. | | | | | | | | 7 | 8 | | | S. G. W. | Inf. Ool. |
| —— excentrica, Mor. & Lyc. | | | | 3 | | | | 7 | | | | G. L. | |
| —— expansa, S. Buckm. | | | | | | 5 | | | | | | D. | |
| —— fimbriata, Lyc. | | | | | | | | 7 | 8 | | | D. S. G. W. | |
| —— flexicostata, Lyc. | | | | | | | | 7 | | | | G. | |
| —— globata, S. Buckm. | | | | | | 5 | | | | | | D. | |
| —— Goldfussi, Oppel | | | | | | | | | | | | D. | Inf. Ool. |
| —— hilpertonensis, Lyc. | | | | | | | | | | 9 | | W. | "*A. hilpertensis.*" |
| —— ? ignota, Lyc. | | | | | | | | | 8 | | | W. | |
| —— interlineata, Lyc. | | | | 3 | | 5 | | 7 | 8 | | | G. O. | *Hiatella.* |
| —— lurida, Sow. | × | 1 | 2 | 3 | | | | | | | × | S. G. | |
| —— magnalis, Whidb. | | | | | | 5 | | | | | | G. | *A. cordiformis*, Lyc. (non Desh.) |
| —— minima, Phil. | | | | 3 | 4 | 5 | | 7 | 8 | | × | S. to Y. | |
| —— multicostata, S. Buckm. | | | | | | 5 | | | | | | D. S. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. | | Inferior Oolite. | | | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. jurensis. | Am. opalinus. | Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | | | | | | | |
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Mollusca—*cont.* | | | | | | | | | | | | | |
| *Lamellibranchiata*—cont. | | | | | | | | | | | | | |
| Astarte obliqua, Desh. | | | | | 4 | 5 | | | | | | D. S. | |
| —— orbicularis, Sow. | | | | 3 | | | | 7 | | | | S. G. W. | |
| —— planata, Sow. | | | | | 4 | 5 | | | | | | D. S. | |
| —— pontonis, Lyc. | | | | 3 | | | | | | | | L. | |
| —— pulchra, S. Buckm. | | | | | | 5 | | | | | | D. | |
| —— pumila, Sow. | | | | | | | | 7 | | | | W. O. G. | |
| —— quadrata, Lyc. | | | | 3 | | | | | | | | G. | |
| —— recondita, Phil. | | | | 3 | | | | | | | | L. Y. | *Pullastra.* |
| —— rhomboidalis, Phil. | | | | 3 | | 5 | | 7 | | | × | D. G. L. | |
| —— rotunda, Mor. & Lyc. | | | | | | | 6 | 7 | | 9 | | D. S. G. | *A. orbicularis,* Sow., pars. |
| —— rugulosa, Lyc. | | | 2 | | | | | | | | | G. | |
| —— rustica (Walton MS.), Lyc. | | | | | | | | 7 | 8 | 9 | | S. W. G. O. | Inf. Ool. |
| —— spissa, S. Buckm. | | | | | | 5 | | | | | | D. S. | |
| —— squamula, d'Arch. | | | | 3 | | | | 7 | | | | G. O. L. | sp. ? in Inf. Ool. |
| —— subangulata, Witc. | | | | | | 5 | | | | | | G. | |
| —— subquadrata, S. Buckm. | | | | | | 5 | | | | | | D. | |
| —— subtrigona, Goldf. | | | | | | 5 | | | | | | G. | |
| —— sufflata, Roem. | | | | | | | | | | | | S. | Inf. Ool. |
| —— tumida, S. Buckm. | | | | | | 5 | | | | | | D. | |
| —— ungulata, Lyc. | | | | | | 5 | | | | 9 | × | D. S. L. Y. | *A. lurida,* Phil. (non Sow.). |
| —— Wiltoni, Mor. & Lyc. | | | | 3 | | | | 7 | | | | G. O. L. | |
| —— See also Opis. | | | | | | | | | | | | | |
| Avicula braamburiensis, Sow. | | | | 3 | | | | | | 9 | × | O. N. L. Y. | |
| —— clathrata, Lyc. | | | | | | 5 | | 7 | | | | G. O. | |
| —— complicata, Buckm. | | | | 3 | 4 | | | | | | | G. | |
| —— costata, Sow. | | | | | | | 6 | 7 | 8 | 9 | | D. S. W. G. O. | |
| —— digitata, Desl. | | | | | | 5 | | | | | | G. | |
| —— echinata, Sow. | | | | | | | 6 | 7 | 8 | 9 | × | D. to Y. | |
| —— elegans, Münst. | | | | 3 | | | | | | | | N. | |
| —— inæquivalvis, Sow. | × | 1 | 2 | 3 | 4 | 5 | | | | | × | D. to Y. | *Monotis.* |
| —— Münsteri, Goldf. | | | | 3 | | 5 | 6 | 7 | | 9 | × | D. to Y. | *Oxytoma.* |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| MOLLUSCA—*cont.* | | | | | | | | | | | | | |
| *Lamellibranchiata*—cont. | | | | | | | | | | | | | |
| Avicula subcostata, Roem. | | | | | | | | 7 | | | | G. | |
| Cardium Buckmani, Mor. & Lyc. | | | | 3 | 4 | 5 | 6 | 7 | 8 | 9 | | D. to L. - | *C. lævigatum*, Lyc. |
| —— citrinoideum, Phil. - | | | | | | 5 | | | | 9 | | G. O. H. Y. | |
| —— cognatum, Phil. - | | | | 3 | | 5 | 6 | 7 | | 9 | × | D. W. to Y. | |
| —— —— var. clypeata, Witc. | | | | | | 5 | | | | | | G. | |
| —— concinnum, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— cordiforme, Lyc. - | | | | 3 | | | | | | | | G. | |
| —— dundriense, Whidb. - | | | | | | | | | | | | S. - - | Inf. Ool. |
| —— Hulli, Wright - - | | | 2 | | | | | | | | | G. | |
| —— incertum, Phil. - | | | | | | | | 7 | | | | O. G. L. | |
| —— lingulatum, Lyc. - | | | | | | | | 7 | | | | O. | |
| —— pes-bovis, d'Arch. - | | | | | | | | 7 | | | | G. | |
| —— pulsatum, Whidb. - | | | | 3 | | | | | | | | S. L. | |
| —— semicostatum, Lyc. - | | | | 3 | | | | 7 | | | | G. | |
| —— Stricklandi, Mor. & Lyc. | | | | | | | 6 | 7 | 8 | 9 | | S. to L. - | *C. striatum*, Buckm. & Strickl. |
| —— substriatulum, d'Orb. | × | 1 | | 3 | | | | | | | | G. O. Y. | |
| —— subtrigonum, Mor. & Lyc. | | | | | | | 6 | 7 | | 9 | | G. O. L. - | Inf. Ool. |
| —— Witchelli, Lyc. - | | | | | | | | 7 | | | | G. | |
| *Cercomya.* See Anatina. | | | | | | | | | | | | | |
| Ceromya bajociana, d'Orb. | | | 2 | 3 | 4 | 5 | 6 | 7 | | | | D. to Y. | |
| —— concentrica, Sow. - | | | | 3 | | | 6 | 7 | 8 | 9 | | D. to L. | |
| —— excentrica, Ag. - | | | | | | | | 7 | | | × | G. | |
| —— plicata, Ag. - - | | | | | | 5 | 6 | 7 | | | | D. S. G. - | Inf. Ool. (var.) |
| —— similis, Lyc. - - | | | | 3 | | | | 7 | | | | G. R. L. | |
| —— striata, Sow. - - | | | | 3 | | 5 | 6 | | | | | G. - - | *Cardita.* |
| —— Symondsi, Mor. & Lyc. | | | | | | | | 7 | | | | G. O. N. L. | Inf. Ool. |
| —— undulata, Mor. & Lyc. | | | | | | 5 | | 7 | | | | S. G. O. | |
| Corbicella bathonica, Mor. & Lyc. | | | | 3 | | | | 7 | | | | G. O. N. | |
| —— compressiuscula, Lyc. | | | | | | 5 | | | | | | G. | |
| —— ovalis, Phil. - | | | | 3 | | | | | | 9 | × | G. Y. - | *Corbis.* |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Passage Beds, Midford Sands. Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Inferior Oolite. Am. humphriesianus. | Inferior Oolite. Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Mollusca—*cont.* | | | | | | | | | | | | | |
| *Lamellibranchiata*—cont. | | | | | | | | | | | | | |
| Corbicella subæquilatera, Lyc. | | | | | | 5 | | | | | | G. | |
| —— subangulata, Lyc. - | | | | | | | | | 8 | | | W. | |
| —— tumidula, Lyc. - | | | | | | 5 | | | | | | G. | |
| Corbis aspera, Lyc. - - | | | | 3 | | | | 7 | | | | G. | |
| —— elliptica, Lyc. - - | | | | | | | | | 8 | | | O. | |
| —— Lajoyei, d'Arch. - | | | | | | | 6 | 7 | | | | D. G. O. | |
| —— —— var. cingenda, Mor. & Lyc. | | | | 3 | | | | 7 | | | | G. L. | |
| —— Neptuni, Lyc. - - | | | | | | | | 7 | | | | G. | |
| —— rotunda, Lyc. - - | | | | 3 | | | | 7 | | | | S. W. L. | |
| Corbula agatha, d'Orb. - | | | | | | | | | 8 | | | W. G. | |
| —— attenuata, Lyc. - | | | | | | 5 | | 7 | 8 | | | D. W. O. | |
| —— Buckmani, Lyc. - | | | | | | 5 | | 7 | 8 | | | G. O. - | *C. involuta,* Münst. |
| —— hulliana, Mor. - - | | | | | | | | 7 | 8 | | | S. G. O. | |
| —— imbricata, Lyc. - | | | | 3 | | | | | | | | G. | |
| —— involuta, Münst. - | | | | 3 | | | | 7 | 8 | 9 | | G. O. Y. - | *C. striata,* Buckm. |
| —— islipensis, Lyc. - - | | | | | | | | 7 | 8 | 9 | | S. O. | |
| —— MacNeilli, Mor. - | | | | | | | | | 8 | 9 | | O. | |
| —— See also Tancredia and Unicardium. | | | | | | | | | | | | | |
| *Corimya.* See Thracia. | | | | | | | | | | | | | |
| Crassatella oolitica, Tate - | | | | | | | | | | | | G. - - | Inf. Ool. |
| Cucullæa cancellata, Phil. - | × | | | 3 | 4 | 5 | | | | | | D. to Y. - | *C. obliqua,* Lyc. |
| —— concinna, Phil. - | | | | | | 5 | 6 | 7 | | | × | D. G. O. L. | |
| —— cucullata, Goldf. - | | | | 3 | | | | 7 | | | | G. L. - | *Arca.* |
| —— elongata, Sow. - | × | | | 3 | | | | | | | × | G. Y. | |
| —— ferruginea, Lyc. - | × | 1 | 2 | | | | | | | | | G. | |
| —— Goldfussi, Roem. - | | | | | | | | 7 | | | | G. | |
| —— lævis, Buckm. - - | | | | | | | | | | | | D. G. - | Inf. Ool. |
| —— oblonga, Sow. - - | | | 2 | 3 | 4 | 5 | | | | | × | D. to L. | |
| —— olivæformis, Lyc. - | | 1 | | | | | | | | | | G. | |
| —— ornata, Buckm. - | | | | | | | | | | | | D. S. G. - | Inf. Ool. |
| —— See also Arca and Sowerbya. | | | | | | | | | | | | | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mollusca—*cont.* | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| *Lamellibranchiata*—cont. | | | | | | | | | | | | | |
| Cypricardia bathonica, d'Orb. | | | | 3 | | | 6 | 7 | 8 | 9 | | S. W. G. N. O. L. Y. | ? var. of *C. cordiformis*, Desh. |
| —— —— var. brevis, Wr. - | | 1 | 2 | 3 | | | | | | | | D. G. O. | |
| —— caudata, Lyc. - - | | | | | | | 6 | 7 | 8 | 9 | | S. W. G. N. H. L. | |
| —— cordiformis, Desh. - | | 1 | 2 | 3 | 4 | 5 | | 7 | | | | D. G. N. Y. | *C. acutangula*, Phil. |
| —— dolabra, Phil. - - | | | | | | | | | | | | G. - - | Inf. Ool. |
| —— elongata, Wr. - - | | | | 3 | 4 | | | | | | | S. | |
| —— filoperta, Whidb. - | | | | | | | | | | | | S. - - | Inf. Ool. |
| —— lebruniana, d'Orb. - | | | | 3 | | | | | | | | D. S. | |
| —— nuculiformis, Roem - | | | | | | | | 7 | | | | G. O. - | sp.? in Inf. Ool. |
| —— rostrata, Sow. - - | | | | | | | | 7 | 8 | 9 | | W. to Y. - | *Isocardia.* |
| —— —— var. truncata, Mor. | | | | | | | | 7 | | | | O.? | |
| —— siliqua, Lyc. - - | | | | 3 | | | | | | | | G. | |
| Cyprina bella, Lyc. - | | | | | | | | | 8 | | | W. | |
| —— curvirostris, Lyc. - | | | | 3 | | | | | | | | G. - - | *Venus.* |
| —— Davidsoni, Lyc. | | | | | | | | | 8 | | | S. W. | |
| —— depressiuscula, Mor. & Lyc. | | | | | | | | 7 | | 9 | | G. O. | |
| —— islipensis, Lyc. - | | | | | | | | 7 | 8 | 9 | | W. G. O. N. | |
| —— jurensis, Goldf. - | | | | | | | | 7 | | | | G. | |
| —— loweana, Mor. & Lyc. | | | | | | | 6 | 7 | 8 | 9 | | D. to L. | |
| —— Lucyi, Witc. - - | | | | | | 5 | | | | | | G. | |
| —— nuciformis, Lyc. - | | | | 3 | | | | 7 | | | | G. L. | |
| —— suevica, Goldf. - | | | | 3 | | | | | | | | G. | |
| —— trapeziformis, Roem. - | | | | 3 | | | | 7 | | | | G. L. | |
| —— —— var. subrotunda, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| Cyrena Cunninghami, Forbes | | | | | | | 6 | | | | | L. | |
| Cytherea dolabra, Phil. - | | | | | | | | | | | | L. Y. - | Inf. Ool. |
| —— picta, Lyc. - - | | | | 3 | | | | | | | | G. - - | *Cyprina.* |
| Exogyra auriformis, Goldf. | | | | | | | | 7 | | | × | G. | |
| —— Davidsoni, Whidb. - | | | | | | | | | | | | G. - - | Inf. Ool. |
| —— globula, Whidb. - | | | | 3 | | | | | | | | N. | |
| —— See also Ostrea. | | | | | | | | | | | | | |
| *Gastrochæna.* See Gervillia. | | | | | | | | | | | | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. jurensis. | Am. opalinus. | Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | | | | | | | |
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Mollusca—*cont.* | | | | | | | | | | | | | |
| *Lamellibranchiata*—cont. | | | | | | | | | | | | | |
| Gervillia acuta, Sow. | | | | 3 | | 5 | 6 | 7 | 8 | 9 | | D. to Y. | *G. lanceolata*, Goldf. |
| —— aurita, Lyc. | | | | 3 | | | | | | | | G. L. | |
| —— aviculoides, Sow. | | | | | | | | | | 9 | × | H. L. Y. | |
| —— bathonica, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— bicostata, Lyc. | | | | | | | | 7 | | | | G. | |
| —— crassicosta, Mor. & Lyc. | | | | | | | | | 8 | | | S. G. N. | |
| —— fornicata, Lyc. | | 1 | | | | | | | | | | G. | |
| —— gladiolus, Whidb. | | | | | | | | | | | | S. | Inf. Ool. |
| —— Hartmanni, Goldf. | | 1 | 2 | 3 | | 5 | | | | | | S. to Y. | ? *G. radians*, Mor. & Lyc. |
| —— intermedia, Whidb. | | | 2 | | 4 | | | | | | | D. S. G. | |
| —— islipensis, Lyc. | | | | | | | | 7 | | 9 | | O. | |
| —— lata, Phil. | | | 2 | 3 | | | | | | | | D. to Y. | |
| —— monotis, Desl. | | | | 3 | | | | 7 | | ? | | G. O. N. | |
| —— ornata, Lyc. | | | | | | | | 7 | | | | G. | |
| —— ovata, Sow. | | | | 3 | | | | 7 | 8 | 9 | | W. G. O. | *Avicula.* |
| —— pernoides, Desl. | | | | | | 5 | | | | | | G. O. | |
| —— prælonga, Lyc. | | | | 3 | | 5 | | | | | | G. Y. | |
| —— subcylindrica, Mor. & Lyc. | | | | | | | | 7 | | | | G. O. | ? var. of *G. acuta*, Sow. |
| —— tortuosa, Sow. | | | | 3 | 4 | 5 | | | | | | G. O. Y. | *Gastrochæna.* |
| —— Waltoni, Lyc. | | | | | | | | 7 | 8 | | | S. W. O. | |
| —— See also Pteroperna. | | | | | | | | | | | | | |
| Goniomya angulifera, Sow. | | | | 3 | | 5 | 6 | | | 9 | | D. W. G. O. Y. | |
| —— hemicostata, Mor. & Lyc. | | | | | | | | 7 | | | | N. | |
| —— literata, Sow. | | | | 3 | | | 6 | 7 | | 9 | × | D. to Y. | |
| —— v. scripta, Sow. | | | | 3 | | | | | | 9 | × | D. to Y. | |
| Gouldia ? mitralis, Whidb. | | | | | 4 | | | | | | | D. | |
| —— ovalis, Quenst. | | | | | 4 | | | | | | | D. | *Cardita.* |
| Gresslya abducta, Phil. | | 1 | 2 | 3 | 4 | 5 | | ? | | | | D. to Y. | |
| —— carditæformis, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— coniformis, Ag. | | | | | | 5 | | | | | | G. | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Mollusca—*cont.* | | | | | | | | | | | | | |
| *Lamellibranchiata*—cont. | | | | | | | | | | | | | |
| Gresslya gregaria, Roem. | | | | 3 | | | | | | | | D. | |
| —— latirostris, Ag. | | | | 3 | | 5 | | 7 | | | | D. to L. | |
| —— peregrina, Phil. | | | | 3 | | | 6 | ? | | 9 | × | D. to Y. | |
| —— —— var. rostrata, Ag. | | | | 3 | | | 6 | 7 | | | | G. L. | |
| Gryphæa abrupta, Whidb. | | | | | | | | | | | | S. | Inf. Ool. |
| —— cygnoides, Whidb. | | | | 3 | 4 | | | | | | | D. S. | |
| —— mima, Phil. | | | | 3 | | | | | | 9 | | D. N. L. Y. | |
| —— minuta, Sow. | | | | | | | | 7 | | | | W. G. | |
| —— plicata, Lyc. | | | 2 | | | | | | | | | G. | |
| —— Sollasi, Whidb. | | | | | | | | | | | | S. | Inf. Ool. |
| —— sublobata, Desh. | | | | 3 | 4 | 5 | | | | | | D. S. G. Y. | *G. Buckmani*, Lyc. |
| Harpax Parkinsoni, Quenst. | | 1 | | | | | | | | | | S. | *H. spinosus*, Sow. |
| —— Tawneyi, Whidb. | | | | | 4 | | | | | | | S. | |
| —— Waltoni, Lyc. | | | | | | | | 7 | 8 | | | S. G. | |
| *Hettangia.* See Tancredia. | | | | | | | | | | | | | |
| *Hiatella.* See Astarte. | | | | | | | | | | | | | |
| Hinnites abjectus, Phil. | | 1 | 2 | 3 | 4 | | | 7 | | 9 | × | D. to Y. | |
| —— gingensis, Waag. | | | | | | | | | | | | D. | Inf. Ool. |
| —— sepultus, Lyc. | | | | 3 | | | | | | | | G. | |
| —— tegulatus, Mor. & Lyc. | | | | 3 | | | | 7 | | | | G. L. | |
| —— tenuistriatus, Münst. | | | | | 4 | 5 | | | | | | D. S. | |
| —— tuberculosus, Goldf. | | | | 3 | | | | | | | | G. | |
| —— tumidus, Ziet. | | | | 3 | | 5 | 6 | 7 | 8 | 9 | × | D. to L. | *H. velatus*, Goldf. |
| Hippopodium | | | | | | | | 7 | | | | G. O. | Inf. Ool. |
| Homomya crassiuscula, Mor. & Lyc. | | | | 3 | | 5 | | | | 9 | | D. to Y. | *Myacites.* |
| —— gibbosa, Sow. | | | | 3 | | 5 | 6 | 7 | 8 | 9 | | D. to Y. | *Myacites.* |
| —— Vezelayi, Laj. | | | | 3 | | 5 | 6 | 7 | | 9 | | G. O. L. | |
| —— See also Myacites. | | | | | | | | | | | | | |
| Inoceramus Fittoni, Mor. & Lyc. | | | | | | | | 7 | | | | O. | ?=*I. amygdaloides*, Goldf. |
| —— ? obliquus, Lyc. | | | | 3 | | | | ? | | | | O. N. R. | |
| —— See also Perna. | | | | | | | | | | | | | |
| Isoarca capitalis, Whidb. | | | | | | 5 | | | | | | G. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Passage Beds, Midford Sands. Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Inferior Oolite. Am. humphriesianus. | Inferior Oolite. Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Mollusca—*cont.* | | | | | | | | | | | | | |
| *Lamellibranchiata*—cont. | | | | | | | | | | | | | |
| Isoarca clypeata, Witc. - | | | | | | 5 | | | | | | G. | |
| —— texata, Münst. - - | | | | | | | | | | | | G. - - | Inf. Ool. *Isocardia cordiformis*, Ziet. |
| Isocardia cordata, Buckm. | | | | 3 | | 5 | | | | | | S. G. O. N. Y. | |
| —— minima, Sow. - - | | | | | | | 6 | 7 | 8 | 9 | × | D. to Y. - | *I. tenera*, Mor. & Lyc. |
| —— nitida, Phil. - - | | | | | | | 6 | | | | | S. | |
| —— See also Ceromya, Cypricardia. | | | | | | | | | | | | | |
| Kellia Etheridgei, Whidb. | | | | 3 | | | | | | | | N. | |
| Leda lachryma, Sow. - | | | | 3 | | 5 | 6 | 7 | 8 | 9 | | D. to Y. | |
| —— mucronata, Sow. - | | | | | | | | 7 | | 9 | | W. O. G. - | *Nucula.* |
| Lima aciculata, Münst. - | | | | | | | | | | | | S. - - | Inf. Ool. |
| —— alticosta, Chap. & Dew. | | | | 3 | 4 | | | | | | | S. G. | |
| —— amnifera, Whidb. - | | 1 | | | | | | | | | | S. | |
| —— *bellula*, Mor. & Lyc. See L. strigillata. | | | | | | | | | | | | | |
| —— cardiiformis, Sow. - | | | | 3 | | 5 | 6 | 7 | 8 | 9 | | D. to Y. | |
| —— compressa, Wr. - | | | | | | 5 | | | | | | G. | |
| —— contorquens, Whidb. - | | | | 3 | | | | | | | | N. | |
| —— cubiferens, Whidb. - | | | | 3 | | | | | | | | N. | |
| —— duplicata, Sow. - | × | | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | D. to Y. Lond. | *Limea.* |
| —— educta, Whidb. - | | | | | 4 | 5 | | | | | | S. G. Y. | |
| —— electra, d'Orb. - - | | 1 | 2 | 3 | | | | | | | | G. O. | |
| —— Etheridgei, Wr. - | | | | 3 | 4 | | | | | | | D. S. G. | |
| —— galathea, d'Orb. - | | 1 | | | | | | | | | | G. | |
| —— gibbosa, Sow. - | | | | 3 | | 5 | 6 | 7 | | 9 | × | D. to Y. | |
| —— impressa, Mor. & Lyc. | | | | 3 | | | | 7 | 8 | 9 | | G. to Y. | |
| —— incisa, Waag. - | | | | 3 | | | | | 8 | | | S. N. - | *L. dustonensis*, Lyc. |
| —— inoceramoides, Whidb. | | | | 3 | | | | | | | | D. S. - | *L. lævis*, Eth. (MS.) |
| —— læviuscula, Sow. - | | | | 3 | | | | | | 9 | × | S. G. H. N.? | |
| —— lunularis, Desh. - | | | | 3 | | | | | | | | G. | |
| —— Lycetti ?, Laube - | | | | 3 | | | | 7 | | 9 | × | D. to Y. - | = specimens named "*L. punctata.*" |
| —— majestica, Whidb. - | | | | 3 | | | | | | | | S. G. N. - | *L. grandis* of Lyc. non Roem. |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Mollusca—*cont.* | | | | | | | | | | | | | |
| *Lamellibranchiata*—cont. | | | | | | | | | | | | | |
| Lima notata, Goldf. - | | | | 3 | 4 | | | | | | | D. S. | |
| —— œpybolus, Whidb. - | | | | 3 | 4 | | | | | | | D. S. | |
| —— ornata, Lyc. - - | | 1 | | | | | | | | | | G. | |
| —— ovalis, Sow. - - | | | | 3 | | | | 7 | | 9 | | S. W. G. O. N. | |
| —— pectiniformis, Schloth. | | | | 3 | 4 | 5 | 6 | 7 | | 9 | × | D. to Y. - | *L. proboscidea*, Sow. |
| —— placida, Whidb. - | | | | 3 | | | | | | | | N. | |
| —— platybolus, Whidb. - | | | | | | | | | | | | G. - - | Inf. Ool. |
| —— plebeia, Chap. & Dew. | | | | | 4 | | | | | | | S. | |
| —— poetica, Whidb. - | | | | | | | | | | | | S. - - | Inf. Ool. |
| —— pontonis, Lyc. - | | | | 3 | | | | | | | | G. N. L. | |
| —— punctatilla, Lyc. - | | | | 3 | | | | 7 | | | | G. | |
| —— rigida, Sow. - - | | | | 3 | | | | 7 | | 9 | × | S. G. O. N. H. L. | |
| —— rigidula, Phil. - - | | | | | | | | 7 | | 9 | × | Be. to Y. | |
| —— rodburgensis, Lyc. - | | | | 3 | | | | | | | | G. O. N. | |
| —— rotundata, Roem. - | | | | 3 | | | | | | | | L. | |
| —— rudis, Sow. - - | | | | 3 | | | | 7 | | | × | G. L. - | *L. luciensis*, d'Orb. |
| —— semicircularis, Goldf. | | | | | 4 | 5 | | 7 | | | | D. S. G. | |
| —— seminuda, Whidb. - | | | | | | | | | | | | G. - - | Inf. Ool. |
| —— Sharpi, Whidb. - | | | | 3 | | | | | | | | N. | |
| —— strigillata, Laube - | | 1 | 2 | 3 | | 5 | | 7 | | | | D. to Y. - | *L. bellula*, M. & L. |
| —— toarcensis, Desl. - | | 1 | 2 | | | | | | | | | S. Nn. Y. | |
| —— Wrighti, Oppel - | | | | 3 | | | | | | | | L. | |
| Limopsis ooliticus, d'Arch. | | | | 3 | | | | 7 | 8 | | | W. G. O. L. | |
| Lithodomus attenuatus, Lyc. | | | | 3 | | | | | | | | G. | |
| —— inclusus, Phil. - - | | | | 3 | | | | 7 | 8 | 9 | × | D. to L. | |
| —— parasiticus, Desl. - | | | | | | | | 7 | | | | G. | |
| —— Porteri, Lyc. - - | | | | | | 5 | | 7 | | | × | S. O. | |
| Lucina bellona, d'Orb. - | × | | | 3 | | | | 7 | | | × | G. L. Y. | |
| —— burtonensis, Lyc. - | | | | | | | | | 8 | 9 | | D. L. | |
| —— clypeata, Witc. - | | | | | | 5 | | | | | | G. | |
| —— crassa, Sow. - - | | | | | | 5 | | 7 | 8 | | | W. G. O. Y. | |
| —— despecta, Phil. - - | | | | 3 | | 5 | 6 | 7 | | | × | D. to Y. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Mollusca—*cont.* | | | | | | | | | | | | | |
| *Lamellibranchiata*—cont. | | | | | | | | | | | | | |
| Lucina despecta var. cardioides, d'Arch. | | | | | | | 6 | | | | | D. | |
| —— Lycetti, Oppel | | | | | | | | 7 | | | | G. | *L. bellona*, var. *depressa*, Mor. & Lyc. |
| —— orbigniana, d'Arch. | | | | 3 | | | | | | | | G. N. L. | |
| —— rotundata, Roem. | | | | | | | | 7 | | | × | G. | Inf. Ool. |
| —— striatula, Buv. | | | | | | | | 7 | | 9 | | O. H. | |
| —— Wrighti, Oppel | | | | 3 | | | | | | | | G. O. N. L. | |
| Macrodon hirsonensis, d'Arch. | | | 2 | 3 | | 5 | | 7 | | 9 | | S. to Y. | *Cucullæa elongata*, Phil. (non Sow.). |
| —— —— var. rugosa, Lyc. | | | | | | | | | 8 | | | S. W. | |
| —— ? rapidus, Whidb. | | | | | 4 | | | | | | | S. | |
| —— rasilis, Whidb. | | | | | 4 | | | | | | | D. | |
| Modiola Binfieldi, Mor. & Lyc. | | | | 3 | | | | 7 | | | | G. L. | |
| —— bipartita, Sow. | | | | 3 | | 5 | | 7 | | 9 | × | D. to Y. | |
| —— compressa, Goldf. | | 1 | | | | | | 7 | 8 | 9 | | G. O. N. | *Mytilus.* |
| —— cuneata, Sow. | | 1 | | 3 | | 5 | | | | 9 | × | D. to Y. | |
| —— explanata, Mor. | | | | | | 5 | | | | | | G. | *Mytilus.* |
| —— furcata, Goldf. | | | | 3 | | 5 | ? | 7 | 8 | 9 | | D. to Y. | *Mytilus asper*, Sow. |
| —— —— var. bathonica, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— gibbosa, Sow. | | | | 3 | 4 | 5 | 6 | 7 | | 9 | × | D. to Y. | *M. reniformis*, Sow. |
| —— imbricata, Sow. | | | | 3 | | 5 | 6 | 7 | 8 | 9 | × | D. to Y. | *Mytilus.* |
| —— Leckenbyi, Mor. & Lyc. | | | | 3 | | | | | | | | N. Y. | |
| —— Lonsdalei, Mor. & Lyc. | | | | 3 | | | 6 | 7 | 8 | 9 | × | D. to Y. | Inf. Ool. |
| —— Lycetti, Morris | | | | | | | | 7 | | | × | D. W. G. Y. | Inf. Ool. *M. pulcherrima*, Roem. |
| —— solenoides, Mor. & Lyc. | | | | | | | | 7 | | | | G. O. | |
| —— —— var. subreniformis, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— sowerbyana, d'Orb. | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | 9 | | D. to Y. | *M. plicata*, Sow. |
| —— tenuistriata, Münst. | | | | 3 | | | | 7 | | | | G. O. L. | |
| —— ungulata, Y. & B. | | | | 3 | | | | 7 | | | | G. L. Y. | *Mytilus tumidus*, M. & L. |
| Myacites æquatus, Phil. | | | | | | 5 | 6 | | | | × | G. Y. | |
| —— Beani, Mor. & Lyc. | | | | | | | | | | 9 | | O. Y. | |
| —— calceiformis, Phil. | | | | 3 | | 5 | 6 | 7 | | 9 | × | D. to Y. | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. jurensis. | Am. opalinus. | Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | | | | | | | |
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Mollusca—*cont.* | | | | | | | | | | | | | |
| *Lamellibranchiata*—cont. | | | | | | | | | | | | | |
| Myacites compressiusculus, Lyc. | | | | | | 5 | | | | | | G. L. Y. | |
| —— compressus, Mor. & Lyc. | | | | 3 | | | | 7 | | | | G. N. | |
| —— decurtatus, Phil. | | | | 3 | | | | 7 | 8 | 9 | × | D. to Y. | |
| —— dilatus, Phil. | | | | 3 | | 5 | 6 | 7 | | | | G. Y. | |
| —— elongatus, Ag. | | | | | | 5 | | | | | | G. | |
| —— Goldfussi, Lyc. | | | | 3 | | 5 | | | | | | G. O. Y. | |
| —— jurassi, Brongn. | | | | 3 | 4 | 5 | ? | | | 9 | × | D. S. G. O. | |
| —— oblongus, Buckm. | | | | 3 | | | | | | | | G. L. Y. | *Sanguinolaria.* |
| —— obtusus, Ag. | | | | | | | | | | | | G. | Inf. Ool. |
| —— punctatus, Buckm. | | | | 3 | | | | | | | | G. | |
| —— recurvus, Phil. | | | | | | | | | | 9 | × | D. to Y. | |
| —— scarburgensis, Mor. & Lyc. | | | | 3 | | | | 7 | | | | O. N. L. Y. | |
| —— securiformis, Phil. | | | | 3 | | 5 | ? | 7 | | 9 | × | D. to Y. | *Amphidesma.* |
| —— semistriatus, Ag. | | | 2 | | | | | | | | | S. | |
| —— sinister, Ag. | | | | | | | | | | 9 | | W. H. Y. | |
| —— subelongatus, Ag. | | | | | | 5 | | | | | | G. | |
| —— subsidens, Whidb. | | | | | | | | | | | | S. G. | Inf. Ool. |
| —— tenuistriatus, Münst. | | | 2 | 3 | 4 | 5 | 6 | | | | | D. S. G. | |
| —— Terquemeus, Buv. | | | | | | | 6 | 7 | | 9 | | D. W. G. | |
| —— tumidus, Mor. & Lyc. | | | | | | | | 7 | | | | G. N. | |
| —— unioniformis, Mor. & Lyc. | | | | 3 | | | | 7 | | | | G. N. | *Homomya.* |
| Myoconcha actæon, d'Orb. | | | | | | | | 7 | | | | G. | |
| —— crassa, Sow. | | 1 | | 3 | 4 | 5 | | 7 | | | | D. to L. | |
| —— elongata, Mor. & Lyc. | | | | 3 | | | | 7 | | | | G. | |
| —— implana, Whidb. | | | | 3 | 4 | | | | | | | D. | |
| —— longirostris, Buckm. | | | | | 4 | | | | | | | D. | |
| —— striatula, Goldf. | | | | 3 | 4 | | | | | | | S. G. N. | |
| —— unguis, Whidb. | | | | | 4 | | | | | | | D. S. | |
| *Myopsis.* See Myacites. | | | | | | | | | | | | | |
| Mytilus crenatus, Mor. & Lyc. | | | | 3 | | | | | | | | G. | |
| —— lunularis, Sow | | | | 3 | | | | | | | | O. N. L. | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Mollusca—*cont.* | | | | | | | | | | | | | |
| *Lamellibranchiata*—cont. | | | | | | | | | | | | | |
| Mytilus pectinatus, Sow. - | | | | 3 | | | | | 8 | 9 | × | D. G. W. | |
| —— primipilaris, Whidb. - | | | | 3 | | | | | | | | N. | |
| —— striatissimus, Whidb. | | | | 3 | | | | | | | | S. G. | |
| —— sublævis, Sow. - - | | | | | | | | 7 | 8 | 9 | | S. to Y. - | ? *M. jurensis*, Roem. |
| —— subrectus, Lyc. - | | | | 3 | | | | | | | | G. | |
| —— See also Modiola and Myoconcha. | | | | | | | | | | | | | |
| Neæra Ibbetsoni, Morris - | | | | 3 | | 5 | 6 | 7 | | 9 | | O. R. N. L. | |
| Nucula jurensis, Quenst. - | | 1 | | | | | | | | | | G. | |
| —— Menkei, Roem. - | | | | | | | 6 | 7 | 8 | 9 | × | D. to N. | |
| —— nuciformis, Whidb. - | | | | 3 | | 5 | | | | | | D. S. | |
| —— subglobosa, Roem. - | | | | | 4 | 5 | | | | | | D. G. - | *N. nucleus*, Desl. |
| —— variabilis, Sow. - | | | | 3 | | 5 | 6 | 7 | 8 | 9 | | D. to Y. | |
| —— Waltoni, Mor. & Lyc.- | | | | | | | 6 | 7 | 8 | | | S. G. | |
| Opis angustatus, Buckm. - | | | | | | 5 | | | | | | D. | |
| —— carinatus, Wr. - | | | 2 | | 4 | | | | | | | G. | |
| —— cordiformis, Lyc. - | | | | | | 5 | | | | | | D. G. L. | |
| —— Deshayesi, Mor. & Lyc. | | | | | | 5 | | 7 | | | | W. G. | |
| —— elongatus, Lyc. - | | | | 3 | | | | | | | | D. S. G. | |
| —— gibbosus, Lyc. - - | | | | 3 | | | | | | | | G. L. | |
| —— luciensis, d'Orb. - | | | | | | | | 7 | | | | W. G. - | Inf. Ool. |
| —— lunulatus, Sow. - | × | | 2 | | | 5 | | | | | | D. to L. - | *Astarte.* |
| —— Painei, Wtc. - - | | | | | | 5 | | | | | | G. | |
| —— pulchella, d'Orb. - | | | | | | | | 7 | | | | G. - - | var. of *O. lunulatus*, Sow. |
| —— similis, Sow. - - | | | | 3 | | 5 | | 7 | | | | S. W. G. O. L. Y. | *Cardita.* |
| —— spathulosus, Whidb. - | | | | 3 | | | | | | 9 | | D. N. L. | |
| —— trigonalis, Sow. - | | | | | 4 | | | | | | | D. S. G. - | *Astarte.* |
| Ostrea acuminata, Sow. - | | | | | | 5 | 6 | 7 | 8 | 9 | | D. to L. | |
| —— concentrica, Münst. var. munda, Whidb. | | | | | | 5 | | | | | | S. G. | |
| —— costata, Sow. - - | | | | | | 5 | 6 | 7 | 8 | 9 | | D. to O. | |
| —— explanata, Goldf. - | | | | | 4 | | | | | | | D. G. | |
| —— flabelloides, Lam. - | | | | 3 | | | 6 | 7 | 8 | 9 | × | D. to Y. | { *O. Marshi*, Sow. *Alectryonia.* |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| MOLLUSCA—*cont.* | | | | | | | | | | | | | |
| *Lamellibranchiata*—cont. | | | | | | | | | | | | | |
| Ostrea gregaria, Sow. - | | | | | | | 6 | 7 | 8 | 9 | × | D. to L. Sy. | |
| —— Knorri, Voltz. - - | | | | | | | 6 | | | | | D. S. G. | |
| —— lingulata, Lyc. - - | | | | | 4 | 5 | | | 8 | 9 | | D. S. W. - | *Exogyra.* |
| —— Meadei, Sow. - - | | | | | | | | 7 | | | | S. | |
| —— Münsteri, Bronn - | | | | 3 | | | | | | | | D. | |
| —— palmetta, Sow. var. montiformis, Whidb. | | | | 3 | | | | | | | | D. to L. - - | =*O. gregaria*, Sow. of Inf. Ool. |
| —— pyrus, Whidb. - - | | | | 3 | | | | | | | | N. L. - | *O. sulcifera*, Phil. |
| —— pyxiformis, Wr. - | | | | 3 | | 5 | | | | | | G. O. | |
| —— rugosa, Goldf. - - | | | | 3 | | 5 | | 7 | 8 | 9 | | D. G. O. - | *O. costata*, Sow. of Inf. Ool. |
| —— sandalina, Goldf. - | | 1 | | | | | | | | | | Nu. | |
| —— Sowerbyi, Lyc. - | | | | | | | 6 | 7 | 8 | 9 | | D. to L. Sy. | |
| —— sphæroidalis, Whidb. - | | | 2 | | | | | | | | | S. | |
| —— subrugulosa, Mor. & Lyc. | | | | | | | 6 | 7 | 8 | 9 | | D. to L. Sy. | |
| —— wiltonensis, Lyc. - | | | | | | | | 7 | 8 | | | G. W. - | ? var. of *O. acuminata.* |
| Pachyrisma grande, Lyc. - | | | | | | | | 7 | | | | G. | |
| *Panopæa.* See Myacites. | | | | | | | | | | | | | |
| Pecten anisopleurus, Buv. - | | | | | | | | 7 | | 9 | × | G. N. H. Y. | |
| —— annulatus, Sow. - | | | | | | | | 7 | 8 | 9 | × | D. to L. | |
| —— arctus, Waag. - - | | | | 3 | 4 | 5 | | | | | | S. G. L. Y. | |
| —— arcuatus, Sow. - - | | | | | | 5 | | 7 | 8 | 9 | × | D. to Y. | |
| —— articulatus, Schloth. - | | | 2 | 3 | | 5 | | | 8 | 9 | × | D. to Y. | |
| —— barbatus, Sow. - | | | 2 | 3 | | | | | | | | D. S. | |
| —— clathratus, Roem. - | | | | 3 | | | | 7 | | | | D. G. O. L. | |
| —— clypeatus, Witc. - | | | | | | 5 | | | | | | G. | |
| —— comatus, Münst. - | | | 2 | 3 | 4 | | | | | | | G. | |
| —— cornutus, Quenst. - | | | | | | | | | | | | D. G. - | Inf. Ool. |
| —— demissus, Phil. - | | | 2 | 3 | 4 | 5 | 6 | 7 | | 9 | | D. to Y. | |
| —— —— var. inutilis, Whidb. | | 1 | | | | | | | | | | S. | |
| —— fenestralis, Whidb. - | | | | 3 | | | | | | | | D. G. | |
| —— fibrosus, Sow. - - | | | | | | | | 7 | 8 | 9 | × | D. S. G. O. | |
| —— gingensis, Whidb. - | | | | 3 | | | | | | | | N. L. | |
| —— Griesbachi, Lyc. - | | | | | | | | 7 | | | | N. | |
| —— hemicostatus, Mor. & Lyc. | | | | | | | 6 | 7 | | 9 | | D. W. G. O. | var. of *P. vagans.* |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. | | Inferior Oolite. | | | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. jurensis. | Am. opalinus. | Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | | | | | | | |
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Mollusca—*cont.* | | | | | | | | | | | | | |
| *Lamellibranchiata*—cont. | | | | | | | | | | | | | |
| Pecten inæquicostatus, Phil. | | | | | | | | | | 9 | × | H. Y. | |
| —— intermittens, Whidb. - | | | | | 5 | | | | | | | G. | |
| —— intertextus, Roem. - | | | | | | | | 7 | | 9 | × | N. H. Y. - | *P. michaelensis*, Buv. |
| —— læviradiatus, Waag. - | | | 2 | 3 | | 5 | | | | | | D. S. | |
| —— lens, Sow. - - | | | | 3 | | 5 | 6 | 7 | 8 | 9 | × | D. to Y. | |
| —— paradoxus, Goldf. - | | | 2 | 3 | | | | | | | | D. S. G. L. Y. | *P. contrarius*, von Buch. *P. cornutus*, Whidb. (non Quenst.). |
| —— peregrinus, Phil. - | | | | | | | | 7 | | 9 | | G. O. N. L. - | ? var. of *P. vagans*. |
| —— personatus, Goldf. - | | | | 3 | | 5 | | 7 | 8 | 9 | | G. O. N. L. - | ? Young forms of *P. cornutus*, Quenst. |
| —— puellaris, Whidb. - | | | | | | | | | | | | D. N. - | Inf. Ool. |
| —— pumilus, Lam. - - | × | 1 | | 3 | | | | | | | | N. | |
| —— retiferus, Mor. & Lyc. | | | | | | 5 | | 7 | | 9 | | G. O. N. | |
| —— rigidus, Sow. - - | | | | | | | | 7 | 8 | 9 | | D. to N. | |
| —— rushdenensis, Lyc. - | | | | | | | | | 8 | 9 | | D. G. N. Sy. | Inf. Ool. |
| —— spinicostatus, Whidb. | | | | | 4 | | | | | | | S. | |
| —— subcomatus, Münst. - | | | | 3 | | | | | | | | G. | |
| —— subspinosus, Schloth. | | | | | | 5 | | | 8 | | | S. G. | |
| —— symmetricus, Mor. - | | | | | | 5 | | | | | | G. | |
| —— textorius, Schloth. - | × | | 2 | 3 | | | | | | | | D. G. L. | |
| —— texturatus, Münst. - | | | | 3 | 4 | | | | | | | D. G. L. | |
| —— triformis, Whidb. - | | | | 3 | | | | | | | | N. | |
| —— vagans, Sow. - - | | | | | | | 6 | 7 | 8 | 9 | × | D. to Y. | |
| —— virguliferus, Phil. - | | | | 3 | | | | | | | | G. Y. | |
| —— wollastonensis, Lyc. - | | | | 3 | | | | | | 9 | | S. O. N. | |
| —— Woodwardi, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| Perna foliacea, Lyc. - | | | | | | | | 7 | | | | G. | |
| —— isognomoides, Stahl. - | | | | | | 5 | | | | | | G. Y. | |
| —— mytiloides, Lam. - | | | | 3 | 4 | | | | 8 | | × | S. G. Y. | |
| —— obliqua, Lyc. - - | | | | | | | | | 8 | | | W. N. | |
| —— rugosa, Goldf. - - | | 1 | | 3 | | 5 | | 7 | 8 | | | G. W. O. N. Y. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| MOLLUSCA—*cont.* | | | | | | | | | | | | | |
| *Lamellibranchiata*—cont. | | | | | | | | | | | | | |
| Perna rugosa var. quadrata, Phil. | | | | 3 | | | | 7 | | 9 | | G. L. Y. | |
| Pholadomya acuticosta, Sow. | × | | | | | | 6 | 7 | 8 | 9 | | W. to Y. | |
| — bellula, Whidb. | | | | | | | | | | | | D. | Inf. Ool. |
| — *bucardium*, Ag. See P. deltoidea. | | | | | | | | | | | | | |
| — callæa, Whidb. | | | | | 4 | | | | | | | D. S. | |
| — deltoidea, Sow. | | | | | | | 6 | 7 | | 9 | × | D. to Y. | |
| — Dewalquei, Lyc. | | | | | 4 | 5 | | | | | | G. O. | |
| — fidicula, Sow. | | 1 | 2 | 3 | | 5 | | | | | | D. to Y. | |
| — fortis, Whidb. | | | | | | | | | | | | S. | Inf. Ool. |
| — Heraulti, Ag. | | | 2 | | 4 | 5 | 6 | 7 | 8 | 9 | | D. to Y. Sy. | |
| — lyrata, Sow. | | | | | | | 6 | 7 | | 9 | | D. to L. | *P. carinata,* Goldf. Inf. Ool. |
| — media, Ag. | | | 2 | 3 | 4 | 5 | | | | | | D. to Y. | |
| — Murchisoni, Sow. | | | | | | | 6 | 7 | | 9 | | G. O. L. | |
| — Newtoni, Whidb. | | | | | | | | | | | | D. | Inf. Ool. |
| — oblita, Mor. & Lyc. | | | | 3 | 4 | 5 | 6 | | | 9 | | D. to L. | |
| — ovalis, Sow. | | | | 3 | | | 6 | | | 9 | × | S. to Y. | Inf. Ool. |
| — ovulum, Ag. | | | | 3 | 4 | 5 | 6 | 7 | | | | D. to Y. | |
| — parvula, Roem. | | | | 3 | | | | | | 9 | | L. | |
| — Phillipsi, Mor. | | | | 3 | | | | 7 | | 9 | × | D. S. N. H. L. Y. | *P. Murchisoni,* Phil. (non Sow.). |
| — Sæmanni, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| — socialis, Mor. & Lyc. | | | | 3 | | | 6 | 7 | | | | D. S. G. O. N. | |
| — *solitaria,* Mor. & Lyc. See P. deltoidea. | | | | | | | | | | | | | |
| — spatiosa, Whidb. | | | | | 4 | | | | | | | S. | |
| — truncata, Sow. | | | | | | | 6 | | | | | G. | |
| — Zieteni, Ag. | | | | | | | | | | | | G. O. L. | Inf. Ool. |
| Pholas costellata, Mor. & Lyc. | | | | | | | | 7 | | | | O. | |
| — oolitica, Mor. & Lyc. | | | | 3 | | | | 7 | | | | G. L. | |
| — sp. | | | | | | | | | 8 | | | D. W. | |
| Pinna ampla, Sow. | | | | | | | 6 | 7 | | 9 | × | D. to Be. N. | |
| — claviformis, Whidb. | | | | | | | | | | | | G. | Inf. Ool. |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Passage Beds, Midford Sands. Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Inferior Oolite. Am. humphriesianus. | Inferior Oolite. Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| MOLLUSCA—*cont.* | | | | | | | | | | | | | |
| *Lamellibranchiata*—cont. | | | | | | | | | | | | | |
| Pinna cuneata, Phil. | | | | 3 | | 5 | | 7 | 8 | 9 | | G. to Y. | |
| —— dundriensis, Whidb. | | | | | 4 | | | | | | | S. | |
| —— fissa, Goldf. | | | 2 | | | | | | | | | G. | |
| —— Hartmanni, Ziet. | | | | 3 | | | | | | | | D. G. | |
| —— hastata, Lyc. | | | | 3 | | | | | | | | G. | |
| —— lanceolata, Sow. | | | | 3 | | | | | | 9 | × | L. Y. | |
| Placuna rupertina, Whidb. | | | | 3 | | | | | | | | N. | |
| —— saggitalis, Whidb. | | | | | | | | | | | | S. | Inf. Ool. |
| Placunopsis jurensis, Roem. | | | | 3 | | | | 7 | 8 | | | W. G. O. | |
| —— ornatus, Mor. & Lyc. | | | | 3 | | | | 7 | | | | G. N. | |
| —— radians, Mor. & Lyc. | | | | | | | 6 | 7 | | | | D. G. | |
| —— semistriatus, Bean | | | | | | | | | ? | 9 | | S. G. H. Y. | Inf. Ool. *Anomia.* |
| —— socialis, Mor. & Lyc. | | | | 3 | | 5 | 6 | 7 | 8 | 9 | | D. to L. | |
| *Platymya.* See Myacites. | | | | | | | | | | | | | |
| *Pleuromya.* See Myacites. | | | | | | | | | | | | | |
| Plicatula armata, Lyc. | | | | 3 | | | | | | | | G. | |
| —— complicata, Lyc. | | | | 3 | | | | | | | | G. | |
| —— fistulosa, Mor. & Lyc. | | | | | 4 | 5 | | 7 | | | × | D. G. | |
| —— Sollasi, Whidb. | | | | | 4 | | | | | | | S. | |
| —— subserrata, Goldf. | | | | | 4 | | | | | | | D. | |
| —— tuberculosa, Mor. & Lyc. | | | 2 | 3 | | | | 7 | | | | S. G. L. | |
| Posidonomya opalina, Quenst. | | | | | | | 6 | | | | | G. | |
| *Psammobia.* See Quenstedtia. | | | | | | | | | | | | | |
| Pteroperna clypeata, Witc. | | | | | | 5 | | | | | | G. | |
| —— costatula, Desl. | | | | 3 | | | | 7 | 8 | | | G. O. L. | *Avicula, Gervillia.* |
| —— emarginata, Mor. & Lyc. | | | | | | | | 7 | 8 | | | G. O. | |
| —— gibbosa, Lyc. | | | | 3 | | | | | | | | G. L. | |
| —— plana, Mor. & Lyc. | | | | 3 | 4 | | 6 | 7 | | | | D. G. L. Y | |
| —— pygmæa, Dunk. | | | | 3 | | | | 7 | | | × | G. O. L. | |
| —— See also Gervillia. | | | | | | | | | | | | | |
| *Ptychomya.* See Astarte. | | | | | | | | | | | | | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Mollusca—*cont.* | | | | | | | | | | | | | |
| *Lamellibranchiata*—cont. | | | | | | | | | | | | | |
| *Pullastra.* See Astarte and Quenstedtia. | | | | | | | | | | | | | |
| Quenstedtia lævigata, Phil. | | | | 3 | | | | 7 | | 9 | × | G. N. L. Y. | *Psammobia.* |
| — oblita, Phil. | | | | 3 | | 5 | | 7 | | | | G. to Y. | *Pullastra.* |
| — oblonga, Phil. | | | | | | | | | | 9 | | L. | |
| *Sanguinolaria.* See Anatina and Mycites. | | | | | | | | | | | | | |
| Sowerbya elongata, Witc. | | | | | | 5 | | | | | | G. O. | |
| — triangularis, Phil. | | | | 3 | | | 6 | | 8 | | × | G. O. Y. | *Cucullæa.* |
| — Woodwardi, Lyc. | | | | | | 5 | | 7 | | | | G. O. | |
| Sphæra crassicosta, d'Orb. | | | | | | | | | | | | G. | Inf. Ool. |
| — fimbriata, Whidb. | | | | | 4 | 5 | | | | | | D. S. | |
| — Madridi, d'Arch. | | | | 3 | 4 | | 6 | 7 | 8 | | | D. to Y. | *Corbis.* |
| Spondylus nidulans, Desl. | | | | | 4 | | | | | | | S. G. | |
| Tancredia angulata, Lyc. | | | 2 | | | | 6 | 7 | | | | S. G. L. | |
| — axiniformis, Phil. | | | | 3 | | 5 | 6 | 7 | | | | G. to Y. | |
| — brevis, Mor. & Lyc. | | | | | | | | 7 | 8 | | | W. G. O. | |
| — compressiuscula, Terq. | | | | | | | | | | | | G. | Inf. Ool. |
| — curtansata, Phil. | | | | | | | | 7 | | | × | G. O. | *Corbula.* |
| — donaciformis, Lyc. | | | 2 | 3 | | 5 | | | | | | D. S. G. O. L. | |
| — extensa, Lyc. | | | | | | | | 7 | 8 | | | G. O. Sy. | *T. axiniformis,* Phil. (of Gt. Ool.). |
| — gibbosa, Lyc. | | | | | | | | 7 | 8 | | | S. W. G. | Inf. Ool. |
| — Lycetti, Oppel | | | | | | | | | | | | G. | Inf. Ool. |
| — mactræoides, Lyc. | | | | | | | | 7 | | | | O. | |
| — planata, Mor. & Lyc. | | | | | | | 6 | 7 | | | × | G. L. | |
| — similis, Lyc. | | | | | | | | 7 | | | | O. | |
| — subcurtansata, Mor. & Lyc. | | | | | | | | 7 | | | | W. G. O. | Inf. Ool. |
| — truncata, Lyc. | | | | | | | | 7 | 8 | | | G. O. | |
| *Tellina.* See Thracia. | | | | | | | | | | | | | |
| Thracia amygdaloidea, Lyc. | | | | | | | | 7 | | | | G. | |
| — curtansata, Mor. & Lyc. | | | | | | | | 7 | | | | G. O. N. L. | |
| — lata, Münst. | | | | 3 | | 5 | | | | | | D. S. Y. | *Sanguinolaria.* |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. jurensis. | Am. opalinus. | Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | | | | | | | |
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| MOLLUSCA—*cont.* | | | | | | | | | | | | | |
| *Lamellibranchiata*—cont. | | | | | | | | | | | | | |
| Thracia leguminosa, Whidb. | | | | | | | | | | | | S. - - | Inf. Ool. |
| —— Studeri, Ag. - - | | | | | 4 | 5 | | | | 9 | × | D. W. | |
| Trichites nodosus, Lyc. - | | | | 3 | | ? | | 7 | | | | S. G. L. | |
| —— Ploti, Lhwyd - - | | | | | | | | | | | | G. - - | Inf. Ool. |
| —— undulatus, Lyc. - | | | | | 4 | 5 | | | | | | G. L. | |
| Trigonia angulata, Sow. - | | | | 3 | | 5 | | | | | | S. G. O. - | *T. conjungens*, Phil. |
| —— arata, Lyc. - - | | | | | | | | | 8 | | | S. G. | |
| —— arduenna, Rig. & Sauv. | | | | | | | | | | | | O. - - | Inf. Ool. |
| —— bathonica, Lyc. - | | | | | | | | 7 | | | | S. W. | |
| —— beesleyana, Lyc. - | | | | 3 | | 5 | | | | | | O. | |
| —— bella, Lyc. - - | | | | | | 5 | | | | | | D. | |
| —— Brodiei, Lyc. - - | | | | 3 | | | | | | | | O. | |
| —— cassiope, d'Orb. - | | | | | | | | | | 9 | | N. L. Y. | |
| —— clathrata, Ag. - - | | | | | | | | | | 9 | | O. | |
| —— clytia, d'Orb. - - | | | | | | | | 7 | 8 | 9 | | S. W. G. N. | |
| —— compta, Lyc. - - | | | | 3 | | | | | | | | N. | |
| —— costata, Sow. - - | | | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | D. to L. | |
| —— —— var. elongata, Mor. & Lyc. | | | | | | | | 7 | | | | G. | |
| —— costatula, Lyc. - | | | | 3 | 4 | | | | | | | G. - | *T. exigua*, Lyc. |
| —— denticulata, Ag. - | | | 2 | 3 | | 5 | | | | | × | G. O. R. Y. | |
| —— detrita, Terq. & Jourd. | | | | | | | | | 8 | | | S. G. | |
| —— duplicata, Sow. - | | | | | | 5 | | 7 | | | | D. S. G. O. | |
| —— elongata, Sow. - - | | | | | | | 6 | | | 9 | × | D. N. Y. | |
| —— flecta, Mor. & Lyc. - | | | | | | | | 7 | 8 | 9 | | G. W. O. L. | |
| —— formosa, Lyc. - - | | 1 | 2 | 3 | 4 | | | | | | | D. S. G. L. Y. | |
| —— —— var. lata, Lyc. - | | | 2 | 3 | | | | | | | | D. S. O. | |
| —— gemmata, Lyc. - | | | | | | 5 | | | | | | G. O. Y. | |
| —— —— var. bifera, Lyc. - | | | | | | 5 | | | | | | G. | |
| —— Goldfussi, Ag. - - | | | | | | | | 7 | | 9 | | G. O. | |
| —— Griesbachi, Lyc. - | | | | | | | | 7 | | | | W. G. N. - | *T. tuberculosa*, Lyc. |
| —— Guisei, Lyc. - - | | | | | | 5 | | | | | | O. | |
| —— hemisphærica, Lyc. - | | | | 3 | | 5 | | | | | | D. G. to Y. | |
| —— —— var. gregaria, Lyc. | | | | 3 | | | | | | | | G. R. L. Y. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Passage Beds, Midford Sands. Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Inferior Oolite. Am. humphriesianus. | Inferior Oolite. Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Mollusca—*cont.* | | | | | | | | | | | | | |
| *Lamellibranchiata*—cont. | | | | | | | | | | | | | |
| Trigonia imbricata, Sow. | | | | | | | 6 | 7 | | | | S. W. G. | |
| —— impressa, Sow. | | | | 3 | | | | 7 | | 9 | | G. O. N. | |
| —— Lycetti, Walf. | | | | | | 5 | | | | | | O. | |
| —— —— var. corrugata, Walf. | | | | | | 5 | | | | | | O. | |
| —— Moretoni, Mor. & Lyc. | | | | | | | 6 | 7 | 8 | 9 | | D. to Y. Sy. ? | Inf. Ool. ? |
| —— —— var. oxoniensis, Lyc. | | | | | | 5 | | | | | | D. O. | |
| —— Painei, Lyc. | | | | | | 5 | | 7 | 8 | | | S. G. O. L. | |
| —— parcinoda, Lyc. | | | | | | | | | | | | D. | Inf. Ool. |
| —— Phillipsi, Mor. & Lyc. | | | | 3 | | | | | | | | G. N. L. Y. | |
| —— producta, Lyc. | | | | | | 5 | | | | | | G. O. | |
| —— pullus, Sow. | | | | 3 | | 5 | | 7 | 8 | 9 | | D. to Y. Sy. | *T. costata*, var. *pullus.* |
| —— Ramsayi, Wr. | | | 2 | | | | | | | | | G. Y. | |
| —— scarburgensis, Lyc. | | | | | | | | | ? | 9 | | D. N. to Y. | |
| —— sculpta, Lyc. | | | 2 | 3 | | 5 | | | 8 | | | D. to Y. | |
| —— —— var. cheltensis, Lyc. | | | | | | | | | | | | G. | Inf. Ool. |
| —— var. Rolandi, Cross | | | | | | | | | | 9 | | W. O. N. L. | |
| —— sharpiana, Lyc. | | | 2 | 3 | | | | | | | | S. N. Y. | |
| —— signata, Ag. | | | | 3 | | 5 | | | | | | D. G. O. N. Y. | { *T. decorata*, Lyc. *T. clavo-costata*, Lyc. |
| —— —— var. decurtata, Lyc. | | | | | | 5 | | | | | | O. | |
| —— —— var. rugulosa, Lyc. | | | | | | 5 | | | | | | O. | |
| —— —— var. Stutterdi, Lyc. | | | | | | 5 | | | | | | O. | |
| —— —— var. Zieteni, Lyc. | | | | | | 5 | | | | | | O. Y. | |
| —— spinulosa, Y. & B. | | | | 3 | | | | | | | | G. Y. | *T. composita*, Lyc. |
| —— striata, Sow. | | | 2 | 3 | 4 | 5 | | 7 | | | | D. to L. | |
| —— subglobosa, Mor. & Lyc. | | | | 3 | | | | 7 | | | | G. | |
| —— tenuicosta, Lyc. | | | | 3 | 4 | | | | | | | D. G. Y. | |
| —— tripartita, Forbes | | | | | | | | | | 9 | | W. | |
| —— tuberculosa, Lyc. | | | | | | | | | | 9 | | G. N. H. | Inf. Ool. |
| —— undulata, Fromherz | | | | | | | | 7 | 8 | 9 | | D. to L. | |
| —— v. costata, Lyc. | | | | 3 | | 5 | | | | | | G. O. N. Y. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Passage Beds, Midford Sands. Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Inferior Oolite. Am. humphriesianus. | Inferior Oolite. Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Mollusca—*cont.* | | | | | | | | | | | | | |
| *Lamellibranchiata*—cont. | | | | | | | | | | | | | |
| Trigonia Walfordi, Lyc. - | | | | | | | | ? | | | | O. - - | Inf. Ool. |
| —— Windoesi, Lyc. - | | | | | | | | | | | | O. - - | Inf. Ool. |
| —— Witchelli, Lyc. - | | | | | | | 6 | | | | | G. | |
| Unicardium depressum, Phil. | | | | 3 | 4 | 5 | | | | | × | D. G. L. Y. | *Corbula.* |
| —— gibbosum, Mor. & Lyc. | | | | 3 | 4 | | 6 | 7 | | | × | D. G. N. L. Y. | |
| —— impressum, Mor. & Lyc. | | | | 3 | | | 6 | 7 | 8 | 9 | | G. O. N. | |
| —— incertum, Phil. - | | | | | | 5 | | | | | | G. | |
| —— parvulum, Mor. & Lyc. | | | | 3 | | 5 | | 7 | | | | G. L. | |
| —— varicosum, Sow. - | | | | 3 | | 5 | | 7 | 8 | 9 | | D. to N. | |
| Unio, sp. - - - | | | | | | | 6 | | | | | L. | |
| *Venus.* See Cyprina. | | | | | | | | | | | | | |
| Brachiopoda. | | | | | | | | | | | | | |
| *Acanthothyris.* See Rhynchonella. | | | | | | | | | | | | | |
| *Aulacothyris.* See Waldheimia. | | | | | | | | | | | | | |
| Argiope? oolitica, Dav. - | | | | | | | | 7 | | | | S. - - | Inf. Ool. |
| Crania antiquior, Jelly - | | | | | | | | 7 | | | | S. | |
| —— canalis, Moore - | | | | | 4 | | | | | | | D. S. | |
| —— Saundersi, Moore - | | | | | 4 | | | | | | | S. G. | |
| Discina dundriensis, Moore | | | | | 4 | | | | | | | S. | |
| —— Etheridgei, Dav. - | | | | | 4 | | | | | | | S. G. | |
| —— Gunni, Dav. - - | | | | 3 | | | | | | | | O. | |
| —— reflexa, Sow. - - | × | 1 | | 3 | | | | | | | | G. N? Y. | |
| *Dictyothyris.* See Terebratula. | × | | 2 | | | | | | | | | | |
| *Glossothyris.* See Terebratula. | | | | | | | | | | | | | |
| Lingula Beani, Phil. - | × | | 2 | | | | | | | | | N. Y. | |
| *Plesiothyris.* See Waldheimia. | | | | | | | | | | | | | |
| Rhynchonella angulata, Sow. | | | | 3 | 4 | 5 | | | | | | D. S. G. O. N. | |
| —— var. subangulata, Dav. | | | | 3 | | 5 | | | | | | D. G. | |
| —— balinensis, Szajnocha - | | | | 3 | | | | | | | | D. S. | |
| —— Beneckei, Haas. - | | 1 | | | | | | | | | | D. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Passage Beds, Midford Sands. Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Inferior Oolite. Am. humphriesianus. | Inferior Oolite. Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | | × | | |
| BRACHIOPODA—*cont.* | | | | | | | | | | | | | |
| Rhynchonella *bilobata*, see R. liostraca. | | | | | | | | | | | | | |
| —— Boueti, Dav. - - | | | | | | | | | 8 | 9 | | D. | |
| —— bradfordensis, Walker. See R. spinosa. | | | | | | | | | | | | | |
| —— buteo, Szaj. - - | | | | 3 | | | | | | | | D. | |
| —— concinna, Sow. - | | | | 3 | | 5 | 6 | 7 | 8 | 9 | | D. to L. Sy. | |
| —— —— var. yaxleyensis, Dav. | | | | | | | | | | 9 | | W. H. | |
| —— Crossi, Walk. - - | | | | 3 | | | | | | | | N. R. L. Y. | *Acanthothyris.* |
| —— cynocephala, Rich. - | | 1 | 2 | 3 | | | | | | | | D. to Y. - | *R. Stephensi*, Dav. |
| —— decorata, Dav. - - | | | | 3 | | | | | | | | G. Y. | |
| —— distracta, Waag. - | | | | 3 | | | | | | | | D. S. | |
| —— dorsetensis, S. Buckm. | | | | | 4 | | | | | | | D. S. | |
| —— dundriensis, S. Buckm. | | | | 3 | 4 | | | | | | | D. S. | |
| —— Forbesi, Dav. - - | | | | 3 | | 5 | | | | | | D. S. G. | |
| —— gingensis, Waag. - | | | | 3 | | | | | | | | D. | |
| —— hampenensis, S. Buckm. | | | | | | 5 | | | | | | S. G. | |
| —— jurensis, Quenst. - | × | 1 | 2 | | | | | | | | | D. G. | |
| —— Leedsi, Walk. - - | | | | | | | | | | 9 | | N. H. Y. | |
| —— liostraca, S. Buckm. - | | | | 3 | | | | | | | | D. S. - | *R. bilobata*, S. Buckm. |
| —— ? lopensis, Moore - | | | | | | | | | | | | S. - - | Inf. Ool. |
| —— Lycetti, Dav. - - | | | | 3 | 4 | | | | | | | S. G. | |
| —— Moorei, Dav. - - | × | 1 | | | | | | | | | | S. | |
| —— Morièrei, Dav. - - | | | | | | | | 7 | 8 | 9 | | D. O. N. H. | |
| —— obsoleta, Sow. - - | | | | | 4 | 5 | 6 | 7 | 8 | 9 | × | D. to Y. | |
| —— oolitica, Dav. - - | | | | 3 | | | | | | | | G. | |
| —— palma, Szajnocha - | | | | 3 | | | | | | | | D. | |
| —— panacanthina, S. Buckm. & Walk. | | | | | | 5 | | | | | | D. S. - | *Acanthothyris.* *R. senticosa* of Dav. (non von Buch.). |
| —— parvula, Desl. - - | | | | | | 5 | | | | | | D. | |
| —— paucispina, S. Buckm. & Walk. | | | | 3 | 4 | | | | | | | D. S. - | *Acanthothyris.* |
| —— —— var. cortonensis, B. & W. | | | | 3 | | | | | | | | S. | |
| —— plicatella, Sow. - | | | | 3 | | 5 | | | | | | D. S. G. L. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Passage Beds, Midford Sands. Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Inferior Oolite. Am. humphriesianus. | Inferior Oolite. Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | + | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| BRACHIOPODA—*cont.* | | | | | | | | | | | | | |
| Rhynchonella quadriplicata, Ziet. | | | | 3 | 4 | 5 | | | | | | D. S. G. O. L. | |
| —— ringens, Herault - | | | 2 | 3 | | 5 | | | | | | D. S. G. | |
| —— *senticosa,* von Buch. See R. panacanthina. | | | | | | | | | | | | | |
| —— spinosa, Schloth. - | | | | | 4 | 5 | 6 | | | | | D. to Y. - | *Acanthothyris.* |
| —— spinosa, var. bradfordensis, Walk. | | | | | | | | | | 8 | | D. W. G. - | *Acanthothyris.* |
| —— —— var. obornensis, Buckm. & Walk. | | | | | | 5 | | | | | | D. S. | |
| —— —— var. powerstockensis, B. & W. | | | | | | | 6 | | | | | D. | |
| —— subangulata, Dav. - | | | | 3 | | | | | | | | D. G. O. | |
| —— subdecorata, Dav. - | | | 2 | 3 | 4 | | | | | | | D. G. O. L. | |
| —— subobsoleta, Dav. - | | | | 3 | 4 | | | | | | | G. Y. | |
| —— subringens, Dav. - | | | | 3 | 4 | | | | | | | D. S. | |
| —— subtetrahedra, Dav. - | | | | 3 | 4 | 5 | | | | | | D. to Y. | |
| —— Tatei, Dav. - - | | | | 3 | | | | | | | | G. | |
| —— tenuispina ?, Waag. - | | | | | 4 | | | | | | | D. - - | *Acanthothyris.* |
| —— triangularis, Moore - | | | | | 4 | | | | | | | S. | |
| —— varians, Schloth. - | | | | | | | 6 | 7 | 8 | 9 | × | D. to L. | |
| —— —— var. Smithi, Walk. | | | | | | | 6 | | | | | D. S. - | *T. media,* Smith (non Sow.). |
| —— Wrighti, Dav. - - | | | | 3 | 4 | | | | | | | G. | |
| Spiriferina ? minima, Moore | | | | | 4 | | | | | | | S. | |
| —— ? oolitica, Moore - | | | | | 4 | | | 7 | | | | S. | |
| Terebratella Buckmani, Moore. | | | | | | | | 7 | | | | S. | |
| —— furcata, Sow. - - | | | | | | | | 7 | | | | S. | |
| —— Moorei, Dav. - - | | | | | | | | 7 | | | | S. | |
| Terebratula Bentleyi, Dav. | | | | | | | | | | 9 | | N. H. L. Y. | |
| —— —— var. sub-Bentleyi, Dav. | | | | 3 | 4 | | | | | | | G. - - | *T. galeiformis,* M'Coy. |
| —— bradfordensis, Walk. | | | | | | | | | 8 | | | D. W. G. | |
| —— Buckmani, Dav. - | | | | 3 | 4 | 5 | | | | | | D. S. G. N. L. | |
| —— —— var. buckmaniana, Walk. | | | | | 4 | | | | | | | D. G. | |
| —— coarctata, Park. - | | | | | | | | 7 | 8 | 9 | | D. to G. H. L. Sy. | *Dictyothyris.* |

| SPECIES. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Passage Beds, Midford Sands. Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Inferior Oolite. Am. humphriesianus. | Inferior Oolite. Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | LOCALITIES. | REMARKS. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| BRACHIOPODA—*cont.* | | | | | | | | | | | | | |
| Terebratula coarctata var. recticulata, Sow. | | | | | | | 6 | | | | | S. W. | |
| —— conglobata, E. Desl. - | | | | 3 | | | | | | | | S. | |
| —— cortonensis, S. Buckm. | | | | 3 | | | | | | | | D. S. | |
| —— Craneæ, Dav. - - | | | | | 4 | 5 | | | | | | D. | |
| —— curviconcha, Oppel - | | | | | 4 | | | | | | | D. - - | *Glossothyris.* |
| —— curvifrons, Oppel - | | | | 3 | 4 | | | | | | | D. S. G. - | *Glossothyris.* |
| —— decipiens, Desl. - | | | | | 4 | 5 | | | | | | D. S. | |
| —— dorsoplana, Waag. - | | | | 3 | | | | | | | | D. | |
| —— emarginata, Sow. - | | | | | | 5 | | | | | | D. S. G. | |
| —— Etheridgei, Dav. - | | | | 3 | 4 | | | | | | | D. S. G. | |
| —— Eudesi, Oppel - - | | | | 3 | | 5 | | | | | | D. S. G. | |
| —— eudesiana, S. Buckm.- | | | | 3 | | | | | | | | D. S. | |
| —— Ferryi, Desl. - - | | | | | | 5 | | | | | | D. S. | |
| —— fimbria, Sow. - - | | | | 3 | | | | | | | | G. O. L. | |
| —— flabellum, Defr. - | | | | | | | | | 8 | | | W. G. | |
| —— Fleischeri, Oppel. - | | | | 3 | 4 | | | | | | | D. G. - | *T. euides*, S. Buckm. |
| —— Fraivrei, Bayle - | | | | | | 5 | | | | | | D. | |
| —— galeiformis, Dav. - | | | | 3 | | | | | | | | G. - - | *Dictyothyris.* |
| —— globata, Sow. - - | | | | | | 5 | 6 | | | | | D. to Y. | |
| —— —— var. birdlipensis, Walk. | | | | | | 5 | 6 | | | | | D. G. | |
| —— gravida, Szajnocha - | | | | | 4 | | | | | | | D. | |
| —— hemisphærica, Sow. - | | | | | | | | 7 | 8 | 9 | | S. O. | |
| —— Hollandæ, S. Buckm. - | | | | | 4 | 5 | | | | | | D. | |
| —— hybrida, Desl. - - | | | | | | 5 | | | | | | D. S. - | *Dictyothyris.* |
| —— infra-oolitica, Desl. - - | | | 2 | | | | | | | | | D. S. G. | |
| —— intermedia, Sow. - | | | | | | | | 7 | 8 | 9 | × | D. to Y. | |
| —— —— var. langtonensis, Walk. | | | | | | | | | 8 | 9 | | D. | |
| —— Leesi, S. Buckm. - | | | | 3 | | | | | | | | D | |
| —— linguifera, S. Buckm. - | | | | | | | 6 | | | | | D. | |
| —— maxillata, Sow. - | | | | 3 | | 5 | 6 | 7 | 8 | 9 | | D. to Y. Sy. | Including var. submaxillata, Mor. |
| —— minuta, Moore - | | | | | | | | 7 | | | | S. | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| **Brachiopoda**—*cont.* | | | | | | | | | | | | | |
| Terebratula Morièrei, Desl. | | | | | | 5 | | | | | | D. S. - | *Dictyothyris.* |
| —— notgrovensis, S. Buckm. | | | | 3 | | | | | | | | G. | |
| —— ovoides, Sow. - - | | | | 3 | 4 | | | | | | | O. L. Y. | |
| —— perovalis, Sow. - | | | | 3 | 4 | 5 | | | | | | D. to L. | |
| —— —— var. ampla, J. Buckm. | | | | | | 5 | | | | | | D. | |
| —— —— var. Kleini, Lam. - | | | | | | 5 | | | | | | G. | |
| —— Phillipsi, Morris - | | | | | 4 | 5 | 6 | | | | | D. to L. | |
| —— —— var. phillipsiana, Walk. | | | | | 4 | | | | | | | D. G. | |
| —— pisolitica, S. Buckm. - | | | | 3 | | | | | | | | G. | |
| —— plicata, J. Buckm. - | | | | 3 | | | | | | | | G. O. L. | |
| —— provincialis, Desl. - | | | | 3 | | | | | | | | S. - - | *Glossothyris.* |
| —— punctata, Sow. var. haresfieldensis, Dav. | | 1 | 2 | | | | | | | | | G. - - | { *T. subpunctata*, Dav. ? var. of *T. trilineata.* |
| —— sherbornensis, S. Buckm. | | | | 3 | | | | | | | | D. S. | |
| —— simplex, Buckm. - | | | | 3 | | | | | | | | D. G. O. | |
| —— sphæroidalis, Sow. - | | | | | 4 | 5 | | | | | | D. S. L. | |
| —— Stephani, Dav. - | | | | | | 5 | | | | | | D. S. | |
| —— Tawneyi, Whidb. - | | | | | 4 | | | | | | | S. | |
| —— trilineata, Y. & B. - | | | 2 | 3 | | | | | | | | O. N. Y. | |
| —— ventricosa, Hartm. - | | | | | 4 | | | | | | | G. | |
| —— Whitakeri, Walk. - | | | | 3 | 4 | 5 | | | | | | G. | |
| —— Wrighti, Dav. - - | | | | | | 5 | | | | | | D. G. | |
| Terebratulina radiata, Moore. | | | | | | | | 7 | | | | S. | |
| —— —— var. dundriensis, Dav. | | | | | 4 | | | | | | | S. | |
| Thecideum Bouchardi, Dav. | | | | 3 | | | | | | | | S. | |
| —— Dickensoni, Moore - | | | | 3 | | | | | | | | S. | |
| —— duplicatum, Moore - | | | | 3 | | | | | | | | S. | |
| —— Forbesi, Moore - | | | | 3 | | | | | | | | S. | |
| —— granulosum, Moore - | | | | 3 | | | | | | | | S. | |
| —— septatum, Moore - | | | | 3 | | | | | | | | S. | |
| —— serratum, Moore - | | | | 3 | | | | | | | | S. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| **Brachiopoda**—*cont.* | | | | | | | | | | | | | |
| Thecideum triangulare, d'Orb. | | | | 3 | | | 6 | 7 | 8 | | | S. G. Sy. | |
| Waldheimia anglica, Oppel | | 1 | 2 | 3 | 4 | 5 | | | | | | D. S. O. G. - | *Zeilleria.* |
| —— bisulcata, S. Buckm. - | | | | | | 5 | | | | | | D. - - | *Aulacothyris.* |
| —— Brodiei, S. Buckm. - | | | | | 4 | | | | | | | D. - - | *Plesiothyris.* |
| —— bullata, Sow. - - | | | | 3 | 4 | 5 | 6 | | | | | D. S. G. Y. | |
| —— cadomensis, E. Desl. - | | | | | | 5 | 6 | | | | | D. S. G. | |
| —— cardium, Lam. - | | | | | | | | 7 | 8 | 9 | | S. W. G. O. N. | ? Inf. Ool. |
| —— —— var. leckhamptonensis, Walk. | | | | 3 | 4 | | | | | | | D. G. | |
| —— carinata, Lam. - | | | | 3 | 4 | 5 | | | | | | D. S. G. - | *Aulacothyris.* |
| —— —— var. Blakei, Walk. | | | 2 | | | | | | | | | D. S. Y. | |
| —— —— var. crewkernensis, S. Buckm. | | | | | | 5 | | | | | | S. | |
| —— —— var. Mandelslohi, Oppel. | | | 2 | | 4 | | | | | | | D. G. O. | |
| —— digona, Sow. - - | | | | | | | | 7 | 8 | 9 | | D. to L. Sy. | |
| —— disculus, Waag. - | | | | 3 | | | | | | | | D. S. - | *Zeilleria.* |
| —— emarginata, Sow. - | | | | | | 5 | | | | | | D. S. - | *Zeilleria.* |
| —— Haasi, S. Buckm. - | | | | | 4 | | | | | | | D. - - | *Aulacothyris.* |
| —— Hughesi, Walk. - | | | | | | 5 | | | | | | D. G. | |
| —— lagenalis, Schloth. - | | | | | | | 6 | | | 9 | | D. to Y. - | *W. sublagenalis*, Dav. |
| —— Leckenbyi, Walk. - | | | | 3 | 4 | | | | | | | D. G. - | *Zeilleria.* |
| —— Meriana, Oppel - | | | | | 4 | 5 | | | | | | D. S. G. - | *Aulacothyris.* |
| —— obovata, Sow. - - | | | | | | | | | 8 | 9 | × | D. to Y. | |
| —— —— var. siddingtonensis, Walk. | | | | | | | | | | 9 | | W. G. N. Y. | |
| —— —— var. stiltonensis, Walk. | | | | | | | | | | 9 | | O. N. H. Y. | |
| —— —— var. subovata, Walk. | | | | | | | | | | 9 | | O. N. | |
| —— ornithocephala, Sow. - | | | | | | | 6 | | 8 | 9 | × | D. to Y. | |
| —— reversa, S. Buckm. - | | | | | 4 | | | | | | | D. - - | *Plesiothyris.* |
| —— subbucculenta, Chap. & Dew. | | | | | | 5 | | | | | | D. | |
| —— triquetra, Sow. - | | | | | | 5 | | | | | | D. | |
| —— Waltoni, Dav. - | | | 2 | 3 | 4 | 5 | | | | | | D. S. G. - | *Zeilleria.* |
| —— Witchelli, S. Buckm. | | | | 3 | | | | | | | | G. - - | *Zeilleria.* |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Brachiopoda—*cont.* | | | | | | | | | | | | | |
| *Zeilleria.* See Waldheimia. | | | | | | | | | | | | | |
| Zellania Davidsoni, Moore | | | | 3 | | | | | | | | S. | |
| —— globata, Moore - | | | | | | | 6 | 7 | 8 | | | S. Sy. | |
| —— Laboucherei, Moore - | | | | 3 | | | | | | | | S. | |
| —— oolitica, Moore - | | | | 3 | | | | | | | | S. | |
| Polyzoa. | | | | | | | | | | | | | |
| *Alecto.* See Stomatopora. | | | | | | | | | | | | | |
| Apsendesia clypeata, Haime | | | | 3 | | | | | | | | O. | |
| —— cristata, Haime - | | | | | | | | 7 | | | | S. | |
| *Berenicia.* See Diastopora. | | | | | | | | | | | | | |
| Bisidmonea tetragona, Lamx. var. ovalis, Walf. | | | | | | 5 | | | | | | D. | |
| Cellepora - - - | | | | | | | | | | 9 | | H. | |
| *Ceriopora.* See Heteropora. | | | | | | | | | | | | | |
| Cricopora cæspitosa, Lamx. | | | | | | | | 7 | | | | S. W. | |
| —— tessonis, Mich. - | | | | | | | | 7 | | | | G. | |
| —— See also Entalophora. | | | | | | | | | | | | | |
| Chrysaora similis, McCoy. | | | | | | | | 7 | | | | S. | |
| —— See also Neuropora. | | | | | | | | | | | | | |
| Diastopora cricopora, Vine. | | | | 3 | | 5 | | 7 | | | | O. G. | |
| —— Davidsoni, Haime - | | | | | | | | 7 | | | | G. | |
| —— diluviana, Lamx. - | | | | 3 | | | | 7 | 8 | 9 | × | D. to H. Sy. | *Berenicia.* |
| —— eudesiana, M. Edw. - | | | | | | | | 7 | | | | G. | |
| —— foliacea, Lamx. - | | | | | | | | 7 | | | | S. | |
| —— Lamourouxi, Haime - | | | | 3 | | | | | 8 | | | G. Sy. | |
| —— mettensis, Haime - | | | | 3 | | | | | | | | G. - - | *Elea.* |
| —— Michelini, Haime - | | | | 3 | | | | | | | | S. G. | |
| —— microstoma, Mich. - | | | | | | | | 7 | 8 | | | S. Sy. | |
| —— —— var. connectens, Vine. | | | | | | | | | 8 | | | Sy. | |
| —— oolitica, Vine. - - | | | | 3 | | | | 7 | | | | O. | |
| —— scobinula, Mich. - | | | | | | | | 7 | | | | S. | |
| —— ventricosa, Vine - | | | | | | | | 7 | | | | G. O. - | Inf. Ool. |
| —— verrucosa, M. Edw. - | | | | | | | | 7 | | | | S. W. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Passage Beds, Midford Sands. Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Inferior Oolite. Am. humphriesianus. | Inferior Oolite. Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| POLYZOA—*cont.* | | | | | | | | | | | | | |
| Diastopora Waltoni, Haime. | | | | 3 | | | | | | | | G. | |
| —— Wrighti, Haime | | | | 3 | | | | | | | | G. | |
| Entalophora cæspitosa, Lamx. | | | | | | | | 7 | 8 | | | W. | |
| —— magnipora, Walf | | | | | | 5 | | | | | | D. | |
| —— raripora, d'Orb. | | | | | | 5 | | | | | | D. | |
| —— —— var. anomala, Reuss. | | | | | | 5 | | | | | | D. | |
| —— richmondensis, Vine. | | | | | | | | | 8 | | | Sy. | |
| —— —— var. pustulopora, Vine. | | | | | | | | | 8 | | | Sy. | |
| —— straminea, Phil. | | | | 3 | | | | | 8 | 9 | | D. to Y. Sy. | { *Millepora,* *Cricopora, Spiropora.* |
| —— subgracilis, d'Orb, var. corrugata, Walf. | | | | | | 5 | | | | | | D. | |
| Fasciculipora Waltoni, Haime. | | | | 3 | | | | | 8 | | | G. Sy. ? | |
| Heteropora conifera, Haime | | | | 3 | | | | 7 | 8 | | | S. G. O. Sy. | *Millepora.* |
| —— dumetosa, Lamx. | | | | | | | | 7 | | | | S. | *Millepora, Ceriopora.* |
| —— pustulosa, Mich. | | | | 3 | | | | 7 | | | | S. G. | *Ceriopora.* |
| —— ramosa, Mich. | | | | | | | | 7 | | | | G. | |
| Idmonea claviformis, Walf. | | | | | | 5 | | | | | | D. | |
| —— stomatoporoides, Walf. | | | | | | 5 | | | | | | D. | |
| —— triquetra, Haime | | | | | | | | | 8 | | | S. Sy. | |
| —— —— var. Parkinsoni, Walf. | | | | | | 5 | | | | | | D. | |
| —— —— var. Y-formis, Walf. | | | | | | 5 | | | | | | D. | |
| Lichenopora Phillipsi, Haime. | | | | 3 | | | | 7 | 8 | | | S. G. Sy. ? | |
| Neuropora damicornis, Haime. | | | | | | | | 7 | | | | S. | *Chrysaora.* |
| —— Defrancei, Haime | | | | | | | | 7 | | | | S. | |
| —— spinosa, Haime | | | | | | | | 7 | | | | S. | |
| Proboscina Davidsoni, Haime. | | | | | | | | 7 | | | | S. | |
| —— incrustans, Walf. | | | | | | 5 | | | | | | D. | |
| —— (cf.) prorepens, Waag. | | | | 3 | | | | | | | | O. | |
| —— spatiosa, Walf. | | | | | | 5 | | | | | | D. | |
| —— —— var. brevior, Walf. | | | | | | 5 | | | | | | D. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Passage Beds, Midford Sands. Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Inferior Oolite. Am. humphriesianus. | Inferior Oolite. Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| POLYZOA—*cont.* | | | | | | | | | | | | | |
| Proboscina spatiosa, var. brevis, Walf. | | | | | | 5 | | | | | | D. | |
| Stomatopora dichotoma, Lamx. | | | | | | 5 | | 7 | 8 | 9 | | D.S.W.O.Sy. | *Alecto. Aulopora.* |
| —— dichotomoides, Haime | | | | 3 | | 5 | | | 8 | | | D. G. | |
| —— —— var. attenuata, Walf. | | | | | | 5 | | | | | | D. | |
| —— elongata, Walf. | × | | | | | 5 | | | | | | D. | |
| —— porrecta, Walf. | | | | | | 5 | | | | | | D. | |
| —— spirata, Walf. | | | | | | 5 | | | | | | D. | |
| —— Waltoni, Haime | | | | ? | | | | | 8 | | | W. O. Sy. | |
| erebellaria increscens, Vine. | | | | | | | | | 8 | 9 | | Lond. Sy. | |
| —— ramosissima, Lamx. | | | | | | | | 7 | 8 | | | S. W. O. | *Diastopora.* |
| Theonoa Bowerbanki, Haime. | | | | 3 | | | | | | | | G. | |
| —— clathrata, Lamx. | | | | | | | | 7 | | | | S. W. | |
| Tubulipora spatiosa, Walf. | | | | | | 5 | | | | | | D. | |
| CRUSTACEA. | | | | | | | | | | | | | |
| *Macroura.* | | | | | | | | | | | | | |
| Eryma elegans, Oppel | × | | | 3 | | | | 7 | | | | G. N. | *E. Guisei*, Wr. |
| Eryon Stoddarti, H. Woodw. | | | | | | | | 7 | | | | O. | |
| Glyphea pseudoscyllarus, Schloth. | | | | | | | 6 | | | | | G. | |
| —— rostrata, Phil. | | | | | | | | 7 | | 9 | × | O. H. Y. | ? Inf. Ool. Dorset. |
| Goniochirus platycheles, McCoy. | | | | | | | | 7 | | | | G. | |
| Magita | | | | | | | 6 | | | | | G. | |
| *Brachyura.* | | | | | | | | | | | | | |
| Palæinachus longipes, H. Woodw. | | | | | | | | | 8 | | | W. | |
| Prosopon mammillatum, H. Woodw. | | | | | | | | 7 | | | | O. | |
| *Isopoda.* | | | | | | | | | | | | | |
| Cyclosphæroma trilobatum, H. Woodw. | | | | | | | | 7 | | | | N. | |
| *Cirripedia.* | | | | | | | | | | | | | |
| Pollicipes ooliticus, Buckm. | | | | | | | | 7 | | | | G. | |
| —— sp. | | | | 3 | | | | | | | | L. | |

| SPECIES. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Passage Beds, Midford Sands. Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Inferior Oolite. Am. humphriesianus. | Inferior Oolite. Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | LOCALITIES. | REMARKS. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| CRUSTACEA—*cont.* | | | | | | | | | | | | | |
| *Ostracoda.* | | | | | | | | | | | | | |
| Bairdia fullonica, Jones & Sherb. | | | | | | | 6 | | | | | S. | |
| —— Hilda, Jones | | | | | | | | | 8 | | | Sy. | |
| —— juddiana, Jones | | | | | | | 6 | | 8 | | | S. Sy. | |
| —— jurassica, Jones | | | | | | | | | 8 | | | Sy | |
| —— —— var. tenuis, Jones | | | | | | | | | 8 | | | Sy. | |
| —— trigonalis, Jones | | | | | | | 6 | | | | | S. | |
| Bythocypris winwoodiana, Jones & Sherb. | | | | | | | 6 | | | | | S. | |
| Cythere blakeana, Jones | | | | | | | | | 8 | | | Sy. | |
| —— bradiana, Jones | | | | | | | | | 8 | | | Sy. | |
| —— corrosa, J. & S. | | | | | | | 6 | | | | | S. | |
| —— drupacea, Jones | | | | | | | | | 8 | | | Sy. | |
| —— guembeliana, Jones | | | | | | | | | 8 | | | Sy. | |
| —— juglandica, Jones, var. major, J. & S. | | | | | | | | | 8 | | | W. | |
| —— —— var. minor, J. & S. | | | | | | | 6 | | | | | S. | |
| —— oscillum, J. & S. | | | | | | | 6 | | | | | S. | |
| —— quadrilatera, Roem. | | | | | | | | | 8 | | | Sy. | *Cythereis.* |
| —— ? speciosa, J. & S. | | | | | | | 6 | | | | | S. | |
| —— sphærulata, J. & S. | | | | | | | 6 | | | | | S. | |
| —— ? tenella, Jones | | | | | | | | | 8 | | | Sy. | |
| —— trapezioides, J. & S. | | | | | | | 6 | | | | | G. | |
| —— walfordiana, J. & S. | | | | | | | 6 | | | | | G. | |
| Cythereis fullonica, J. & S. | | | | | | | 6 | | | | | S. | |
| —— walfordiana, J. & S. | | | | | | | 6 | | | | | G. | |
| Cytherella catenulata, J. & S. | | | | | | | 6 | | | | | S. G. | |
| —— fullonica, J. & S. | | | | | | | 6 | | | | | S. G. | |
| —— jugosa, Jones | | | | | | | | | 8 | | | Sy. | |
| —— subovata, Jones | | | | | | | | | 8 | | | Sy. | |
| Cytheridea acutiplicata, J. & S. | | | | | | | 6 | | | | | S. | |
| —— æquabilis, J. & S. | | | | | | | 6 | | | | | S. | |
| —— bicarinata, J. & S. | | | | | | | 6 | | | | | S. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. | | Inferior Oolite. | | | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. jurensis. | Am. opalinus. | Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | | | | | | | |
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| CRUSTACEA—*cont.* | | | | | | | | | | | | | |
| *Ostracoda*—cont. | | | | | | | | | | | | | |
| Cytheridea blakeana, Jones | | | | | | | 6 | | | | | S. | |
| —— bradiana, Jones - | | | | | | | 6 | | | | | S. | |
| —— coarctata, J. & S. - | | | | | | | 6 | | | | | S. | |
| —— craticula, J. & S. - | | | | | | | 6 | | | | | S. | |
| —— dolabra, J. & S. - | | | | | | | 6 | | | | | S. | |
| —— egregia, J. & S. - | | | | | | | 6 | | | | | S. | |
| —— eminula, J. & S. - | | | | | | | 6 | | | | | S. | |
| —— eximia, J. & S. - | | | | | | | 6 | | | | | S. | |
| —— fulgurata, J. & S. - | | | | | | | 6 | | 8 | | | S. W. | |
| —— horatiana, J. & S. - | | | | | | | 6 | | | | | S. | |
| —— ignobilis, J. & S. - | | | | | | | 6 | | | | | S. | |
| —— limaciformis, J. & S. - | | | | | | | 6 | | | | | S. | |
| —— obovata, J. & S. - | | | | | | | 6 | | | | | S. | |
| —— ostreata, J. & S. - | | | | | | | 6 | | | | | S. | |
| —— parallela, J. & S. - | | | | | | | 6 | | | | | S. | |
| —— pentagonalis, J. & S. - | | | | | | | 6 | | | | | S. | |
| —— persica, J. & S. - | | | | | | | 6 | | | | | S. | |
| —— politula, J. & S. - | | | | | | | 6 | | | | | G. | |
| —— pulvinar, J. & S. - | | | | | | | 6 | | | | | S. | |
| —— punctiputeolata, J. & S. | | | | | | | 6 | | | | | S. | |
| —— pura, J. & S. - | | | | | | | 6 | | | | | S. | |
| —— puteolata, J. & S. - | | | | | | | 6 | | | | | S. | |
| —— refecta, J. & S. - | | | | | | | 6 | | | | | S. | |
| —— renoides, J. & S. - | | | | | | | 6 | | | | | S. | |
| —— retorrida, J. & S. - | | | | | | | 6 | | | | | S. | |
| —— rugifera, J. & S. - | | | | | | | 6 | | | | | G. | |
| —— sedata, J. & S. - | | | | | | | 6 | | | | | S. | |
| —— spinifastigiata, J. & S. | | | | | | | 6 | | | | | S. | |
| —— spinigyrata, J. & S. - | | | | | | | 6 | | | | | S. | |
| —— striblita, J. & S. - | | | | | | | 6 | | | | | S. | |
| —— subeminula, J. & S. - | | | | | | | 6 | | | | | G. | |
| —— subperforata, Jones - | | | | | | | | | 8 | ? | | W. Sy. | |
| —— subtrigona, J. & S. - | | | | | | | 6 | | | | | S. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Crustacea—*cont.* | | | | | | | | | | | | | |
| *Ostracoda*—cont. | | | | | | | | | | | | | |
| Cytheridea sugillata, J. & S. | | | | | | | 6 | | | | | S. | |
| —— terræ-fullonicæ, J. & S. | | | | | | | 6 | | | | | S. G. | |
| —— transversiplicata, J. & S. | | | | | | | 6 | | | | | S. | |
| —— trapezoidalis, J. & S. - | | | | | | | 6 | | | | | S. | |
| —— ventrosa, J. & S. - | | | | | | | 6 | | | | | S. | |
| —— visceralis, J. & S. - | | | | | | | 6 | | | | | S. G. | |
| —— vulsa, J. & S. - - | | | | | | | 6 | | | | | S. G. | |
| —— winwoodiana, J. & S. - | | | | | | | 6 | | | | | S. | |
| Macrocypris horatiana, J. & S. | | | | | | | 6 | | | | | S. | |
| —— terræ-fullonicæ, J. & S. | | | | | | | 6 | | | | | S. | |
| Insecta. | | | | | | | | | | | | | |
| *Coleoptera.* | | | | | | | | | | | | | |
| Blapsidium Egertoni, Westw. | | | | | | | | 7 | | | | O. | |
| —— Studeri, Gieb. - - | | | | | | | | 7 | | | | G. | |
| Bruchus - - - | | | | | | | | 7 | | | | G. | |
| *Buprestidium.* See Prionus. | | | | | | | | | | | | | |
| Coccinella Wittsi, Brod. - | | | | | | | | 7 | | | | G. - - | *Pimelia.* |
| Carabus ? - - - | | | | | | | | 7 | | | | G. | |
| Curculioides - - - | | | | | | | | 7 | | | | O. | |
| Melolontha - - - | | | | | | | | 7 | | | | G. | |
| Pimelia Zekeli, Gieb. - | | | | | | | | 7 | | | | G. | |
| Prionus ooliticus, Brodie - | | | | | | | | 7 | | | | G. O. - | *P. Bucklandi*, Mant. |
| (Elytra of Beetles) - - | | | | | | | | 7 | 8 | | | G. O. S. - | Inf. Ool. ? |
| *Neuroptera.* | | | | | | | | | | | | | |
| Æschna - - - | | | | | | | | 7 | | | | G. | |
| Hemerobioides giganteus, Buckl. | | | | | | | | 7 | | | | O. | |
| Libellula Westwoodi, Phil. | | | | | | | | 7 | | | | O. | |
| *Hemiptera.* | | | | | | | | | | | | | |
| Palæontina oolitica, Butler | | | | | | | | 7 | | | | O. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Passage Beds, Midford Sands. Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Inferior Oolite. Am. humphriesianus. | Inferior Oolite. Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| **Annelida.** | | | | | | | | | | | | | |
| Galeolaria socialis, Goldf. - | | | | 3 | | 5 | | | | | | G. O. N. L. - | *Serpula.* |
| Pachynereis corrugatus, Eth. | | | | | | | | 7 | | | | G. | |
| Serpula convoluta, Goldf. - | | | | 3 | | | | | | 9 | | G. O. N. L. | |
| —— crassa, Sow. - - | | | | | | | 6 | | | | | S. | |
| —— deplexa, Bean - - | × | 1 | | 3 | | | | | | 9 | | S. to Y. - | *S. flaccida*, Goldf. |
| —— filiaria, Goldf. - - | | | | | | | | | | | | G. O. - | Inf. Ool. |
| —— grandis, Goldf. - | | | | 3 | 4 | | | | 8 | 9 | | G. | |
| —— intestinalis, Phil. - | | | | | | | | | 8 | 9 | × | D. to Y. Sy. | |
| —— lacerata, Phil. - - | | | | | | | | | 8 | | | Sy. | |
| —— lævigata, Lyc. - - | | | | 3 | | | | | | | | G. | |
| —— limax, Goldf. - - | × | | | | 4 | | | | | 9 | | D. G. | |
| —— obliquestriata, Mor. & Lyc. | | | | | | | 6 | 7 | | 9 | | D. G. | |
| —— plicatilis, Goldf. - | | | | 3 | | 5 | | | 8 | 9 | | W. G. O. Y. | |
| —— quadrata, Phil. - | | | | | | | 6 | | | | | S. | |
| —— quadrilatera, Goldf. - | | | | 3 | | | | | | | | S. G. | |
| —— squamosa, Phil. - | | | | | | | | | | 9 | × | H. Y. | |
| —— tetragona, Sow. - | × | | | | | | 6 | | 8 | 9 | × | D. to Y. | |
| —— triangulata, Sow. - | | | | | | | | 7 | | | | W. | |
| —— tricarinata, Sow. - | | | 2 | | | | 6 | | 8 | 9 | × | D. S. W. G. | |
| —— vagans, Sow. - - | | | | | | | | | | 9 | | D. | |
| —— vertebralis, Sow. - | | | | | | | | | | 9 | × | W. | |
| Vermicularia nodus, Phil. - | | | | | | | | | 8 | 9 | | N. L. Y. Sy. | Inf. Ool. |
| Vermilia quinquangularis, Goldf. | | | | | | | | 7 | | | × | G. | |
| —— sulcata, Sow. - - | | | | | | 5 | | | | | × | G. O. L. Y. | |
| **Echinodermata.** | | | | | | | | | | | | | |
| *Crinoidea.* | | | | | | | | | | | | | |
| Actinometra abnormalis, P. H. Carp. | | | | | | | | | 8 | | | G. | |
| —— Mülleri, P. H. Carp. - | | | | | | | | 7 | | | | S. | |
| Antedon latirafia, P. H. Carp. | | | | | | | | 7 | | | | W. | |
| —— prisca, P. H. Carp. - | | | | | | | | | 8 | | | G. | |
| Apiocrinus exutus, McCoy | | | | | | | | | 8 | | | W. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| **Echinodermata**—*cont.* | | | | | | | | | | | | | |
| *Crinoidea*—cont. | | | | | | | | | | | | | |
| Apiocrinus Parkinsoni. Schloth. | | | | | | | | 7 | 8 | 9 | | D. S. W. | *A. rotundus*, Park. *A. elegans*, Defr. |
| —— See also Millericrinus. | | | | | | | | | | | | | |
| Bourgeticrinus ooliticus, McCoy. | | | | | | | | | 8 | | | W. | |
| Millericrinus Pratti, Gray | | | | 3 | | | | 7 | | | | W. G. O. N. | "Lansdown Encrinite." |
| —— Milleri, Schloth. | | | | | | | | | 8 | | | W. | |
| Pentacrinus Austeni, Wr. | | | | 3 | | | | | | | | G. | |
| —— cingulatus, Goldf. | | | | | | | | | 8 | | | W. | |
| —— Desori, Wr. | | | | 3 | | | | | | | | G. | |
| —— jurensis, Goldf. | × | | | | | | | 7 | | | | G. | |
| —— Lorioli, Wr. | | | | 3 | | | | | | | | G. | |
| —— Milleri, Aust. | × | | | 3 | | | | | 8 | | | D. S. W. O. | |
| —— scalaris, Goldf. | × | | | | | | | | 8 | | | W. | |
| *Echinoidea.* | | | | | | | | | | | | | |
| Acrosalenia hemicidaroides, Wr. | | | | | | | | 7 | 8 | 9 | × | D. to N. | *A. aspera*, Ag. |
| —— loweana, Wr. | | | | | | | | | 8 | | | W. O. | |
| —— Lycetti, Wr. | | | | 3 | | | | | | | | G. N. L. | |
| —— pustulata, Forbes | | | | | | | | 7 | 8 | 9 | | W. G. O. N. Sy. | |
| —— spinosa, Ag. | | | | 3 | | | | 7 | 8 | 9 | × | D. to L. | *A. radiata*, Forbes. |
| —— Wiltoni, Wr. | | | | | | | | 7 | 8 | 9 | | W. G. O. N. L. | |
| —— Woodwardi, Wr. | | | | | | | | | | ? | | ? British. | |
| Cidaris Bouchardi, Wr. | | | | 3 | 4 | 5 | | | ? | | | D. G. | |
| —— bradfordensis, Wr. | | | | | | | | 7 | 8 | 9 | | D. to G. Sy. | |
| —— confluens, Forbes | | | | | | | | | | | | S. | Inf. Ool. |
| —— Fowleri, Wr. | | | | 3 | | | | | | | | G. | |
| —— propinqua, Goldf. | | | | | | | | 7 | | | | G. | |
| —— Wrighti, Desor. | | | | 3 | | | | | | | | G. | |
| Clypeus Agassizi, Wr. | | | | | 4 | 5 | | | | | | D. S. | |
| —— altus, McCoy | | | | | 4 | 5 | | | | | | D. S. | |
| —— Hugii, Ag. | | | | | | 5 | ? | | | | | D. S. G. | |
| —— Michelini, Wr. | | | | 3 | 4 | | | | | | | G. L. Y. | |
| —— Mülleri, Wr. | | | | | | | | 7 | 8 | 9 | | G. O. N. H. L. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Passage Beds, Midford Sands. Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Inferior Oolite. Am. humphriesianus. | Inferior Oolite. Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| ECHINODERMATA—*cont.* | | | | | | | | | | | | | |
| *Echinoidea*—cont. | | | | | | | | | | | | | |
| Clypeus Ploti, Klein | | | | | | 5 | 6 | 7 | | 9 | | W. to L. | *C. sinuatus*, Park. |
| Collyrites bicordata, Leske | | | | | 4 | 5 | | | | | | D. | *Dysaster.* |
| —— ovalis, Leske | | | | | | 5 | | | | 9 | | D. S. W. | |
| —— ringens, Ag. | | | | | 4 | 5 | | | | 9 | | D. S. G. | *C. Eudesi*, Ag. |
| *Diadema.* See Pseudodiadema. | | | | | | | | | | | | | |
| Diplocidaris Desori, Wr. | × | | | 3 | | | | | | | | S. G. | |
| —— Wrighti, Desor. | | | | 3 | | | | | | | | G. | |
| *Diplopodia.* See Pseudodiadema. | | | | | | | | | | | | | |
| *Dysaster.* See Collyrites. | | | | | | | | | | | | | |
| Echinobrissus clunicularis, Lhwyd. | | | | 3 | | 5 | ? | 7 | 8 | 9 | | D. to Y. | *Nucleolites æqualis*, McCoy. |
| —— Griesbachi, Wr. | | | | | | | | 7 | | | | G. O. N. | |
| —— orbicularis, Phil. | | | | | | | | | | 9 | × | S. to Y. | |
| —— quadratus, Wr. | | | | | | | | | | 9 | | W. G. H. N. | |
| —— Woodwardi, Wr. | | | | | | | | 7 | | | | G. O. N. L. | |
| Galeropygus agariciformis, Forbes. | | | | 3 | 4 | | | 7 | | | | D. S. G. N. L. | *Hyboclypus.* |
| Hemicidaris alpina, Ag. | | | | | | | | | 8 | | | W. | |
| —— Bravenderi, Wr. | | | | | | | | 7 | | 9 | | D. G. | |
| —— granulosa, Wr. | | | | 3 | | | | | 8 | | | S. W. | |
| —— icaunensis, Cott. | | | | | | | | 7 | | | | G. | |
| —— luciensis, d'Orb. | | | | | | | | 7 | | | | G. | *H. confluens*, Forbes (non McCoy). |
| —— minor, Ag. | | | | | | | | 7 | | | | S. | |
| —— pustulosa, Ag. | | | | | | | | | 8 | | | D. W. | Inf. Ool. |
| —— Ramsayi, Wr. | | | | | | | | 7 | | | | S. | |
| —— Stokesi, Wr. | | | | | | | | 7 | | | | G. O. | |
| —— Wrighti, Desor. | | | | | | | | | 8 | | | W. G. | |
| —— See also Acrosalenia and Cidaris. | | | | | | | | | | | | | |
| Hemipedina Bakeri, Wr. | | | | 3 | | | | | | | | G. | |
| —— Bonei, Wr. | | | | 3 | | | | | | | | G. | |
| —— Davidsoni, Wr. | | | | | | | | 7 | | | | G. | |
| —— microgramma, Wr. | | | | | | | | | | 9 | | N. | |
| —— perforata, Wr. | | | | 3 | | | | | | | | G. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. | | Inferior Oolite. | | | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. jurensis. | Am. opalinus. | Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | | | | | | | |
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| ECHINODERMATA—*cont.* | | | | | | | | | | | | | |
| *Echinoidea*—cont. | | | | | | | | | | | | | |
| Hemipedina Smithi, Forbes | | | | 3 | | | | | | | | S. G. | |
| —— tetragramma, Wr. - | | | | 3 | | | | | | | | G. | |
| —— Waterhousei, Wr. - | | | | 3 | | | | | | | | G. | |
| —— Woodwardi, Wr. - | | | | | | | | | | 9 | | D. W. | |
| Holectypus depressus, Leske. | | | | | | 5 | 6 | 7 | 8 | 9 | × | D. to Y. | |
| —— hemisphæricus, Ag. - | | | | | 4 | 5 | ? | | | | | D. S. G. | |
| Hyboclypus caudatus, Wr. | | | | | | | | 7 | | | | G. - - | Inf. Ool. |
| —— gibberulus, Ag. - | | | | | 4 | 5 | ? | | | | | D. S. | |
| —— ovalis, Wr. - - | | | | | | 5 | | | | | | G. | |
| —— See also Galeropygus. | | | | | | | | | | | | | |
| Magnotia Forbesi, Wr. - | | | | | 4 | | | | | | | S. G. | |
| *Nucleolites.* See Echinobrissus. | | | | | | | | | | | | | |
| Pedina rotata, Wr. - - | | | | 3 | | 5 | | 7 | | 9 | | G. N. H. - | *Echinopsis.* |
| —— Smithi, Wr. - - | | | | | | | | 7 | | 9 | | G. O. | |
| Polycyphus Deslongchampsi, Wr. | | | | 3 | | | | | | | | G. | |
| —— normannus, Desor. - | | | | | | 5 | | 7 | 8 | 9 | | G. W. - | *P. nodulosus,* Goldf. |
| Pseudodiadema Bailyi, Wr. | | | | | | | | | | 9 | | W. O. | |
| —— Bakeriæ, S. P. Woodw. | | | | | | | | | | 9 | | N. | |
| —— depressum, Ag. - | | | | 3 | | 5 | | 7 | 8 | ? | | S. G. O. N. L. | *Diadema armatum,* Forbes. |
| —— homostigma, Ag. - | | | | 3 | | | | 7 | 8 | 9 | | G. W. N. | |
| —— Parkinsoni, Desor. - | | | | | | | | 7 | ? | ? | | G. O. | |
| —— pentagonum, McCoy - | | | | | | | | 7 | | 9 | | G. H. | |
| Pygaster conoideus, Wr. - | | | | 3 | | | | | | | | G. L. | |
| —— macrostoma, Wr. - | | | | | | | | | | | | G. - - | Inf. Ool. ? |
| —— Morrisi, Wr. - - | | | | | | | | | | 9 | | W. | |
| —— semisculatus, Phil. - | | | | 3 | | | | 7 | | | | G. to Y. | |
| Pygurus Michelini, Cott. - | | | | | | | | 7 | 8 | 9 | | D. to H. - | Inf. Ool. |
| Rhabdocidaris Thurmanni, De Lor. var regens, Whidb. | | | | | 4 | | | | | | | S. | |
| Stomechinus bigranularis, Lam. | | | | | 4 | 5 | | | | | | D. Y. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. | | Inferior Oolite. | | | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. jurensis. | Am. opalinus. | Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | | | | | | | |
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| ECHINODERMATA—*cont.* | | | | | | | | | | | | | |
| *Echinoidea*—cont. | | | | | | | | | | | | | |
| Stomechinus germinans, Phil. | | | | 3 | | | | 7 | | | | S. G. O. N. Y. | *S. perlatus*, Desm. |
| —— intermedius, Ag. - | | | | | | 5 | | | | 9 | | S. to H. - | *Echinus granularis*, Wr. |
| —— microcyphus, Wr. - | | | | | | | | 7 | | | | G. | |
| *Ophiuroidea.* | | | | | | | | | | | | | |
| Ophiurella Griesbachi. Wr. | | | | | | | | 7 | 8 | | | D. G. N. | |
| *Asteroidea.* | | | | | | | | | | | | | |
| Astropecten cotteswoldiæ, Buckm. | | | | | | | | 7 | | | | G. | |
| —— —— var. stamfordensis, Wr. | | | | 3 | | | | | | | | L. | |
| —— —— var. stonesfieldensis, Wr. | | | | | | | | 7 | | | | O. | |
| —— Hooperi, Wr. - - | | | | | | | | | | 9 | | S. | |
| —— Huxleyi, Wr. - - | | | | | | | | | 8 | | | W. | |
| —— Phillipsi, Forbes - | | | | | | | | | 8 | | | S. | |
| —— Wittsi, Wr. - - | | | | | | | | 7 | | | | G. | |
| Goniaster hamptonensis, Wr. | | | | | | | | 7 | | | | G. | |
| —— obtusus, Wr. - - | | | | 3 | | | | | | | | G. | |
| Solaster moretonis, Forbes | | | | | | | | 7 | | | | G. | |
| Stellaster Sharpi, Wr. - | | | | 3 | | | | | | | | N. | |
| Uraster spiniger, Wr. - | | | | | | | | | 8 | | | W. | |
| *Holothuroidea.* | | | | | | | | | | | | | |
| Chirodota Carpenteri, Moore | | | | | | | | | | | | | Inf. Ool. |
| —— convexa, Whidb. - | | | | | 4 | | | | | | | D. | |
| —— ? gracillima, Whidb. - | | | | | 4 | | | | | | | D. | |
| ACTINOZOA. | | | | | | | | | | | | | |
| Adelastræa burgundiæ, E. & H. | | | | | | | | 7 | | | | G. | |
| —— consobrina, Tomes - | | | | 3 | | | | | | | | G. - - | { *Clausastræa.* *Confusastræa.* |
| —— magnifica, Tomes - | | | | | | | | 7 | | | | G. | |
| —— tenuistriata, Tomes - | | | | 3 | | | | | | | | G. - - | *Confusastræa.* |
| Anabacia complanata, Defr. | | | | 3 | | 5 | 6 | 7 | 8 | 9 | × | D. to L. - | *A. orbulites*, Lam. |
| —— hemisphærica, E. & H. | | | | | | 5 | | 7 | | | | S. O. | |
| Astrocœnia Phillipsi, Tomes | | | | | | | | 7 | | | | G. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Passage Beds, Midford Sands. Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Inferior Oolite. Am. humphriesianus. | Inferior Oolite. Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Actinozoa—*cont.* | | | | | | | | | | | | | |
| Axosmilia elongata, Dunc. - | | | | 3 | | | | | | | | G. | |
| —— *Wrighti*, E. & H. See Donacosmilia. | | | | | | | | | | | | | |
| Bathycœnia Slatteri, Tomes | | | | | | | | 7 | | | | S. G. O. | |
| —— solida, Tomes - - | | | | | | | | 7 | | | | O. | |
| Calamophyllia radiata, Lamx. | | | | | | | | 7 | | | | S. W. G. O. | *Eunomia.* |
| Chorisastræa gregaria, McCoy. | | | | 3 | | | | | | | | S. G. L. - | *Thecosmilia.* |
| —— obtusa, d'Orb. - - | | | | | | | | 7 | | | | S. G. - | *Thecosmilia.* |
| —— rugosa, Tomes - - | | | | 3 | | | | | | | | G. | |
| Cladophyllia babeana, Edw. | | | | | | | | 7 | 8 | | | S. G. O. | |
| *Clausastræa.* See Adelastræa and Platastræa. | | | | | | | | | | | | | |
| Comoseris vermicularis, McCoy. | | | | 3 | | | | 7 | | | | S. G. | |
| *Confusastræa.* See Adelastræa. | | | | | | | | | | | | | |
| Convexastræa Waltoni, E. & H. | | | | 3 | | | | 7 | | | | S. G. O. | |
| Cryptocœnia Haimei, Tomes | | | | | | | | 7 | | | | O. | |
| —— insignis, Dunc. - | | | | | | | | 7 | | | | G. O. - | *Cyathophora.* |
| —— microphylla, Tomes - | | | | | | | | 7 | | | | S. G. | |
| —— Pratti, E. & H. - | | | | | | | | 7 | | | | S. O. - | *Cyathophora.* |
| —— tuberosa, Dunc. - | | | | | | | | 7 | | | | G. - - | *Cyathophora.* |
| Cyathophora Bourgueti, Defr. | | | | | | | | 7 | | | | O. - - | *C. solida*, Phil. |
| —— luciensis, d'Orb. - | | | | | | | | 7 | 8 | | | W. O. - | *Cryptocœnia.* |
| —— Richardi, Mich. - | | | | | | | | 7 | | | | O. | |
| Cyathophyllia oolitica, Tomes. | | | | 3 | | | | | | | | G. | |
| *Cyclolites.* See Dimorpharæa. | | | | | | | | | | | | | |
| Dimorpharæa Beani, Dunc. | | | | 3 | | | | | | | | D. - - | *Cyclolites.* |
| —— expansa, Tomes - | | | | | | | | | | | | S. - - | Inf. Ool. |
| —— Fromenteli, Tomes - | | | | | | | | | | | | G. - - | *Thamnastræa*, Inf. Ool. |
| —— Lycetti, Dunc. - | | | | 3 | | | | | | | | G. - - | { *D. dubia*, Tomes. *Cyclolites.* |
| —— oolitica, Dunc. - | | | | 3 | | | | | | | | S. - | *Dimorphoseris.* |
| —— pedunculata, Tomes - | | | | | | | | | | | | G. - - | Inf. Ool. |

| Species. | | Passage Beds, Midford Sands. | | Inferior Oolite. | | | | | | | | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lower Beds of Lias. | Am. jurensis. | Am. opalinus. | Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | | |
| Actinozoa—*cont.* | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Dimorphastræa fungiformis, Tomes. | | | | | | | | 7 | | | | S. | |
| *Dimorphoseris.* See Dimorpharæa. | | | | | | | | | | | | | |
| Discocyathus Eudesi, Mich. | | | | 3 | 4 | 5 | | | | | | D. S. | |
| Donacosmilia Wrighti, E. & H. | | | | 3 | | | | | | | | S. G. - | *Axosmilia. Montlivaltia Holli,* Dunc. |
| Enallohelia clavata, Tomes | | | | | | | | 7 | | | | G. O. | |
| —— socialis, Tomes - | | | | | | | | 7 | | | | S. | |
| Epismilia porpita, Tomes - | | | | | | | | | | | | G. - - | Inf. Ool. |
| Favia pedunculata, Tomes | | | | | | | | 7 | | | | O. | |
| Goniocora concinna, Tomes | | | | 3 | | | | | | | | G. | |
| Heliocœnia oolitica, Tomes | | | | | | | | 7 | | | | S. | |
| Isastræa Beesleyi, Tomes - | | | | | | | | 7 | | | | G. | |
| —— Conybearei, E. & H. - | | | | 3 | | 5 | | 7 | | | | G. O. L. - | *Clausastræa.* |
| —— depressa, Tomes - | | | | 3 | | | | | | | | S. G. O. - | *I. expansa,* Tomes. |
| —— explanulata, McCoy - | | | | | | | | 7 | | | | S. G. O. - | Inf. Ool. |
| —— gibbosa, Dunc. - | | | | | | | | 7 | | | | G. | |
| —— limitata, Lamx. - | | | | 3 | | 5 | | 7 | | | | S. W. G. O. L. | |
| —— Lonsdalei, E. & H. - | | | | | | | | | | | | S. - - | Inf. Ool. |
| —— microphylla, Tomes - | | | | | | | | 7 | | | | S. O. | |
| —— Richardsoni, E. & H. - | | | | 3 | | 5 | | | | | | S. O. N. L. | |
| —— serialis, E. & H. - | | | | | | | | 7 | | | | S. | |
| —— tenuistriata, E. & H. - | | | | 3 | | 5 | | | | | | S. G. | |
| Latimæandra Davidsoni, E. & H. | | | | 3 | | 5 | | | | | | G. O. N. L. | |
| —— Flemingi, E. & H. - | | | | 3 | | | | | | | | S. G. L. | |
| —— Haimei, Tomes - | | | | | | | | | | | | G. - - | Inf. Ool. |
| —— lotharinga, Mich. - | | | | | | | | 7 | | | | G. O. | |
| —— tabulata, Tomes - | | | | | | | | | | | | G. - - | Inf. Ool. |
| —— See also Montlivaltia. | | | | | | | | | | | | | |
| Latimæandraria concentrica, Tomes. | | | | 3 | | | | | | | | G. - - | *Oroseris.* |
| Leptophyllia Flouresti, E. de From. | | | | 3 | | | | | | | | G. | |
| Microsolena excelsa, E. & H. | | | | | | | | 7 | | | | S. G. O. L. - | Inf. Ool.? |
| —— porosa, Lam. - - | | | | 3 | | | | | | | | G. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Actinozoa—*cont.* | | | | | | | | | | | | | |
| Microsolena regularis, E. & H. | | | | | | | | 7 | | | | S. G. - | Inf. Ool. |
| Montlivaltia caryophyllata, Lam. | | | | | | | | 7 | | | | S. G. O. | |
| —— concinna, Tomes - | | | | 3 | | | | | | | | G. | |
| —— cupuliformis, E. & H. | | | | 3 | | | | | | | | D. S. G. | |
| —— De la Bechei, E. & H. | | | | 3 | 4 | 5 | | | | | | D. S. G. O. | |
| —— depressa, E. & H. - | | | | | | | | | | | | G. - - | Inf. Ool. |
| —— dilatata, Mich. - | | | | 3 | | | | | | | | G. - - | { *Caryophyllia.* *M. Morrisi,* Dunc. |
| —— *Holli,* Dunc. See Donacosmilia Wrighti. | | | | | | | | | | | | | |
| —— fairfordensis, Tomes - | | | | | | | | 7 | | | | G. | |
| —— lens, E. & H. - - | | | 2 | 3 | | 5 | | 7 | | | | D. S. G. O. | |
| —— *Morrisi,* Dunc. See M. dilatata. | | | | | | | | | | | | | |
| —— painswicki, Dunc. - | | | | 3 | | | | | | | | G. O. | |
| —— *porpita,* Tomes. See Epismilia. | | | | | | | | | | | | | |
| —— Slatteri, Tomes - | | | | | | | | 7 | | | | G. | |
| —— Smithi, E. & H. - | | | | | | | | 7 | | | | S. G. - | Inf. Ool. |
| —— Stutchburyi, E. & H. - | | | | | | | | | | | | S. L. - | Inf. Ool. |
| —— tenuilamellosa, E. & H. | | | | 3 | | | 6 | | | | | D. S. G. L. | |
| —— trochoides, E. & H. - | | | | 3 | 4 | 5 | 6 | 7 | | | | S. G. O. N. | |
| —— Waterhousei, E. & H. | | | | 3 | | | | 7 | | | | G. | |
| —— Wrighti, E. & H. - | | | | | | 5 | | | | | | G. | |
| Oroseris contorta, Tomes - | | | | | | | | | | | | G. - - | Inf. Ool. |
| —— gibbosa, Tomes - | | | | | | | | | | | | G. - - | Inf. Ool. |
| —— incrustans, Tomes - | | | | | | | | | | | | G. - - | Inf. Ool |
| —— oolitica, Tomes - | | | | 3 | | | | 7 | | | | S. G. | |
| —— Slatteri, Tomes - | | | | | | | | 7 | | | | G. | |
| —— See also Latimæandraria. | | | | | | | | | | | | | |
| Phyllogyra Etheridgei, Dunc. | | | | 3 | 4 | | | | | | | G. O. - | *Symphy a.* |
| —— sinuosa, Tomes - | | | | | 4 | | | | | | | G. | |
| Phylloseris rugosa, Tomes | | | | 3 | | | | | | | | G. | |
| Placophyllia gracilis, Tomes. | | | | 3 | | | | | | | | G. | |

| Species. | | Passage Beds, Midford Sands. | | Inferior Oolite. | | | | | | | | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lower Beds of Lias. | Am. jurensis. | Am. opalinus. | Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | | |
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Actinozoa—*cont.* | | | | | | | | | | | | | |
| Platastræa endothecata, Tomes. | | | | | | 5 | | | | | | O. | |
| —— Pratti, E. & H. - | | | | | | | | 7 | | | | S. - - | { *Isastræa, Conybearei?, Plerastræa.* |
| Podoseris constricta, Dunc. | | | | ? | | | | | | | | D. - - | *Leptophyllia.* |
| Scyphocœnia? - - | | | | | | | | 7 | | | | S. | |
| Stephanocœnia dendroidea, Tomes. | | | | 3 | | | | | | | | G. | |
| —— expansa, Tomes - | | | | 3 | | | | | | | | G. | |
| Stylina conifera, E. & H. - | | | | | | | | 7 | | | | S. O. | |
| —— Ploti, E. & H. - - | | | | | | | | 7 | | | | S. W. G. | |
| —— solida, McCoy - - | | | | 3 | | | | 7 | | | | S. G. | |
| Stylosmilia excelsa, Tomes | | | | | | | | 7 | | | | S. | |
| —— reptans, Tomes - | | | | | | | | 7 | | | | S. G. | |
| *Symphyllia.* See Phyllogyra. | | | | | | | | | | | | | |
| *Synastræa.* See Thamnastræa. | | | | | | | | | | | | | |
| Thamnastræa Browni, Dunc. | | | | | | | | 7 | | | | G. | |
| —— crickleyensis, Tomes - | | | | 3 | | | | | | | | G. | |
| —— defranciana, Mich. - | | | | 3 | 4 | 5 | | | | | | D. to L. | |
| —— Duncani, Tomes - | | | | 3 | | | | | | | | G. | |
| —— expansa, Tomes - | | | | 3 | | | | | | | | G. | |
| —— flabelliformis, Tomes | | | | 3 | | | | | | | | G. | |
| —— fungiformis, E. & H. | | | | 3 | | 5 | | | | | | S. G. | |
| —— heteromorpha, Tomes | | | | 3 | | | | | | | | G. | |
| —— Lyelli, E. & H. - | | | | 3 | | | | 7 | | | | G. O. L. | |
| —— McCoyi, E. & H. - | | | | | | | | | | | | S. - - | Inf. Ool. |
| —— mammosa, E. & H. - | | | | | | | | 7 | | | | S. G. O. | |
| —— Manseli, Dunc. - | | | | | | | | | | | | S. - - | { Inf. Ool. *Synastræa.* |
| —— mettensis, E. & H. - | | | | 3 | | | | | | | | G. | |
| —— microphylla, Tomes - | | | | | | | | 7 | | | | O. | |
| —— scita, E. & H. - - | | | | | | | | 7 | | | | S. | |
| —— Terquemi, E. & H. - | | | | 3 | | | | | | | | G. O. | |
| —— Walcotti, Dunc. - | | | | 3 | | | | | | | | S. G. | |
| —— Waltoni, E. & H. | | | | | | | | 7 | | | | S. G. | |
| —— Wrighti, Tomes - | | | | 3 | | | | | | | | G. O. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| ACTINOZOA—*cont.* | | | | | | | | | | | | | |
| Thamnocœnia oolitica, Tomes. | | | | | | | | 7 | | | | S. | |
| Thamnosmilia annulata, Tomes. | | | | 3 | | | | | | | | G. | |
| Thecocyathus discus, E. de From. | | | | | | 5 | | | | | | D. | |
| Thecoseris polymorpha, Tomes. | | | | 3 | | | | | | | | D. S. G. - | *Palæoseris.* |
| Thecosmilia gregaria, McCoy. | | | | 3 | | | | | | | | S. to Y. - | *Chorisastræa.* |
| —— ramosa, d'Orb. - | | | | 3 | | | | | | | | G. | |
| —— Slatteri, Tomes - | | | | | | | | 7 | | | | G. O. | |
| —— Wrighti, Dunc. - | | | | 3 | | | | | | | | G. O. | |
| Tricycloseris limax, Tomes | | | | | | | | 7 | | | | G. | |
| Trochocyathus magnevillianus, Michel. | | | | | | 5 | | | | | | D. | |
| Zaphrentis? Waltoni, E. & H. | | | | | | | | | | | | S. - - | Inf. Ool. (probably derived. H. Woods.) |
| HYDROZOA. | | | | | | | | | | | | | |
| Hydractinia - - - | | | | | | | | 7 | | | | G. | |
| SPONGIDÆ. | | | | | | | | | | | | | |
| Blastinia costata, Goldf. - | | | | 3 | | | | | 8 | | | G. Sy. - | *B. cristata,* Hinde. |
| Calathiscus variolatus, Sollas. | | | | | | 5 | | | | | | D. | |
| *Cnemidium.* See Holcospongia. | | | | | | | | | | | | | |
| Corynella cribrata, Hinde - | | | | | | | | 7 | | | | S. | |
| —— elegans, Hinde - | | | | | | | | 7 | | | | S. | |
| —— lycoperdioides, Lamx. | | | | | | | | 7 | 8 | 9 | | D. W. | |
| —— punctata, Hinde - | | | | 3 | | | | | | | | G. | |
| Craticularia clathrata, Goldf. | | | | | | 5 | | | | | | D. | |
| —— foliata, Quenst. - | | | | | | 5 | | | | | | D. - - | { *Leptophragma gile,* Sollas. |
| Diaplectis auricula, Hinde | | | | 3 | | | | | | | | G. | |
| —— infundibulum, Hinde - | | | | | | | | 7 | | | | W. | |
| Elasmostoma palmatum, Hinde. | | | | | | | | 7 | 8 | | | S. W. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. | | Inferior Oolite. | | | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. jurensis. | Am. opalinus. | Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | | | | | | | |
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Spongidæ—*cont.* | | | | | | | | | | | | | |
| *Emploca.* See Melonella. | | | | | | | | | | | | | |
| Eudea pisum, Quenst. - | | | | | | 5 | | | | | | D. | |
| —— Walfordi, Hinde - | | | | | | 5 | | | | | | D. | |
| Eusiphonella prolifera, Hinde. | | | | | | | | 7 | | | | S. | |
| Geodites - - - | | | | | | 5 | | | | | | D. | |
| Holcospongia bella, Hinde | | | | | | 5 | | | | | | D. | |
| —— contorta, Hinde - | | | | | | 5 | | | | | | D. | |
| —— liasica, Quenst. - | | | | | | 5 | | 7 | | | | D. S. - | *Myrmecium depressum*, Sollas. |
| —— mitrata, Hinde - | | | | | | 5 | | | | | | D. | |
| —— polita, Hinde - - | | | | | | | | 7 | | | × | S. | |
| —— sulcata, Hinde - | | | | | | 5 | | | | | | D. | |
| *Inobolia.* See Lymnorella. | | | | | | | | | | | | | |
| Leiodorella contorta, Hinde | | | | | | 5 | | | | | | D. | |
| *Leptophragma.* See Craticularia. | | | | | | | | | | | | | |
| Lymnorella inclusa, Hinde | | | | 3 | | | | | | | | G. - - | *Lymnorea. Inobolia.* |
| —— mamillosa, Lamx. - | | | | 3 | | | | | | | | G. | |
| —— micula, Hinde - - | | | | | | | | 7 | 8 | | | S. Sy. | |
| —— pygmæa, Sollas - | | | | 3 | | 5 | | 7 | | | | D. S. G. | |
| —— ramosa, Hinde - | | | | 3 | | | | | | | | G. | |
| *Mastodictyum.* See Verrucocœlia. | | | | | | | | | | | | | |
| Melonella ovata, Sollas - | | | | | 4 | | | | | | | S. - - | *Emploca.* |
| Myrmecium biretiforme, Sollas. | | | | | | 5 | | | | | | D. - - | |
| —— See also Holcospongia. | | | | | | | | | | | | | |
| Oculospongia minuta, Hinde. | | | | | | 5 | | | 8 | | | D. Sy. | |
| Peronidella metabronni, Sollas. | | | | | | 5 | | | | | | D. - - | *Peronella.* |
| —— nana, Hinde - - | | | | | | 5 | | | 8 | | | D. Sy. | |
| —— pistilliformis, Lamx. - | | | | | | | | 7 | 8 | 9 | | D. S. W. G.- | *P. repens*, Sollas. |
| —— tenuis, Hinde - - | | | | 3 | | | | | | | | G. | |
| —— Waltoni, Hinde - | | | | | | | | 7 | | | | S. | |

| Species. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Passage Beds, Midford Sands. Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Inferior Oolite. Am. humphriesanus. | Inferior Oolite. Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | Localities. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| Spongidæ—*cont.* | | | | | | | | | | | | | |
| Platychonia affinis, Hinde | | | | | | 5 | | | | | | D. | |
| —— elegans, Sollas - - | | | | | | 5 | | | | | | D. | |
| —— tenuis, Hinde - - | | | | | | 5 | | | | | | D. | |
| *Plectospyris.* See Verrucocœlia. | | | | | | | | | | | | | |
| Stauroderma explanatum, Hinde. | | | | | | 5 | | | | | | D. | |
| *Stellispongia.* See Holcospongia. | | | | | | | | | | | | | |
| Talpina - - - | | | | | | | | 7 | | | | O. - - | Nature of organism doubtful. |
| Thamnonema pisiforme, Sollas. | | | | | | | | 7 | | | | S. | |
| Tremadictyon incertum, Hinde, | | | | | | 5 | | | | | | D. | |
| —— sparsum, Hinde - | | | | | | 5 | | | | | | D. | |
| Verrucocœlia elegans, Sollas. | | | | | | 5 | | | | | | D. - - | *Plectospyris.* |
| —— major, Sollas - - | | | | | | 5 | | | | | | D. - - | Do. |
| —— Whidbornei, Sollas - | | | | | | 5 | | | | | | D. - - | *Mastodictyum.* |
| Foraminifera. | | | | | | | | | | | | | |
| Cristellaria crepidula, F. & M. | × | | | | | | 6 | | 8 | 9 | × | S. W. Sy. | |
| —— cultrata, Montf. - | × | | | | | | | | 8 | 9 | | W. Sy. | |
| —— rotulata, Lam. - - | × | | | | | | 6 | | 8 | 9 | × | S. W. Sy. | |
| Dentalina - - - | | | | | | | | | 8 | | | G. N. | |
| Flabellina - - - | | | | | | | | | 8 | | | N. | |
| Frondicularia oolitica, Terq. var. regularis, Jones. | | | | | | | | | 8 | | | Sy. | |
| —— peregrina, Reuss - | | | | | | | 6 | | | | | S. | |
| Lagena lævis, W. & J. - | | | | | | | | | 8 | | | Sy. | |
| —— sp. - - - | | | | | | | | 7 | | | | G. | |
| Lituola nautiloidea, Lam. var. depressa, ? Jones. | | | | | | | | | | 9 | | W. | |
| Marginulina glabra, d'Orb. | × | | | | | | | | 8 | | | S. | |
| —— raphanus, Linn. - | × | | | | | | | | 8 | | × | Sy. | |

| SPECIES. | Lower Beds of Lias. | Passage Beds, Midford Sands. | | Inferior Oolite. | | | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | LOCALITIES. | REMARKS. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. jurensis. | Am. opalinus. | Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | | | | | | | |
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| FORAMINIFERA—*cont.* | | | | | | | | | | | | | |
| Marginulina sp. - - | | | | | | | | 7 | 8 | | | G. N. | |
| Miliola - - - | | | | | | | | | 8 | | | Sy. - - | *Quinqueloculina.* |
| Nodosaria lineolata, Reuss | | | | | | | 6 | | | | | S. | |
| Nubecularia - - - | | | | | | | | | 8 | | | N. | |
| Planorbulina farcta, F. & M. | | | | | | | | | 8 | | | Sy. | |
| —— Haidingeri, d'Orb. - | | | | | | | | | 8 | | | Sy. | |
| Planularia (cf.) reticulata, Cornuel. | × | | | | | | 6 | | | | × | S. | |
| Pulvinulina elegans, d'Orb. var. tenella, Jones. | × | | | | | | | | 8 | | | Sy. | |
| Rotalia - - - | | | | | | | | 7 | | | | G. | |
| Spirillina crassa, Kübler & Zwingli. | | | | | | | | | 8 | | | Sy. | |
| —— helvetica, Kübler & Zwingli. | | | | | | | | | 8 | | | Sy. | |
| Textularia - - - | | | | | | | | | 8 | | | N. | |
| Trochammina incerta, d'Orb. | | | | | | | | | 8 | | × | N. | |
| Vaginulina harpa, Roem. - | | | | | | | | | 8 | | × | N. | |
| —— lævigata, Roem. - | × | | | | | | | | 8 | | | Sy. | |
| —— legumen, Linn. - | × | | | | | | 6 | | 8 | | | S. W. | |
| —— strigillata, Reuss - | | | | | | | | | 8 | | | N. | |
| Verneuilina - - - | | | | | | | | | 8 | | | N. | |
| Webbina - - - | | | | | | | | | 8 | | | N. Sy. | |
| PLANTÆ. | | | | | | | | | | | | | |
| ANGIOSPERMÆ? | | | | | | | | | | | | | |
| Bensonia ovata, Buckm. - | | | | | | | | 7 | | | | G. | |
| Lilia lanceolata, Buckm. - | | | | | | | | 7 | | | | G. | |
| Naiadita obtusa, Buckm. - | | | | | | | | 7 | | | | G. - - | *Naiadea. N. ovata,* Buckm. |
| Pandanocarpum ooliticum, Carr. | | | | | | | | 7 | | | | N. - - | *Kaidacarpum.* |
| Podocarya Bucklandi, Unger. | | | | | | | | | | | | D. - | Inf. Ool.; allied to *Pandanus.* |
| Salicites longifolius, Buckm. | | | | | | | | 7 | | | | G. - - | Doubtful. |
| Stricklandinia acuminata, Buckm. | | | | | | | | 7 | | | | G. | |
| Yuccites megaphylla, Phil. | | | | | | | | | | | | O. - - | *Palæozamia.* |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Am. jurensis. | Am. opalinus. | Am. Murchisonæ. | Am. humphriesianus. | Am. Parkinsoni. | | | | | | | |
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| PLANTÆ—*cont.* | | | | | | | | | | | | | |
| GYMNOSPERMÆ. | | | | | | | | | | | | | |
| *Coniferæ.* | | | | | | | | | | | | | |
| Araucarites Brodiei, Carr. | | | | | | | | 7 | | | | O. | |
| —— Cleminshawi, Mansel-Pleydell. | | | | | | | | | | | | D. - - | Inf. Ool. |
| —— sphærocarpus, Carr. - | | | | | | | | | | | | S. - - | Inf. Ool. |
| Echinostrobus expansus Sternb. | | | | | | | | 7 | | | | G. O. - | *Caulerpites bucklandianus*, Sternb. *Thuites articulatus* Sternb. |
| Taxites podocarpoides, Brongn. | | | | | | | | 7 | | | | O. | |
| Thuytes cupressiformis, Sternb. | | | | | | | | 7 | | | | G. O. | |
| —— divaricatus, Sternb. - | | | | | | | | 7 | | | | O. | |
| —— expansus, Phil. - | | | | | | | | 7 | | | | G. | |
| Walchia Williamsonis, Brongn. | | | | | | | | 7 | | | | O. - - | *Palissya.* *Lycopodites.* *Pachyphyllum.* |
| *Cycadeæ.* | | | | | | | | | | | | | |
| Clathraria Bucklandi, Presl. | | | | | | | | 7 | | | | O. - - | *Bucklandia squamosa*, Brongn. |
| Cycadeostrobus primævus, L. & H. | | | | | | | | | | | | N. - - | Inf. Ool. |
| Cycadinocarpus conicus, L. & H. | | | | | | | | 7 | | | | G. - - | *Cycadcospermum.* *Carpolithes.* |
| —— lindleyanus, Gutb. - | | | | | | | | 7 | | | | O. - - | *C. diospyriformis*, Sternb. |
| Nilssonia compta, Phil. - | | | | 3 | | | | | | | | N. Y. - | *Pterophyllum.* |
| Podozamites lanceolatus, L. & H. | | | | | | | | 7 | | | | O. - - | *Zamites.* *Palæozamia longifolia*, Phil. |
| Pterophyllum Buckmani, Phil. | | | | | | | | 7 | | | | G. | |
| Ptilophyllum acutifolium, Morris. | | | | | | | | 7 | | | | O. - - | *Pterophyllum.* *Palæozamia taxina*, Lindl.; *P. pectinata*, Brongn. |
| Williamsonia pecten, Phil. | | | | 3 | | | | | | | | N. Y. - | *Palæozamia.* *Pterophyllum.* |
| Zamiostrobus primævus, L. & H. | | | | ? | | | | | | | | N. - - | Inf. Ool. *Pinites, Cycadeostrobus.* |
| CRYPTOGAMÆ. | | | | | | | | | | | | | |
| *Filices.* | | | | | | | | | | | | | |
| Glossopteris longifolius, Phil. | | | | | | | | 7 | | | | G. | |
| Hymenophyllites macrophyllus, Brongn. | | | | | | | | 7 | | | | O. - - | *Sphenopteris.* |

| SPECIES. | Lower Beds of Lias. | Passage Beds, Midford Sands. Am. jurensis. | Passage Beds, Midford Sands. Am. opalinus. | Inferior Oolite. Am. Murchisonæ. | Inferior Oolite. Am. humphriesianus. | Inferior Oolite. Am. Parkinsoni. | Fuller's Earth, Clay, and Rock. | Great Oolite and Stonesfield Slate. | Forest Marble and Bradford Clay. | Am. macrocephalus, Cornbrash. | Higher Beds of Oolite. | LOCALITIES. | REMARKS. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | × | | |
| PLANTÆ—*cont.* | | | | | | | | | | | | | |
| *Filices*—cont. | | | | | | | | | | | | | |
| Pachypteris lanceolata, Brongn. | | | | | | | | 7 | | | | O. Y. | |
| Pecopteris approximata, Phil. | | | | | | | | 7 | | | | O. | |
| —— dentata, L. & H. - | | | | 3 | | | | | | | | N. - - | *Polypodites huttoniana*, Presl. |
| —— diversa, Phil. - - | | | | | | | | 7 | | | | O. | |
| —— incisa, Phil. - - | | | | | | | | 7 | | | | O. | |
| Phlebopteris polypodioides, Brongn. | | | | 3 | | | | | | | | N. Y. - | *Pecopteris. Polypodites Lindleyi*, Göpp. |
| Sphenopteris cysteoides, Lind. & Hutt. | | | | | | | | 7 | | | | O. | |
| —— plumosa, Phil. - - | | | | | | | | 7 | | | | O. | |
| Tæniopteris angustata, Phil. | | | | | | | | 7 | | | | O. - - | *Microdictyon.* |
| —— vittata, Brongn. - | | | | | | | | 7 | | | | O. - - | *T. latifolia*, Brongn. *T. scitaminea*, Presl. *Oleandridium.* |
| *Characeæ.* | | | | | | | | | | | | | |
| Chara - - - | | | | | | 5 | | | | | | O. | |
| *Algæ.* | | | | | | | | | | | | | |
| Algæ - - - - | | | | | | | | | | | | O. - - | Inf. Ool. |
| Halymenites ramulosus, Sternb. | | | | | | | | 7 | | | | O. - - | *Sphærococcites.* |
| *Fungi.* | | | | | | | | | | | | - - - | Found in leaves of Cycads in Oolites. Carruthers, *Proc Geol. Assoc.*, v. 15. |

# INDEX.

N.B.—Names of Persons (authors, observers, and informants) are in small capitals.
Names of Fossils of which there are figures, or to which special reference is made, are in *italics*.

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