PROCEEDINGS

OF THE

Boston Society of Natural History.

VOL. XXIV.

WITH NINE PLATES.

BOSTON:
PRINTED FOR THE SOCIETY.
1890.

PUBLISHING COMMITTEE.

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PROCEEDINGS

OF THE

BOSTON SOCIETY OF NATURAL HISTORY.

TAKEN FROM THE SOCIETY'S RECORDS.

Annual Meeting, May 2, 1888.

The Vice President, George L. Goodale, in the chair.

The following reports were presented:

Report on Museum. By Alpheus Hyatt, Curator.

The affairs of the Society have taken on a more promising aspect, and a revival of interest in its doings has been apparent during the past year. This has been noticed in the increase of average attendance at the meetings mentioned in the Secretary's report, in the number and variety of the original communications and in the number of new members elected.

We have, also, after more than twenty years of consideration, at last taken definite steps towards the establishment of a Natural

History Garden. This has attracted additional interest to us and our affairs, especially during the last month, since the scheme began to appear in the newspapers. It is, however, unnecessary to go into details in this report. A full account of the past history and present condition of this new enterprise has been given in our proceedings. The records of the special meeting, called to consider the question whether the Society would consent to empower the council to take necessary measures for the establishment of a Natural History Garden, have been printed in the volume for this year[1] and also added as an appendix to the reprints of this report.

The large amount of time necessarily spent in attending committee meetings, and other general work, have prevented the Curator from giving as much attention as has been customary to the collections. Two of the three cases, erected in the vestibule for dynamical zoology, still remain vacant owing to this cause, and also the fact that the collections which are being prepared for this part of our exhibit have demanded more time and study than had been anticipated.

Considerable time has already been spent in devising ways of exhibiting the phenomena of dynamical zoölogy, but progress is necessarily very slow in the absence of funds that can be devoted to the purchase of specimens.

Geology.

Mr. Crosby has finished the preparation and arrangement of the introductory and dynamical geological collections; and a guide to these collections has also been made ready for publication.

The lithological collection in Room B has been thoroughly revised and to a considerable extent rearranged, and many new specimens have been added. An explanatory text or Guide similar to the guide published for the mineralogical collection has been planned for this collection.

The principal accessions include valuable series of specimens obtained by exchange from the National Museum and some interesting material collected by Mr. Crosby in the Black Hills of Dakota.

[1] See Proc. vol. XXIII, p. 523.

Botany.

The Curator, in his last report, devoted a paragraph to summarizing the benefits, which have accrued to the Society from the generosity of Mr. John Cummings, during the preceding thirteen years in connection with this and other departments. The same policy has been continued by Mr. Cummings during the past year, and the Society is now under additional obligations to this gentleman for his generous support of this and helpfulness in other departments of the Museum.

During the past year the endogens have been nearly finished by Miss Carter, and have been found to consist of 4,265 specimens, representing 29 orders, 442 genera and 2,099 species. The Bouvé collection of woods, fruits, etc., in the western gallery, has been numbered and catalogued.

The New England herbarium has been enriched with fine specimens from Mr. F. S. Collins and Mr. Edward Faxon. Some progress has been made in the poisoning of the specimens in the herbarium.

The Curator is pleased to be able to note the significant fact that a greater demand has been made on the time of the assistant in showing specimens and assisting students than in any previous year.

The Sprague collection of lichens has proved to be an additional attraction to our herbarium.

The following accessions have been made during the year:

Prof. Johann Müller of Geneva, 85 specimens of lichens.

Baron Ferd. von Müller of Melbourne, Australia, 264 specimens of dried plants.

Mr. Frank S. Collins, 70 specimens for New England collection.

Mr. Edward Faxon, 8 specimens for New England collection.

All of the above have been mounted and properly distributed. Thanks are due Prof. N. L. Britton, of Columbia College, for the determination of a number of Cyperaceæ.

Comparative Anatomy.

About a dozen specimens and preparations have been procured and added to this collection by Mr. Samuel Henshaw.

A fine skeleton of a kangaroo, a species of Macropus, has been obtained through the kindness of Dr. Thomas Dwight and has been cleaned and wired ready for mounting by Mr. Henshaw.

Sponges.

Miss Martin has spent some time in continuation of the work done last year, but has been principally occupied in verifying the measurements of the skeletal threads of the Keratosa and recording them on the slides.

Mollusca.

Good progress has been made by Mr. Henshaw and Miss Martin in the work of sorting and arranging the miscellaneous specimens which had accumulated in this department.

The New England collection has been enlarged by the addition of about fifty species and varieties.

The arrangement of the exhibition collection of Lamellibranchs is nearly completed and will be reported upon next year.

Mr. E. W. Roper has donated a number of desirable species to the New England collection, and a small lot has been received from Mr. H. C. Bradlee.

Crustacea.

The arrangement of the general collection has been completed by Mr. Henshaw, and it is found to contain about 450 species. Two-thirds of this number are identified.

Insects.

The New England and general collections of Arachnida have been sorted into families by Mr. Henshaw assisted by Miss Martin. There are about 1,000 lots.

The general collection of Neuroptera has been identified and labelled by Mr. Henshaw.

The slides of parasitic forms received with the Burnett collection have been sorted and in part identified.

The general collection of Diptera has been sorted into families, and the Harris, the New England and general collections of Hymenoptera have been worked out, and about two-thirds of the whole identified and labelled by Mr. Henshaw.

The Harris collection contains quite a number of Thomas Say's types which will be more fully reported upon at some future time.

Birds.

Early in the winter Mr. William Brewster resigned the charge of this department, in consequence of inability to give the time necessary for the care of the collection.

Mr. Brewster's services have been of great value and the collection has sensibly improved while under his charge. The Society owes him thanks for the interest he took in its work, and his voluntary labor in their museum.

After consultation with others the Curator nominated Mr. C. B. Cory of Boston, a well-known ornithologist, to the council of the Society, and the council empowered the Curator to invite this gentleman to become the assistant in charge of this department. Mr. Cory has accepted, but has not yet entered upon the duties of his office, having been prevented from doing so by absence at the south, and, since his return, by labors for the benefit of the Marine Biological Laboratory.

A leak in the roof, which had not previously been a source of danger, was developed during the winter and the birds in gallery room, R, sustained considerable damage from dampness. Mr. Henshaw was obliged to spend almost his whole time during the summer and autumn in working over them. There are over three thousand birds in this gallery and each one required to be cleaned several times. The leak has been remedied, and we need no longer fear damage from this source. These birds have been relabelled by Miss Martin, the old labels having been rendered illegible by dampness and mould.

This accident showed the need of securing the valuable type specimens in our collections, and, under Mr. Brewster's direction, Mr. Henshaw removed 700 of the birds belonging to the Lafresnaye collection from the stands upon which they were mounted, reduced them to skins, and packed them away in trays. Our collection of Neotropical skins amounting to about 1240 specimens have been sorted out, and sent to Mr. Robert Ridgway in Washington for identification. The collection of nests and eggs has been brought together and arranged by Mr. Henshaw.

The principal additions consist of a large albatross from Cape Horn received through the kindness of Mrs. E. D. Cheney, and a pair of Kiwis, *Apteryx australis*, presented by Messrs. W. C. Pope & Co.

Microscopy.

The collection bequeathed to the Society by Mr. R. C. Greenleaf has been received, sorted and catalogued by Mr. Henshaw.

It contains, in addition to a large amount of unmounted material, 2,112 mounted specimens, which have been roughly grouped as follows:

Diatomaceæ, 1,110 slides; anatomical specimens, 390 slides; insects, 250 slides; plants, 240 slides; miscellaneous, 132 slides.

The microscopical apparatus, which accompanied this collection, consist of two stands made by Tolles, nine objectives, and a number of other less valuable pieces.

Paleontology.

Considerable work of a difficult and delicate kind has been done by Miss E. D. Boardman on the Curator's collection of Steinheim shells, which, thanks to her exertions, is well advanced towards completion. Miss Martin has dusted the specimens of the American and European collections in rooms G and H, which had become dirty through long exposure in the old and loosely made cases, and has remounted a number of specimens.

Teachers' School of Science.

The liberal action of the Trustee of the Lowell fund in defraying the expenses of the lessons, and also in granting the use of Huntington Hall, has enabled the Society to continue its efforts to extend the benefit of the instruction in this school to teachers of all the neighboring towns, as well as to those living in Boston. The agents who acted in the adjoining towns and villages last year continued their kind offices, distributing and receiving applications and also tickets according to the plan of which details were given in a former report. The Superintendent of Public Schools in this city has also kindly assisted us by attending to similar technical details in Boston.

The five lessons on "Problems in Physical Geography," delivered by Prof. W. M. Davis, during the winter of 1886–87, were so novel and useful to teachers, that he was invited to give a course of ten lessons, during the winter just past, upon the "Physical Geography of the United States." This course was in part a continuation of last year's lessons, but the addition of new matter, new models, more extended illustrations, and the special attention given to our own country, made the lectures practically distinct from those previously given.

The objects of the course were as follows: to illustrate the value of systematic classification in the study of physical geography in order that forms of similar origin might be grouped together; to advocate the importance of studying the evolution of geographic forms in time, so that forms similar in origin but dissimilar in age, and consequently in degree of development, might be regarded in their natural relations; to apply these principles to the physical geography of our own land; and, finally, to promote the use of models in geographic teaching.

The different parts of the country were considered, not in order of location, but in their natural order: (1) the mountains as constituting the framework of the continent; (2) the plains and plateaux flanking the mountains; (3) the rivers carrying the waste of the land into the ocean; (4) the lakes, temporarily interrupting the transportation of waste to the ocean and retarding the action of the rivers; (5) the shore line where the land dips under the sea.

The lessons were given as usual in Huntington Hall, at the Massachusetts Institute of Technology, beginning Jan. 7 and ending March 10. The average attendance was two hundred persons.

One of the results of this course will, it is hoped, prove important to the future progress of geographical teaching in this country. Professor Davis prepared with the assistance of Mr. James H. Emerton a series of models of large size which illustrate his views, and can be used by teachers in the instruction of classes. These will probably be manufactured and sold at reasonable prices by some publisher, and if adopted by teachers will be great improvements upon the current methods of teaching this subject.

Mr. B. H. Van Vleck was also engaged to give a special course of fifteen lessons on zoölogy and spent a considerable proportion of his time during the summer in preparing specimens for this work. Such advantages for the study of the general morphology of animals, were never before offered in this school. A large number of the preparations were made with great care, and enabled the teachers to see and study structures not usually within their reach, especially in cases where the aid of the microscope was essential.

The work was mainly directed to the practical observation and study of the structure of a limited number of types, but general points in physiology and anatomy were also taken up in a comparative way, for the purpose of giving a better understanding of the animals which are commonly used in teaching. Attention was also given to the use of the microscope in connection with the examination of some minute organisms.

There were but thirty-eight seats available in our Laboratory where the lessons were given. Forty tickets to the public schools and ten admission and complimentary tickets were issued. The average number in attendance was thirty-seven.

The following statistics show to whom tickets were given out.

Number of tickets distributed.		To teachers.	To others.
Zoölogy,	50	40	10
Physical geography,	1110	843	267
	1160	883	277

GRADE OF TEACHERS.

Boston Public Schools.		Out-of-town Schools.	
Tickets distributed to	Phys. Geog.	Tickets distributed to	Phys. Geog.
Masters, or Principals	36	Masters, or Principals,	53
Sub-masters	26	Sub-masters	4
Assistants	465	Assistants	259
	527		316

LIST BY TOWNS.

Belmont	1	Cochituate	1	Melrose	16
Boston	527	Dedham	13	Milton	11
Bridgewater	2	Everett	18	Newton	2
Brockton	5	Haverhill	2	Quincy	51
Brookline	11	Hingham	4	Salem	5
Cambridge	81	E. Lexington	1	Somerville	13
Canton	3	Malden	25	Waltham	19
Chelsea	19	Medford	7	Woburn	6
				Total	843
Complimentary					136
Miscellaneous					131
					1110

Tickets were given out to the following people for the course on Zoölogy, by Mr. Van Vleck, 1887–88.

Complimentary	2	Out-of-town schools	7
Private addresses	8	Boston public schools	29
" schools	4		—
			50

In addition to these two courses, there was a third, which has been undertaken by the school, but this is not under the patronage of the Trustee of the Lowell fund.

The teachers who attended the lessons in geology conducted in 1887 by Mr. George H. Barton, Instructor in Geology, Massachusetts Institute of Technology, had expressed a desire for a continuation of the course, and a similar series was begun in response to their wishes on Saturday, April 7, 1888.

The object of the course will be instruction and practice in making observations in the field. Localities of special geological interest in the vicinity of Boston, in addition to those studied last year, will be visited and carefully examined. A few excursions to more distant points, such as Fitchburg, Bolton, Smithfield, R. I., etc., will also be made, if desired.

In consequence of the absence of funds sufficient to cover the course, a fee of $1.00 per lesson has been charged. Each excursion will be essentially complete in itself, so that persons may join or leave the class at any time, and a charge will be made only for the lessons actually attended.

The class now consists of forty-six persons, of whom six hold complimentary tickets.

Winter Laboratory.

Besides the class described above, composed of teachers of the public schools, the laboratory has been used by the following classes: one in Zoölogy and Paleontology from the Massachusetts Institute of Technology, one in Zoölogy from the Boston University, these two being under the charge of the Curator; also, one in Botany and one in Physiology, from the Boston University, both being under the charge of Mr. B. H. Van Vleck.

The Woman's Education Association also received permission to use this room and the microscopes for a special course in botany under the charge of Dr. R. W. Greenleaf. There were fifteen students in this course.

Expedition.

During the summer of 1887, the Curator accompanied by Mr. Henry Brooks, Mr. George L. Parmelee of the Institute of Technology, and his son, made a trip to the islands of the northern part of Lake Huron. The party started on the 7th of July, reaching Bruce Mines on the 11th. Here a boat and an experienced man, a cook and a stout boy were hired, provisions laid in and the expedition started on the 14th from Bruce Mines. We visited and collected on Sugar Island, St. Josephs, Drummond, Cockburn, the west end of Grand Manitoulin, as far as Gore Bay, and on most of the smaller islands lying in the North Channel, which were known to consist of limestone. The weather proved to be unusually dry and favorable, so that the party were rarely detained by rains and experienced no serious delays though necessarily travelling all day in an open boat and obliged to seek a camp every night on the land.

Large collections were made from the limestones of the Silurian system, which form the shores of these islands. Many large and fine specimens of Endoceras, and especially of the rare Discosorus and Huronia were obtained, and also a very excellent representative collection of all classes of fossils from the interesting strata of this region. The boxes containing these fossils were shipped as opportunity offered, from the different villages, or steamboat landings, visited by the party; but, upon our return to Bruce Mines, we found that the different shipments had been retained at Collingwood by the authorities of the Northern and North-Western railroad, on the plea that the freight must be guaranteed. This was done through Mr. Samuel Marks of Bruce Mines, who had stood our friend in other matters. The company still continued to hold the fossils, including three large trunks, in which were packed the outfit of tents and camp equipage, tools, etc., belonging to the Curator, on the plea that a consul's certificate was needed.

What especial purpose this would have served, except to put a fee in the pocket of a U. S. official, or what good this would have done the railroad company, nobody seemed to know. It was, however, insisted on, and while it was being procured, the building in which the goods were stored took fire, and the fossils, and other property, were destroyed. The action of the railroad officials, in this case, was rendered still more puzzling by the fact that they forwarded two of our boxes, one shipped early in the season and the other at one of the last ports visited, and these arrived here without accident.

Mr. Crosby spent the month of September in the Black Hills of Dakota, and in the adjacent Bad Lands of the White River region.

He made an interesting collection of the Archæan and Paleozoic rocks. His investigations, a paper on which was read before the Society at the meeting held March 7, treated principally of the nature and relations of the Archæan strata of the Black Hills. He also gave an account of the origin of the coarse, tin-bearing granites; the cause of the conformable contact between the Potsdam and Carboniferous throughout the western country; the date and history of the Black Hills uplift; the nature of the volcanic masses, which are stated to be chiefly intrusive sheets and laccolites. The absence of true glacial phenomena was also noted, the coarse gravel and erratic boulders covering the surrounding plains being in his opinion residual deposits of Tertiary age.

Report on the Secretary's Department and the Library, by Edward Burgess, Secretary.

During the past year no important event has occurred in the Secretary's department. The usual data in regard to meetings, membership, library and publications, will be found below.

Membership.

The membership of the Society remains exactly the same as last year. Eighteen Associate Members have been elected, but no Corporate, Corresponding or Honorary Members.

During the past year we have lost three Associate Members by death, four by resignation and two whose names have been dropped for non-payment of dues. Three Corporate Members have died.

Dr. Chas. E. Ware and Mr. Wm. Perkins, patrons of the Society, Mr. Nathaniel Cummings, Mr. Wm. E. Baker and Mr. Avery Plummer, Life Members, have died during the year.

The Society has lost by death Mr. R. C. Greenleaf, a patron and Ex-Vice President of the Society.

In the death of Prof. Spencer F. Baird, secretary of the Smithsonian Institution, and Prof. Asa Gray, we have to mourn the loss of our most distinguished honorary members.

Meetings.

There have been held fourteen general meetings and one special meeting during the past year. At the beginning of the year a proposition was made to hold a single meeting every month instead of two, but after discussion this plan was abandoned. The meetings in October were, however, omitted, by an earlier vote of the Society.

The average attendance has been forty-four, the largest ninety and the smallest fifteen. These figures are encouraging as they indicate an increased interest in the meetings. During 1886–87 when the regular attendance was about the same as during the last five years, the average attendance was twenty-seven, the largest seventy-six and the smallest seven.

It is also to be remembered that several meetings of the past year came on the same evenings as lectures given in aid of the Marine Biological Laboratory. As many of the most active members of the Society were especially interested in these lectures it necessarily diminished the attendance at our meetings on these evenings. Notwithstanding this fact, however, at no meeting were the numbers so small as at some of the meetings last year, and at most of them the attendance was much above the average for 1886–87.

Twenty-nine communications were made to the Society as announced by cards. Four papers have been presented by title. Numerous verbal unannounced communications have also been made.

A special meeting was held on March 28, to consider a vote of the council in regard to a Natural History Garden and Aquaria to be under the direction of the Society. The subject was enthusiastically discussed and the action of the council unanimously approved.

Library.

The additions to the library number as follows:

	8vo.	4to.	Fol.	Total.
Volumes,	195	43	1	239
Parts,	1,329	391	29	1,749
Pamphlets,	178	24	3	205
Maps,			19	19
				2,212

We have subscribed to the Journal of Morphology, Broca's Revue d'Anthropologie, the Centralblatt f. Physiologie, the Arch. de Physiologie, La Cellule, Fol's, Recueil de Zoologie, Monatschrift f. Anatomie und Histologie, and Robin's Journal.

Seven hundred and eighty-six books were borrowed from the library by seventy-eight persons. One hundred and seventy-nine books have been bound.

The new author's catalogue will be completed in a few months.

Publications.

The following numbers of the Memoirs have been printed:

Vol. IV, No 2. The Development of the Ostrich Fern, by Dr. Douglas H. Campbell, 36 pp. 4 pls. (Walker Prize for 1886.)

No. 3. The Introduction and Spread of Pieris rapæ, by Samuel H. Scudder, 18 pp., 1 map.

No. 4. North American Geraniaceæ, by William Trelease, 34 pp., 4 pls.

No. 5. The Taconic of Georgia and the Report on the Geology of Vermont, by Jules Marcou, 27 pp., 1 pl.

No. 6. The Entomophthoreæ of the United States, by Roland Thaxter (in press).

The signatures of the Proceedings up to the meeting of Dec. 7, have been distributed. The remainder up to date are in print.

Walker Prize.

No award has been made this year.

I cannot close my last report as your Secretary without expressing my very deep regret at retiring from an office which I have now held for more than sixteen years.

The uniform kindness which has been shown me by both officers and members will never be forgotten; and, although to-night I leave you officially, I am glad to think that I can be present in the future as in the past at the Society's meetings, and I need hardly add that my interest in the Society's work can never flag.

Report of the Treasurer.

Mr. Charles W. Scudder presented the following report:

Annual Statement of Receipts and Expenditures, Boston Society of Natural History, May 2, 1888.

May 1, 1887, to May 1, 1888. Receipts.

Admission Fees	$ 70.00	
Annual Assessments	1,055.00	
Dividends and Income from General Fund	6,141.22	
Income from Walker & Walker Prize Funds.	2,430.00	
" " " Grand " Fund.	10.00	
" " Courtis "	494.00	
" " Bulfinch St. Estate "	1,824.00	
" " S. P. Pratt "	566.00	
" " Huntington F. Wolcott "	790.15	
Entomological Fund	25.00	
Gift Account, Rev. R. C. Waterston for Library	100.00	
" " " Museum	100.00	
Laboratory, from Boston University, etc.	2,736.00	
		$16,341.37

Teachers' School of Science.

Received from Augustus Lowell, Trustee	1,500.00	
Balance	221.59	
		$1,721.59

May 1, 1887, to May 1, 1888. Expenses.

Publications and Printing	$ 607.25		
Less received on this Account	280.05	$ 327.20	
Museum		1,011.78	
Library		385.84	
Salaries and Wages		7,083.16	
Repairs of Building		258.63	
Fuel		198.80	
Gas		49.46	
General Expense		1,009.52	
Laboratory		2,546.66	
Investment from unexpended Income of Huntington F. Wolcott Fund. 5 shares Boston Nat. Bank		641.25	
Investment in General Fund of extra dividend from Pepperell Man'f'g Co. 1 Bond $1000 C. B. & Q. R. R. 4%		881.06	
Balance		1,948.01	
			$16,341.37

Teachers' School of Science.

Paid for Sundry Lectures, etc	1,721.59	
		$ 1,721.59

Boston, May 2, 1888.

CHARLES W. SCUDDER,
Treasurer.

The Society then proceeded to ballot for officers for the year. Messrs. Jackson and Greenleaf were appointed a committee to collect and count the ballots.

The committee announced the election of the following members of the Society to the respective offices for the ensuing year.

PRESIDENT,

FREDERICK W. PUTNAM.

VICE-PRESIDENTS,

JOHN CUMMINGS, GEORGE L. GOODALE.

CURATOR,

ALPHEUS HYATT.

HONORARY SECRETARY,

EDWARD BURGESS.

SECRETARY,

J. WALTER FEWKES.

TREASURER,

CHARLES W. SCUDDER.

LIBRARIAN,

J. WALTER FEWKES.

COUNCILLORS,

Henry P. Bowditch,
William M. Davis,
George Dimmock,
James H. Emerton,
William G. Farlow,
Charles L. Flint,
Edward G. Gardiner,
Henry W. Haynes,
Samuel Henshaw,
B. Joy Jeffries,
Augustus Lowell,
Edward L. Mark,
Edward S. Morse,
William H. Niles,
Ellen H. Richards,
William T. Sedgwick,
Nathaniel S. Shaler,
Charles J. Sprague,
Samuel Wells,
William F. Whitney.

MEMBERS OF THE COUNCIL, EX-OFFICIO,

Ex-President, Thomas T. Bouvé,

Ex-President, Samuel H. Scudder,

Ex-Vice-President, D. Humphreys Storer.

Dr. S. L. Abbot was elected an Honorary Member of the Council.

The following were elected Associate Members: William Beals, W. H. Snyder, Frederick H. Newell, C. M. Saville, O. F. Lincoln, M.D., Geo. E. Ladd, J. L. Gardner, jr., G. W. Beaman, Mrs. Louisa Hopkins and Mrs. G. W. Beaman.

Corporate Members: Henry Brooks, Ralph S. Tarr, W. B. Barrows, A. C. Boyden, L. L. Dame, L. W. Puffer, Miss E. O. Boardman, L. E. Sewall, M. D.

Mr. Edward Muybridge then gave an interesting account of his method of analyzing animal motion by photography and showed in illustration a large series of lantern slides.

After passing a vote of thanks to Mr. Muybridge for his beautiful demonstration, the meeting adjourned.

General Meeting, May 16, 1888.

The President, Prof. F. W. Putnam, in the chair.

The following papers were read:

EVOLUTION OF THE FAUNAS OF THE LOWER LIAS.

BY ALPHEUS HYATT.

This paper is a short abstract of a chapter on the geological and faunal relations of the Arietidæ prepared for a forthcoming memoir upon that family. According to my classification this group comprises the Angulatus group, which I formerly placed in a distinct family, the genus Psiloceras, the normal forms generally supposed to belong to the Arietidæ by all authorities, and also the remarkable genus Oxynoticeras, which I formerly classified as a separate family, and which is very generally referred to the Amaltheus group by other authors. The inclusion of so many important forms makes the Arietidæ, from our point of view, so large that it contains the vast majority of all the lower Lias Ammonitinæ, and it becomes necessarily the source, or ancestral focus for all the later formed groups of the Ammonitinæ[1] of the Jurassic in Europe. There are many more or less complete lists and monographs of local faunas in the province of Central Europe, and extensive collections which afford a solid basis for comparison. The preliminary work of Prof. Jules Marcou[2] in synchronizing the minuter subdivisions of the Jura in Central Europe was completed by the more extensive application of the same principles by Oppel[3], who visited, studied and synchronized the faunas of the different localities and identified the same beds in a large part of this province. The illustrated publications of Hauer[4], Neumayer[5], Wähner[6], Geyer[7] and Herbich[8] have also thrown a strong light upon the peculiarities of the faunas of the eastern part of Europe, particularly the basin of the North-

[1]The Ammonitinæ do not include Lytoceras or Phylloceras, etc. Such forms have been placed by the author in a distinct sub-order, the Lytoceratinæ.

[2] Roches des Jura, p. 23, 162, 173 etc.

[3] Die Jura-Format. Eng. Franr. u. d. südwestl. Deutschl. Württ. Jahresh., vol. 12–14, 1856.

[4] Die Cephal. a. d. Lias d. noröstl. Alpen, Denksch. K. Akad. d. Wissensch., vol. 11.

[5] See note 4, p. 587.

[6] Mojsis. et Neum. Beitr. vols. 2, 3, 4, 5.

[7] Ceph. Heirl. Schich, Abh. k. k. geol. Reichsan., vol. 12.

[8] Das Széklerland, Mitt. Jahrb. d. k. ungar. Anst., vol. 5, pt. 2.

eastern Alps. All of these researches, and many others not mentioned, have made still farther advances in the classification of the minuter subdivisions or beds practicable.

The principles of geographic distribution first announced by Jules Marcou[1] have also been vindicated by Neumayer[2] who has defined the homozoic bands of life in the faunas of what he has denominated the Mediterranean, Central European and Russian provinces.

The province of the Mediterranean according to this author includes the Jura in southern Portugal, southern and southeastern Spain, a part of southeastern France, the Alps in Italy and Austria, the Carpathians, and the Balkans farther to the east. The province of Central Europe includes all the remainder of France and Germany, England, the lands about the Baltic, the neighborhood of Brünn, and Krakau, and perhaps the neighborhood of the Dobrudscha. The Russian province includes central Russia, Petschora land, Spitzbergen and Greenland. According to this author these comparatively well-known areas are parts of homozoic bands, which encircled the globe during the Jurassic period, respectively representing the boreal, temperate and tropical relations of the faunas now existing on its surface.

All the forms of the Arietidæ except Oxynoticeras have been traced by the united work of Quenstedt, Neumayer and myself in the fauna of Central Europe to *Psiloceras planorbe* and this species by Neumayer and the author has been united with its still more primitive congener, *Psil. caliphyllum*, in the Northeastern Alps. Neumayer took the ground that all of the normal forms of the Arietidæ were derived from the more ancient though apparently contemporaneous fauna of the Northeastern Alps. I take great satisfaction in being able to corroborate this opinion, so far as the more important or radical series of the Arietidæ are concerned, but propose a still farther improvement in these views by excepting certain series from this law which I think originated in the basins of Central Europe. Before, however, this question can be considered, it will be essential to pass in review the author's classification, which has made it possible to follow out the chorological migrations of the forms of the Arietidæ more minutely than has been

[1] *Op. cit.* p. 74–91, 230, etc.

[2] Ueber Juraprov. Verh. k. k. geol. Reichsan., 1871, p. 54; Ueber unverm. auftret. Cephal. Jahrb. geol. Reichsan., vol. 28, 1878, et Jurastud. *ibid*, vol. 2, 1871, p. 524.

practicable with classifications founded upon the principles usually accepted.

The Arietidæ comprise the following series: the first branch consists of Schlotheimia or the true *Schl. angulatus* group, and Wæhneroceras, a new genus, of which *Wæh.* (*Aegoc.*) *Panzneri* (sp. *Wähner*) is a good example. This genus is intermediate between Schlotheimia and Psiloceras, and is distinguishable by its young, which until a late stage of growth have whorls, with pilæ and abdomens like those of Psiloceras; the pilæ cross the abdomen, and the deep, well-defined channel of Schlotheimia is not developed at any stage.

Psiloceras in a graphic presentation of the group occupies a central position; this genus being the Radical Stock of the family and a direct descendant of more ancient forms. This genus bears the marks of this descent in its sutures, form and markings, since it is evidently a close ally of Gymnites of the Trias, and a modified survivor of the trunk-stock of the genealogic tree of the order, which has bridged the gap between the Triassic and the Jurassic.

The second branch of the radiating series which sprang from the focus of ancestral affinities centring in Psiloceras includes Caloceras, of which *C. Johnstoni* and *C. raricostatum* are good examples, and the genus Vermiceras, of which *V. Conybeari* is the typical species.

A third branch begins with Arnioceras of which *A. semicostatum* is a good example, and from this, we can pass into Coroniceras of which *C. Bucklandi* is a typical form. A third branch begins with Agassiceras in which are included the typical forms afterwards described by Neumayer as Cymbites. *A. lævigatum* is a well-known example of this series and in it is also included *A. Scipionianum.* The genus Asteroceras, of which *A. obtusum* is a typical example, belongs also to this branch and Oxynoticeras, of which *O. oxynotum* is the type, forms another branch.

The branches may be traced to an origin in certain species more or less closely allied to *Psiloceras caliphyllum.* The Schlotheimian branch to *Psil. planorbe* var. *plicatum;* the Vermiceran branch, to *C. Johnstoni* closely allied to the same form, the Coroniceran branch can be brought to a focus in *A. semicostatum* and *miserabile*, which have varieties frequently identified as *Psil. planorbe* var. *levis* by collectors; the Asteroceran and Oxynoticeran branches can be followed with somewhat less certainty, but still with very great probabilities in favor of the opinion into *Agass. lœvigatum* or *striaries*, two closely allied species also not infrequently mistaken for *Psil. planorbe* var. *levis*.

The series or genera of these branches not only had a real existence as genetic radii arising from Psiloceras, but they can be graphically and truthfully presented in tables of which we have succeeded in constructing several in different faunas. In each basin the taxonomic and chronological relations are in close accordance with the classification. The different branches may, therefore, be traced to their natural foci in two different varieties of *Psiloceras planorbe:* the smooth and more degenerate *Psil. planorbe* var. *levis*, and the pilated variety *Psil. planorbe* var. *plicata*. I have accordingly divided the group into two natural sub-families or stocks, the Levis Stock and the Plicatus Stock; the Plicatus Stock embracing the series of Schlotheimia, Wæhneroceras, Caloceras and Vermiceras; and the Levis Stock taking in the series of Arnioceras, Coroniceras, Agassiceras, Asteroceras and Oxynoticeras.

In each genus or series there are (1) radical forms which approximate to Psiloceras; (2) progressive forms or those which differ most from that radical stock; and (3) degenerate forms. The radicals have been sufficiently noticed above; the progressive forms have distinctly marked channels, ribs, and spines; the degenerate forms, though not very much altered by degeneration, have smooth shells, are apt to lose the channels, and their whorls are more acute on the abdomen. The radical, progressive and degenerate forms constitute regular cycles in each series, and, as has been said in previous papers, occur in proper succession in time, the radicals first, the progressive species next, and the retrogressive last. These relations of the species within the same series is paralleled by the relations of the different series when compared together. They can also be characterized, as radical series in which degenerate forms are rare or more slightly marked; this is the case in Psiloceras and Caloceras. Progressive series are those in which the species are very largely progressive in characteristics, like Vermiceras, Arnioceras, and Coroniceras. Retrogressive series are those in which the shells are all, or in large part, degenerate, such as Agassiceras, Asteroceras, and Oxynoticeras. The chronological succession of series, like that of the species, within each series, coincides with the taxonomical arrangement.

An interesting result of this agreement between chronology and taxonomy is, that the successive faunas of the Lower Lias also present a similar order. Thus, the faunas of the lowest beds, the Planorbis and Laqeuus, or as I have called it, the Caloceras bed, contain in preponderating abundance the forms of the radical stock ; the Angulatus bed is characterized by the progressive forms of the Schlotheimian branch and by numerous radicals of progressive series, the Lower Bucklandi bed by the general blooming out of progressive forms in the normal series, and the Upper Bucklandi or Geometricus bed by the incoming of degenerate forms in these same series, and the beds above this by the advent of degenerate series and the more marked degeneration of species and dying out of the whole family, with the exception of two species of Oxynoticeras that still survive in the Middle Lias.

The life-history of the whole family is, therefore, from every point of view, comparable with the life-history of any one individual. The shell of the individual has a period of early stages of growth during which it passes through progressive stages which, according to Haeckel's nomenclature, may be styled the anaplastic stages, the adult or fully developed progressive stages are equivalents of his metaplastic stages, and the stages of decline can be similarly named the cataplastic stages. Each series, as we have just said, has similar stages or periods of evolution in time, and the entire group is similarly related. Haeckel has named these three in a general way, the epacmatic period of progress, the acmatic or fully developed period in the history of a series, and the paracmatic, or period of the evolution of degenerate forms. The author pointed out these phenomena and their agreements among Cephalopoda, in the same year that Haeckel published his views, but did not propose an appropriate nomenclature.

The successive faunas may now be similarly classified and arranged to accord with the ontology of individual and the evolution of the group, and styled the Epacmatic faunas, the Acmatic faunas, and the Paracmatic faunas. The Epacmatic faunas occupied the Planorbis, Caloceras and Angulatus beds, the Acmatic were in the Bucklandi beds, and the Paracmatic characterized the Tuberculatus, Obtusus, Oxynotus and Raricostatus beds. So far as the Arietidæ are concerned, there is no justification for any chronological subdivision of the Lower Lias faunas unless it be into three parts as indicated by these relations.

Neumayer and Wähner have shown the ancient character of the fauna of the Planorbis and Angulatus beds of the Lower Lias in the basin of the Northeastern Alps. The appearance in the same region of the very abundant fauna of the Trias, so admirably described by Mojsisovics in his "Mediterranean Trias Fauna," makes it still more likely that the geological succession was more direct in this region than in any other.[1]

The richness of the faunas of the lowest beds of the Lower Lias in the basin of the Northeastern Alps so completely described and beautifully illustrated by Neumayer[2] and Wähner,[3] that they are models for imitation, has added a large number of radical species to those few formerly known in Central Europe but has not added correspondingly to the progressive series. Neumayer states,[4] that the radical species of *Psil. planorbe* had varieties in Northeast Alps approximating to some in Central Europe, though probably derived directly from *Psil. caliphyllum* a smooth species of Psiloceras not found in Central Europe. I have had a similar experience in studying the Psiloceratites of Central Europe, and also *Cal. Johnstoni* and other Caloceratites of the same fauna. In these species, varieties are found having more complicated sutures like those of the same species in the Lower Lias of the Northeast Alps. The shells of this fauna are very generally characterized by having more complicated sutures, the outlines of the lobes and saddles resembling the species common in the Trias, and quite distinct from the outlines of the sutures in the normal forms of the Arietidæ of the Lias in Central Europe.

The sutures of the normal forms of the Arietidæ in Central Europe, and of the species originating in that fauna, have, as a rule, simpler outlines and are evidently more or less degenerate. This fact accords with the theory that they were derived from *Psil. planorbe*. The sutures of the Arietidæ are more like those of the young of Psiloceras than those of adults of the same species. The shells of this genus, and in fact all of the Ammonitinæ, have more complicated sutures in the adult than in their own young. Neumayer has also stated that in old age of *Psil. caliphyllum* the sutures de-

[1] This remark has been sustained by the discovery by Clarke of a Triassic form, an Arcestes in the Rhaetic bed of the vicinity of Aachen-See (see Geol. Verhält. d. Geg. nordw. v. Aachen-See, by W. B. Clarke, now of Johns Hopkins University).

[2] Unterst. Lias, Abh. k. k. geol. Reichsan., vol. 7.

[3] Mojsis., et Neum. Beitr. vols. 2, 3, 4, 5.

[4] See 12, p. 43.

generate and then resemble those of the adult of *Psil. planorbe*. The sutures of *Psil. planorbe* var. *levis* are obviously intermediate between those of *Psil. Caliphyllum* and Caloceras. The sutures of the latter are also intermediate between those of Psiloceras and Vermiceras, so that a most perfect series exists in Central Europe between the more complicated outlines common in Psiloceras and Caloceras and those of Vermiceras, which are simpler and purely Arietian in outline. The sutures have been, therefore, to a certain extent, arrested in their development and evolution in the normal forms of the Arietidæ and this is a marked characteristic entirely compatible with progression in other characters.

In studying the genetic history of each series by itself, species after species and variety after variety, it has been found practicable to attempt to follow out the migration of forms on the same horizon from one fauna to another, and, though no doubt very imperfectly, to make a beginning in the direction of tracing the evolution of faunas chorologically. The results of this work are very suggestive, and it may be said with approximate accuracy, that some faunas are autochthonous or give rise to new forms and, that others, which I have called residual faunas, are not favorable for the evolution of new species or varieties.

It seems very probable that the basin of the Northeastern Alps was the place of origin for Psiloceras, Caloceras, Schlotheimia and Wæhneroceras. The migrants that peopled other basins were not the degenerate or highly progressive forms of these series, but often, and perhaps generally, the radical forms. Thus out of the extensive series of the Radical Stock, Psiloceras, and of Wæhneroceras of the Northeastern Alps, but very few species, and these almost wholly the radicals migrated to central Europe. The history is somewhat different in Schlotheimia, though even in this genus, there are many more forms in the basin of the Northeastern Alps than in Central Europe.

There are undoubtedly certain facts, like the earlier appearance of *Schlot. striatissima* in the "gelbe Sandstein" of the Trias in Würtemburg which do not coincide with the assumption of origin of the Schlotheimian series in the basin of the Northeast Alps. It ought to be mentioned here also that *Psil. planorbe* var. *levis* appears in the same basin according to Quenstedt in the Bone-bed, which is either the uppermost bed of the Triassic or the very earliest bed of the Lias. The existence of a bed at the base of the

Planorbis zone containing Psiloceras alone has not yet been demonstrated in the Northeastern Alps, though such a fauna exists in South Germany. Nevertheless the evidences palæozoölogically are so complete, that I feel disposed to support the opinion that the four series of the Arietidæ above mentioned were derived by chorological migration from the Northeastern Alps.

This conclusion must be true, or else the separate and distinct origin of the faunas of South Germany and the Northeastern Alps and perhaps others like that of England will have to be admitted. It is very difficult, if this last theory be accepted, to account for the phenomena subsequently occurring in the residual faunas. The residual faunas show that the radical types of series are apt to occur later in them than in those that have been called autochthonous. The greater completeness of the earlier faunas of the Northeast Alps in radical forms and series also coincides with the similar completeness observed subsequently in the basins of South Germany and Cote D'Or in the forms of the progressive series, which alone appear to have arisen there. Thus in basins where forms and series must have arisen according to the evidence afforded by the earlier appearance of radical species, there are, as a rule, larger numbers of species and varieties than in those which do not possess radical species, or in which they appear later in time. The hypothesis of the independent origin of series in these two principal autochthonous basins, would also involve the corollary that precisely parallel series and identical species connected by similar varieties could also be independently evolved in these different basins. The English basin also possesses very complete series and like South Germany has a bed exclusively occupied by *Psil. planorbe* but the absence of peculiar forms, and the later incoming of radical species of other series, show that the hypothesis of the independent origin of similar species or polygenesis cannot be admitted without more evidence than is now in our possession. The future completion of the geological evidences by the discovery of still more complete series in the Planorbis, and later Triassic of the Northeastern Alps seems, therefore, to be likely since, as we have said above, the unexampled profusion of the Triassic fauna and the progress of recent discoveries point also to the same result. It seems preferable to adopt this conclusion as presenting the least difficulties. The view, that South Germany might have been the basin in which the radical stock and all the radical series of the Arietidæ (except Vermiceras) originated, is directly contrary to all the testimony of paleozoölogy, and has in its favor only the earlier occurrence in that basin of *Psil. planorbe* and *Schl. striatissima* and *catenata*.

Vermiceras has an independent history. The radical species of this genus, *Cal. laqueum*, appeared in South Germany in the Calceras bed and probably migrated thence to the Northeastern Alps appearing in the modified form of *Verm. præspiratissimum* (*sp. Wähner*) in the Angulatus bed of that fauna. This series also met with the most favorable opportunities for the evolution of new modifications in the faunas of South Germany and the Cote D'Or. The members of the genus found in the Mediterranean province are similar to the more degenerate forms of this genus and do not indicate the existence of very favorable surroundings in that basin during the Lower Lias so far as this series was concerned.

The species of Arnioceras are not abundant or large in the Northeastern Alps basin, whereas they are very abundant and represented by large numbers of radical and progressive forms in the basin of South Germany and the Cote D'Or. The radical species also occur in the Angulatus bed of these basins earlier than that of the Northeastern Alps.

The radical species of Coroniceras occur on the Angulatus horizon in all three of the faunas just mentioned, but the evolution of the new forms of the series and two sub-series, and the presence of transitional forms, are marked characteristics of the faunas in South Germany and Cote D'Or and it is probable that it originated in these basins in the province of Central Europe.

Agassiceras lævigatus and *striaries* appeared simultaneously and were about equally developed in the basins of the Cote D'Or and Rhone, but have not been found so early as the Angulatus bed in any other faunas. It seems more likely from this and the abundance of other forms of the series that it appeared first and was best represented in these two basins.

The evidence with regard to Asteroceras is more doubtful. It may have first appeared in South Germany with *Aster. obtusum* in the Upper Bucklandi bed ; or, it may have been an exception to the general rule and appeared first in the residual fauna of Luxemburg where this species occurs on the same horizon. The collateral evidences, however, are in favor of South Germany. It has perhaps more remarkable degenerate forms in England than anywhere else.

Oxynoticeras made its appearance on about the same level in all the faunas so far as can be judged by the evidences; but the other species of this series and of the sub-series of *Oxyn. Greenoughi* show that it probably arose in the Cote D'Or and was distributed from that centre.

The basins of the Northeastern Alps in the Mediterranean province and of South Germany and the Cote D'Or in Central Europe may therefore be considered as marking out a zone during the time of the Lower Lias, running east and west, which was especially favorable for the evolution of the new forms and series which are included in the family of the Arietidæ. I have accordingly named these basins the Zone of Autochthones, or zone of autochthonous faunas in the Lower Lias.

The fauna of the Lower Lias in the basin of the Northeastern Alps is, however, not in the zone of autochthones after the deposition of the Angulatus bed. This zone, before the deposition of the Lower Bucklandi bed, had become narrowed in its easterly extension and was confined to the faunas of South Germany and the Cote D'Or. This is shown not only by the diminution in the number of forms of each series represented in the strata of the basin of the Northeastern Alps, but also by the concentration of the beds and the mixed character of the faunas above the Angulatus bed. The best general summary of the facts in regard to the faunas of the different beds of the Lower Lias has been given by Wähner[1] in his "Heteropischen Differenzirung des Alpinen Lias." This author, whose keen discrimination of species I have had constant occasion to admire, has been able to distinguish all the Oppelian beds from the Planorbis to the Angulatus bed in the Northeastern Alps, but he has entirely failed, as have others, in defining the beds above this, so as to make a parallel series with those of Central Europe. Stur,[2] Gümbel,[3] Geyer,[4] Herbich,[5] and others may be quoted in favor of the opinion that the faunas of the strata above the Angulatus bed are mixed, and that the beds cannot be separated as in the province of Central Europe. They have failed in obtaining any direct evidence of subdivisions after careful investigations, and their citations of the minute work of others show the same result. Some of these authors go so far as to claim that the faunas above the Angulatus beds in the Northeastern Alps not only contain species

[1] Verh. d. k. k. geol. Reichsan., 1888, p. 168.
[2] Geol. d. Steirmark, p. 433.
[3] Geogn. Beschrieb. d. bayeris. Alpen, p. 428.
[4] See *op. cit.*
[5] See *op. cit.*

common to all of the higher beds of the Lower Lias, but also some species which occur only in the Middle and Upper Lias of the basins farther to the west.

So far as we have seen the forms, or noted the observations of others on the species of the Adnether and Hierlatz basins in the Northeastern Alps, this last extreme opinion does not seem to be sustained. That the faunas are mixed, as noted above, seems to be established, however, by the direct observations of several authors, notably Geyer and Herbich.

These facts appear also to accord perfectly with the conclusions given above. If the Northeastern Alps were the seat of origin for the radical series during the time of deposition of the earlier beds, and the more western basins became the originating centres of the more progressive series, and, finally of the degradational series during Bucklandian and later times, then we can account for this confusion as due to return migrations from the western faunas towards the east. The radicals of the different progressive series could then have arrived in the Northeastern Alps with sufficient rapidity of succession to have become mixed in the same rocky stratum ; and the later forms may even have overtaken the radicals while on their journey to the east and have arrived together in this basin, which would thus have become changed from an autochthonous to a residual fauna.

Another fact in favor of this view is the curious confirmation afforded by Neumayer's remarkable conclusion that the faunas of the Mediterranean province are distinguished by the earlier appearance and origin in them of the Lytoceratidæ, a family which is characteristic of the Middle and Upper Lias in Central Europe. This opinion is well sustained by the later observations of Geyer at Hierlatz, and especially by Herbich's discovery of an extensive series of these forms in the Lower Lias of Siebenburgen.

The rise of the Arietidæ is, in large part, more completely recorded in the Northeastern Alps, than in any other basin, but the acme of its history was reached in the faunas of South Germany, and the Cote D'Or. The records of its declining series are about equally well given in the rocks of the Lower Lias in South Germany and Cote D'Or ; and in England there is also a very complete series, especially of what may be called the more degraded forms of Asteroceras, and of the first or oxynotum sub-series of Oxynoticeras.

The faunas of the Italian peninsula have not been completely explored, but so far as known, they belong to the same category as those of the Northeastern Alps, and are included in the Mediterranean province, as has been stated previously by Neumayer. There is no evidence, so far as I know, which sustains the conclusion, that there was a migration of forms of the radical stock or of the radical species of the different series of the Arietidæ from the south through the basin of the Rhone into South Germany. On the contrary, the basin of the Rhone contains a fauna, which is almost entirely residual and might have been derived by migration from South Germany and the Cote D'Or. The faunas to the north of the autochthonous zone of the Arietidæ bear also very strong marks of having been derived from those of South Germany or Cote D'Or. Thus in Luxemburg, Hanover, and North Germany in general, there is a prevalence of the same succession in the beds and similar faunas, which indicate a more exact parallelism with those of South Germany than has been found in the Northeastern Alps. The faunas are, however, less complete, both geologically and palæozoölogically in the lowest beds of the Lower Lias, especially in the smoother varieties of *Psil. planorbe.* In other higher beds there is a paucity in the representation of the forms of the different series a prevalence of smaller-sized specimens, and a later appearance of the radical forms of the different series, which show the basins to have been peopled by migrants from the south.

England also apparently derived its fauna from the south. The beds are presented in detail as in South Germany; but, in spite of this fact, there is in that fauna a generally later appearance of radical species, and, in fact, with the exception of the more degraded species of the Asteroceran series, the fauna does not present any forms, which can be said to have originated there. The shells are of large size in many species and the surroundings were evidently very favorable for the growth of the individual, though not for the evolution of new forms.

Information with regard to the faunas of localities farther north, like those farther south than those mentioned above, is not extensive. So far as they go, the records exhibit more or less deficiency in the deposits of the Lower Lias, and the rocks do not contain rich faunas or earlier appearing radical species. The theory of migration from west to east along a zone which passed to the north of the Alps differs from the suggestion of Mojsisovics in his work "Dolomit-Riffe Süd-Tirols, etc.," that the fauna of Central Europe may have come from Italy by the way of the valley of the Rhone. The faunas of the Italian rocks have been referred to the Mediterranean province by Neumayer and several other authors, and the mixed character of the faunas above the Angulatus beds has been noticed, especially by Geyer. There seems to be every reason for closely associating them throughout the Lower Lias with those of the Northeastern Alps, and all the specimens we have seen are either peculiar forms or have a Mediterranean facies.

It has seemed, therefore, unlikely, that any connection existed during the time of the Lower Lias between the Central European and the Mediterranean province to the west of the Northeastern Alps basin. This opinion, established on purely palæozoölogical grounds, receives confirmation from two different geological considerations. The Planorbis bed is either absent or very slightly and insufficiently presented in Italy according to all the works we have seen, and this is also the case along the shores of Provence. It is present in deposits reaching from the neighborhood of Toulon to Nice, according to M. Dieulefait, but does not contain any Ammonitinæ. This author[1] draws a boundary line between the rocks of the Lowest Lias in southern Provence or department of the Var and those of the valley of the Durance and department of the Basses Alpes. His researches show very clearly by means of the geology and palæontology, that no connections probably existed between these closely approximated areas during the deposition of the Planorbis and Angulatus beds, and farther, that the upper beds of the Lower Lias are entirely wanting in the Mediterranean part of Provence, while they are well developed in the valley of the Durance.

This sustains the views here advanced that the migrations began during the time of deposition of the Planorbis or possibly somewhat earlier beds and flowed out from the Northeastern Alps in two directions. One took the route to the south and west into the Italian region, and, perhaps, farther westward into Spain, though of this last we have no proofs to offer. The other stream of migrants spread more directly westward into Bohemia and South Germany first, then into the Cote d'Or, but reached the Rhone and all faunas south of the autochthonous zone later. In the same way as regards England and the faunas north of this zone, they all, as we

[1] Ann. des Sci. Geol., vol. I, pl. v.

have said above, contain forms which show that they were established later in time than those of the basins of South Germany, or Cote d'Or.

M. Dieulefait's observations also accord with my opinion, that the faunas of the south German basin during the time of the deposition of the Bucklandi bed made a return migration to the east, peopling the Northeastern Alps basin with progressive forms first, and then spread to the south and west into Italy. It would be difficult to account for the absence of the upper beds of the Lower Lias in the Mediterranean part of Provence or for the mixed character of the faunas of these same beds in Italy upon any other theory than direct connection with the similar faunas of the Northeastern Alps in the east and a corresponding isolation from the faunas of Central Europe to the west.

I am well aware of the great difficulties under which one labors in writing an article of this kind so far away from the localities in which the phenomena have been and are still continually being observed. The large amount of negative evidence which has to be taken into consideration in all the countries to the south and north of the autochthonous zone of the Arietidæ will also rightfully create doubt in the minds of specialists. Nevertheless, the positive facts are closely and very remarkably in accord with the genetic classification of the species as traced out graphically in lines spreading from a centre in *Psil. planorbe* or *caliphyllum*, and with the subsequent cycle in the life-history of the individual and of the series to which the individual belongs.

Whether it will be ultimately demonstrated that all the faunas of the Lower Lias were derived by chorological migrations, and corresponding modifications, from radical forms which arose in the three autochthonous basins mentioned above cannot now be discussed. So far, however, as American forms are known to us, they have a distinctly European facies.[1] The geology of North America also supports the conclusion that the Jura was neither very completely

[1] *Caloceras Ortoni* from Chacapoyas in north Peru can only with difficulty be separated from the stouter varieties of *Caloceras salinarium* described and figured by Wähner from the Northeastern Alps, and a form of *Cal. nodotianum* lately received from Peru cannot be separated from some varieties of that species in Central Europe. The South American province includes the Jura of the Argentine Republic, Chili, and Peru. This fauna besides a number of peculiar species is composed of a mixture of Central European and Mediterranean species. The North American province includes California and Vancouver's Island. These faunas over and above their own peculiar species are mixtures of European forms.

represented by deposits nor rich in the number of forms evolved, two deficiencies that in Europe mark what have been called residual faunas.

ON A NEW PARASITE OF AMPHIURA.

BY J. WALTER FEWKES.

The Secretary read a communication on the parasitism of a Crustacean in the brood cavities of a common brittle-star, *Amphiura squamata*, which he had discovered while at work in the Marine Laboratory at Newport.

The Ophiurans, or brittle-stars, have two methods of development or metamorphosis, known as the direct and indirect. In the indirect, the young passes through a stage called the pluteus in which a provisional organism is developed from which the young form by budding, the provisional organism, or pluteus, being eventually absorbed by the growing young of the brittle-star. Our common Ophiopholis, *O. aculeata,* has such a pluteus. In the case of other Ophiurans as Amphiura, however, there is no free pluteus in their metamorphosis, but the young are developed, without nomadic stages, in special sacs of the mother, called brood-sacs, of which there are ten situated in pairs on each side of the arms. The young Amphiura passes its early life in these sacs, at first attached by an umbilicus, afterwards free, and remains there until it has reached a considerable size. Morphologically, both forms of metamorphosis are identical, but while certain structures, as for instance, parts of the calcareous framework of the pluteus, are recognizable, a nomadic pluteus is never formed in this genus.

In collecting adult Amphiurans in order to discover new stages in the development of the young, my attention was often attracted to certain adults of this genus in which a portion of the upper (aboral) surface of the body has a reddish color, while in most specimens the body is chocolate brown. This coloration was noticed to be ordinarily limited to a marginal region of the body just between the radial shields.

It was invariably found, when those adult Amphiuræ with reddish coloration on the aboral surface of the body were dissected, that young were absent from the brood-sacs. It was, moreover, almost invariably found that in these adults the ovary had suffered a change and had degenerated into an amorphous mass in which ova were not recognizable. In the brood-sacs of such, instead of young Amphiuræ there were found small packets of pink-colored ova which, when seen through the wall of the body, impart the reddish color to the aboral body wall. In addition to these packets of ova it was likewise found that the brood cavities of many of the specimens thus abnormally colored harbored a small Crustacean. In an examination of the pinkish clusters of ova in the brood-sac of the Amphiura it was discovered that they are in all conditions of growth from the first stages of segmentation into a well-formed Nauplius. Young Crustaceans free from the packet of ova were also found in great numbers in the brood-sacs. These adults were identified as belonging to the group of Crustacea called the Copepoda.

An interpretation of the above facts seems to be that we have here a strange instance of parasitism. It is also thought to be unique among the Echinoderms. Although many genera of parasitic Copepods are known, I am not familiar with recorded instances where these parasitic Crustaceans enter the brood-sac of an Amphiura and destroy the virility of its host for the good of its own offspring. Many instances of Crustacean parasites castrating other Crustaceans have been recorded by Giard, but in these cases it has not been shown that the castration of the host is a direct benefit to the offspring of the parasite itself. In Amphiura, however, we have a condition where we can legitimately conclude that the amorphous condition of the ovary of the Amphiura is the direct result of the presence of the mother Crustacean in the brood cavity of the Amphiura. We may suppose that the parent of the Crustacean made her way through the genital slits of the Echinoderm into the brood-sacs, and there spayed the Amphiura. Packets of the ova were left in the brood-sacs to develop. With the destruction of the possibility of offspring in Amphiura within her own brood-sacs the future life of the young Crustacea was assured, and we may readily see, if the precaution of preventing the development of young Amphiuræ had not been taken, the young Crustacean might have fallen easy prey to the vigorously growing young of the brittle-star.

Many questions of theoretical interest suggest themselves in regard to the curious condition of parasitism mentioned above. How by a theory of the advantage which has come to the Crustacean has the life within the brood-sac of Amphiura originated? That it is a manifest protection to the young Crustacean to be sheltered by its host appears self-evident and one can on this ground find abundant cause for the mode of life which has been mentioned. Moreover, it is also a great advantage that the young of the Amphiura be destroyed. We may then suppose that in the evolution of this manner of life, after the Crustacean has found a home in the brood-sac of the brittle-star, the ovaries of the Amphiura may have been aborted by the parasite and this habit of destroying the ovary has led to a survival of the young Crustacean. That habit becoming hereditary has led to the condition of life as it now exists. Whether the ovaries were first used as food, and in that way the habit of spaying the Amphiura arose, I cannot say. It is possible that they offered a tempting morsel to the Crustacean, and the advantage thus gained by the parasite over others has led through heredity to the condition which we at present find.

The following paper was read by title:

DATE OF THE PUBLICATION OF THE REPORT UPON THE GEOLOGY OF VERMONT.

BY C. H. HITCHCOCK.

The Boston Society of Natural History has recently published a memoir by Jules Marcou upon "The Taconic of Georgia and the Report on the Geology of Vermont," in which an attempt is made to state the true date of the publication of this report. As I prepared more than half of these volumes for the printer I have thought some misconceptions might be corrected by a statement of the facts.

The printing commenced early in the spring of 1861 under the direction of A. D. Hager, one of the authors, who expected to complete the printing before the year 1862. This would have been accomplished except for his desire to add an appendix, a reprint of descriptions of "Lower Silurian fossils" by E. Billings which had made its appearance only in November. Even the title pages had been printed with the year 1861 upon them before this addition. Nevertheless nothing was crowded over into 1862 except the index. Everything else was printed in 1861. It took some time to arrange sheets and plates into shape for binding, so that the circular announcing that the report "is now ready for distribution" bears date of Jan. 28, 1862. It is easy to trace the progress of the printing from the volumes themselves. On page 386 is a note added to the galley proof which indicates that everything up to that point, including the account of the Georgia slate, had been printed by July 20. By August 10, the whole of Part II, or everything relating to the Paleozoic rocks with the exception of the appendix noted above and the general sections, had been printed. After that date no alterations could possibly have been made to the text. But according to the principles employed by Mr. Marcou in his memoir, the date of the publication of Part II does not depend upon the issuance of the volumes in bound form. Excerpts that have been distributed or exhibited to scientific men before the appearance of the bound volume, are regarded as having been published. Thus he says of the general map in volume 2, "The map had two editions. The first one, distributed in December, 1861, contains," etc. He allows that this map was published in 1861, Then the whole of Part II must have been published as early as September, 1861, since it had been distributed and exhibited to scientific men just as much as the map had been.

The reason why the effort is made to show that the date of the publication is incorrectly stated is that there is a question of the priority of the proposal of the name *Georgia slate*. It seems that on the sixth of November, 1861, Mr. Marcou, at a meeting of the Boston Society of Natural History, in a communication upon the "Taconic and Lower Silurian rocks of Vermont and Canada" devoted a few lines to the description of a band of rocks which he named the *Georgia slates*, referring them to the middle of the Taconic system. The remarks were printed in December, but the blackboard illustrations did not appear till 1880, and most of these he acknowledges in the memoir cited at the beginning of this paper to have been erroneous. Because the Vermont report was not published till 1862, and his remarks were given orally in November 1861 (printed in December), Mr. Marcou claims to be the originator of the name of Georgia slates as applied to a geological deposit. According to the principle of Mr. Marcou, as explained above, my description printed in July was published as early as September, and therefore has the priority over the November communication. But I will not base my claim upon this supposed earlier publication. Credit for original suggestion is based as much upon its correctness as determined by later explorers, as upon earlier publication. It so happens that we have defined this belt of rock very differently. Let that definition be accepted which proves to be the more correct. The Georgia group was proposed by me to embrace two other terranes as well as the one under consideration, and the name of Georgia was employed because the whole group was exhibited within the township with characteristic fossils, and its use did not commit the report to any one of the three views that had been proposed for its age. Its precise place was left to the final decision, as awarded by paleontologists, of the value of the fossils. My definition embraced three points: (1) it rested upon the red dolomitic sandrock; (2) it was 3000 feet thick and much more in the southern terrane; (3) it extended eastward across the railroad and constituted the slates at St. Albans village, the eastern portion being the newest. On the west, it joined the Hudson river slates, and the place of the supposed fault plane was indicated, but its existence was neither affirmed nor denied. Mr. Marcou's Georgia slate (1) underlaid the red rock [Potsdam sandstone] unconformably, (2) was from 500 to 600 feet thick, (3) the rocks to the east of Georgia center belonged to an older series 2500 to 3000 feet thick, called the St. Albans group, because the village of that name rested upon it. Thus this definition includes only a sixth part of the strata called by this name in the Vermont report. Nothing was said of the slates to the west of the red rock in the November communication, but in a later publication they are referred to the Upper Taconic.

An exhaustive survey of this region has recently been made by C. D. Walcott and published in the Bulletins of the U. S. Geological Survey, Vol. IV, No. 30, 1886. No geologist is better qualified than he to settle these questions which we are discussing, especially as he has studied a wider field than either of the disputants. The southern terrane referred in the Vermont report to the Georgia group is referred to the same horizon by Walcott in a later publication. Concerning the rocks under discussion he (1) makes the slates to overlie the red rock, and adds that to the Georgia group, as was done by Logan before him, who used the name of Potsdam; (2) The thickness is nearly 9000 feet; (3) the eastern continuation is to the same line, the eastern part being the highest. The slates west of the red rock are separated from it by the great fault and they are of Hudson river age. The so-called St. Albans group of Marcou is not mentioned by name, but its strata are made a part of the Georgia group. I think any geologist will note a close agreement between the positions taken by the Vermont report and Mr. Walcott, save in the addition of the red rock to the slate group and the adoption of the theory of the fault. Walcott's section is much larger and more detailed than mine in St. Albans a few miles north, but their similarity to each other is obvious. I think I may reasonably claim that the essential points of my definition of the Georgia rocks have been accepted by the later explorer to the detriment of those of Mr. Marcou.

In reference to the reprint of Mr. Billings' paper, Mr. Marcou remarks as follows: "Besides Mr. C. H. Hitchcock has suppressed, without any notice, a whole page of Billings' paper, a very interesting foot-note pp. 11 and 12, containing among other information a letter from C. H. Hitchcock himself." If Mr. Marcou will consult the volume entitled Paleozoic Fossils, *Vol. I* of the Canada Survey, where the pamphlet which afforded the descriptions copied into the Vermont has been reprinted, he will discover that *Mr. Billings has also suppressed this foot-note.* Perhaps it will appear in the next memoir upon the Taconic rocks, that Mr. C. H. Hitchcock suppressed this foot-note in the Canadian volume! It will be a favor to me if Mr. Marcou will furnish the proof that I had any concern in the omission of this page in the Vermont reprint.

I have time for only one more topic. Of my exposition of the Taconic system, p. 434, Vermont Rept., where I attempted to portray truthfully the views of Professor Emmons, it is said by Mr. Marcou, "This brief view of its history as a system is full of reticence and even opposition, and is simply an *ex parte* and partial exposition," etc.

Others have thought differently. The Vermont report has been stated to be an advocate of the Taconic system because of the presence in it of that chapter. But whatever its imperfections, I am prepared to submit to any impartial jury the claim that my sketch is a more truthful exposé of the *Taconic System of Emmons* than are the writings of Jules Marcou. There is nothing more emphatic than the insistence of Professor Emmons upon the *unconformable superposition of the Silurian Potsdam sandstone above the Taconic system.* Professor Emmons prided himself upon having discovered and defined this sandstone, which constituted the base of the Silurian system in this country. It is my belief that he would have abandoned the Taconic system rather than have incorporated the Potsdam with it. But Mr. Marcou makes the Potsdam a part of the Taconic, and therefore he does not accept the views of Emmons. If one were inclined to be humorous he would inquire if it were not possible that Mr. Marcou was trying to suppress the Taconic system.

The writer has no desire to disparage the value of Emmons' observations. He has gone so far as to propose to the International Geological Congress to call the rocks containing the first fauna of Barrande either *Potsdamic* or *Taconic* out of regard for the gentleman who first proposed the use of both names. If general consent could be obtained, either name might be used appropriately for the whole system.

General Meeting, November 7, 1888.

The President, Prof. F. W. Putnam, in the chair.

The President addressed the Society in the following words:

Members of the Society:—We have come together again after our summer excursions or weeks of quiet study, as the case may have been, to renew our pleasant and instructive meetings, and I am sure there will be no lack of subjects to be brought forward for discussion in the fourteen meetings which will be held before another summer again entices us to the fields or to the shore.

We must not forget that we are united as a society for mutual instruction and that the unwritten law which is binding upon all naturalists demands that what has become known to one shall be made known to all. Let obedience to this law be the strong incentive to overcome shyness and false modesty. Do not let fear of giving offence prevent free criticism in our discussions, and above all do not let us blindly follow and agree with others when we are confident that our researches lead to different conclusions. Perfect freedom of discussion, within the limits of the subject before us at any time, I earnestly ask for and sincerely hope you will give.

An object that calls for earnest work upon our part, and one which we must keep constantly in mind, is the carrying out of the plans for the Natural History Park which were started so auspiciously at our meetings at the close of the last season. The committee of the Society will make an early report upon this subject, but we must not leave the committee to do all the work when we, as individual members, can do so much in arousing an interest in the community to which we must look for support.

Another matter, to which I must call your attention at this first meeting of the season, is one that seems to me to be full of good to the Society if properly managed and cordially entered into. It is that of sociability among the members. We are really a society of friends, and yet we meet in this hall with such formality that we feel as if we were hardly acquainted with each other and were waiting for an introduction before we dared to address even the chairman of the meeting. That we should have a proper amount of formality when we are assembled here none will deny being right, but cannot we, as many other learned societies do in other places, be a little social over a cup of coffee or tea at a gathering before our formal meeting begins? Should we not all be benefited by informal discussions and come into our meetings better prepared for the formal ones? I suggest this subject as one worthy of your consideration.

The records of the last meeting were then read and approved.

The President announced the death of Dr. Kneeland as follows:

Since my recent return I have heard with sorrow of the death of Dr. Samuel Kneeland, which took place in Hamburg, on Sept. 27th. I have not had time to make any inquiries about the life of Dr. Kneeland and I am not prepared to make the extended remarks which are due to the memory of one who was for forty-two years a member of the Society, but I cannot let this occasion pass without an acknowledgment of our indebtedness to Dr. Kneeland.

In 1847 the great Agassiz had inspired with a new life the naturalists of this vicinity by the completion of his first course of lectures at the Lowell Institute, and the members of this Society were aroused to grander work than ever before by his enthusiasm and wonderful knowledge. At this time Dr. Warren was elected President of this Society to succeed Dr. Binney, recently deceased, and Dr. Kneeland was made Cabinet-keeper, which office he held for two years. In 1848 the Society purchased the building of the old Medical College, on Mason street, which was modified and duly adapted to its new uses. As cabinet-keeper a large share of the work and responsibility of moving the collections and books to their new home must have fallen upon Dr. Kneeland, who thus entered upon his duties at a time of remarkable activity in the Society.

From 1849 to 1854 he was the curator of comparative anatomy, and in 1856, and again in 1858 and 1859, he was elected curator of the department of fishes, in which office it was my honor to follow him, he having been elected recording secretary in May, 1858, which office he held until 1862, when he resigned to become the third of the noted ninety-eight members of the Society who are recorded by Mr. Bouvé as taking honorable part in the war of the rebellion.

Dr. Kneeland entered the service of his country as Surgeon of the forty-fifth Mass. Infantry and attained the rank of Brevet Lieut. Colonel. Before 1862, however, the rooms in the building on Mason street had become inadequate to the wants of the Society and the building was sold and the collections and books removed to the house in Bulfinch street which Dr. Walker had given to us. In this work Dr. Kneeland took a laborious part, and he occupied the house with his family as custodian of the property of the Society. During this time active work was going on in relation to a new building; plans were discussed and appeals made to the state for a grant of land. As the results of this labor we have our present building and for this we are in part indebted to Dr. Kneeland, who as secretary at the beginning of the work certainly did his portion.

After the war Dr. Kneeland again took an active interest in the Society, and until 1878 was a member of the Council. In 1869 he was one of the small committee to arrange for the celebration of the centennial anniversary of the birth of Humboldt. This celebration was most creditable, and we all know of Agassiz's address on that occasion, when Music Hall was filled; and of the reception in Horticultural Hall and the banquet tendered by the city which followed. To Dr. Kneeland belongs a full share of the labor and success of the remarkable celebration.

Under the arrangement made between the Society and the Institute of Technology, in 1870, Dr. Kneeland delivered a series of lectures upon Zoology in this lecture room, he being at that time an officer in the Institute. As professor of Zoology, and one of its secretaries he was connected with the Institute of Technology for ten years, from 1866–1876.

The records show that Dr. Kneeland was a generous contributor to our museum and library: that he often took part in our meetings, and presented numerous papers, is evident from our printed proceedings. We also know that he was an easy and prolific writer, and did much in presenting scientific matters in a popular form by articles in magazines and encyclopedias and in several interesting volumes. He was, also, an agreeable lecturer at a time when zoological lectures were less burdened with the minutiæ of anatomy and with technicalities than is now generally the case. His lectures in the Lowell Institute I have heard most favorably commented upon as clear and instructive.

Dr. Kneeland was by nature a traveller, and as he used his eyes in his wanderings and knew what was worth collecting in his special lines of research he always returned from his long journeys to the islands of the Pacific, to the shores of Asia, to Iceland, or to various portions of Europe, well supplied with facts which he had observed and specimens which he had obtained. With the latter he was generous, and he gave to us and to others many a pleasant and instructive account of his travels. He made several journeys with particular reference to a study of active volcanoes, but of late years his attention was turned principally to ethnological research. In this department he made many observations of interest and collected objects of great importance and ethnological value, many of which he gave to the Museum under my charge in Cambridge. Particularly should I mention in this connection the large lot of human crania which he collected on the Island of Maui; the collection illustrative of the natives of the Philippines, and the collection of bronze ornaments worn by the Santhals, all of which he exhibited and talked about at our meetings. Among the last communications he made to the Society was one upon the famous "skeleton in armor" found near Fall River, at which time he exhibited some of the supposed armor which had been given to him by the authorities of the Museum at Copenhagen, and which he in turn presented to the Peabody Museum.

From letters which I received before he left us for his last trip, I know that he intended to carry on his ethnological researches, and we must all regret that they have been brought to so sudden a termination by his untimely death in a foreign land, while we must also mourn the loss of one who for so many years was so intimately connected with our Society and did so much to advance its interests.

Dr. Fewkes said:

I wish to add a few words to the remarks which have already been made. Twenty years ago Dr. Kneeland gave a course of Lowell Institute lectures which it was my good fortune to attend.

I well remember the enthusiastic and comprehensive way in which they were given. The course reviewed the animal world from the lowest to the highest forms of life and was of great interest, since Dr. Kneeland drew from a fund of information derived not only from the study of specimens in museums, but also from observations in the field, from travels and personal contact with nature.

To these lectures I abscribe early influences which in part turned my thoughts to natural history studies, and did much to keep alive and increase an interest in studies of nature. I am glad to express my obligation publicly to Dr. Kneeland, whom, however, I regret to say I never personally knew.

As Secretary, I will state that there is hardly a volume of the Proceedings of the Society since 1850 which does not contain notices of papers read at its meetings by Dr. Kneeland. These papers treat of a great variety of subjects and were always fresh and interesting. On every return from his distant travels the best fruits of his trip were always given to the Society in the form of communications at its meetings.

Dr. Kneeland was at one time very active in the Society. He was an officer during some of the most important steps of growth which it has taken. He was a hard worker in the Society at many critical times. Of late years, although not an officer, his interest has continued unabated. We are indebted to him for several important additions to our museum and to our library. He has given us many pamphlets and bound volumes, not the least important of which are his own publications. His interest in the Society continued until his death, and one of his last gifts to our collection of books reached us in May of the present year, only four months before his death.

The Secretary then offered the following resolution :—

Whereas, that in the death of Dr. Samuel Kneeland the Society has lost a member, who was for many years a most efficient and active officer and a most devoted friend,

Resolved, that the Society, recalling Dr. Kneeland's many interesting and valuable communications read at its meetings, his donations to the Library and to the Museum, desires to place on record its appreciation of his many and varied services in its interests.

Professor Hyatt seconded the resolution and spoke of the many valuable services of Dr. Kneeland to the Society and of his gifts to its collections.

The resolution was unanimously adopted.

Prof. H. W. Conn then read a paper on "Coleopterous Larvæ and their Relations to Adults."

COLEOPTEROUS LARVÆ AND THEIR RELATIONS TO ADULTS.

By H. W. Conn.

[ABSTRACT.]

The present paper is the first of a series of investigations which it is my purpose to carry on in connection with larvæ and their relations to adults. My studies are confined to the post ovarian stages and in this discussion the term larva is used to indicate such conditions only. It is my purpose to inquire into the origin of larval forms, both ancestral and acquired, and to compare the results of the study of the larvæ of the various groups of the animal kingdom with the results of the study of adults. The following questions are among those for which an answer is sought.

To what extent are larval forms representatives of ancestral stages in the history of animals and to what extent are they adaptations on the part of the larvæ, and therefore secondary?

How far is it possible to assign reasons for the larval departures from ancestral type?

Has the larval departure from an ancestral type, where it has taken place, occurred in numerous individuals simultaneously, or have the variations appeared in one individual and then been transmitted from it to a long line of posterity?

Have the form and habits of the adult any direct influence on the larvæ, or those of the larvæ on the adult?

Are larvæ reliable as a basis of classification?

Are larvæ of any value in teaching the past history of animals?

Are larvæ of any value in teaching relations?

In cases where larvæ are departures from the ancestral type and therefore secondary, are they of any value in teaching past history or present classification?

Are larvæ more or less variable than adults?

Are adaptive larval characters inherited by succeeding larvæ?

The present paper is the result of the study of the larvæ of beetles, this group being first selected as showing the greatest amount of variation within a single order. As a starting point a Campodeoid form is taken. This is the most widely distributed and has frequently been pointed out as the closest representative of the ancestral insect living at the present day. Starting with the Campodeoid type the different families of beetles have been studied as far as is possible with our present knowledge of them. The following are the most important points presented by the study of this group.

1. With the exception of the Campodeoid type of larvæ, which is found in a number of families, all beetle larvæ are secondary modifications which have been introduced during the larval life of the beetles, and have never been represented by any adult features. They are therefore of no value in teaching the history of beetles except in their larval stages. They do not represent ancestral stages. They may, however, and frequently do, teach relationship, since the presence of a similar larva may indicate a recent common ancestor.

2. It is possible, amid the immense variety of larvæ, to recognize four somewhat distinct types: the Campodeoid type, a type slightly and variously modified from the Campodeoid type, a Scarabid type and a maggot-like type like that of the weevils. In many cases it is possible to determine definitely the sort of conditions that have produced the present type.

3. The division of larvæ into types seems to have no relation to the classification of adult insects into sub-orders. None of the classifications of adult beetles into sub-orders runs in any way parallel to the natural division of larvæ into groups. The classification of the families of larvæ does, however, run parallel to the classification of the families of adults, so that it is usually possible to tell from the structure of a larva to what family it belongs. To this rule there are many exceptions, some of which are easily explained by differences in habit. The exceptions are most common in the low degraded types of larvæ. The classification of families into sub-families and genera seems also as a rule to run parallel with the classification of adults, though there are many exceptions to this rule. The exceptions are such as to indicate that in some cases the adult classifications are at fault, and in other cases that there is really no parallel between the two stages. From this we can draw the conclusion that the present larval types of beetles are about as old as families but not much older.

4. The amount of departure from the primitive larval type that any family of beetles presents, is no indication of the position in the scale of classification that the adults should occupy. At least this is true if we accept the classification of adults recognized at present by our entomologists.

5. Family characteristics are usually well marked in the larvæ. Generic characteristics are also usually quite definite ; specific differences are usually very small and do not seem to be very constant.

6. There is in most cases an evident relation between the habits of the larvæ of a family and those of the adults. This indicates that the habits acquired by one stage have subsequently had their effect on the habits of the other stage. It seems probable that in beetles the larva has been the first to modify its habits and that the adult has subsequently acquired habits related to it. The larval stage seems thus to be more important than the adult ; at all events it is more thoroughly protected and is the first to be adapted to suit its surroundings.

7. The larvæ of beetles are much more diversified than their adults.

8. Although habits and the conditions that surround the larvæ have been very important features in the production of the present larval forms, some other force has been at work in producing or rather in retaining them. For we find a great variety of larvæ at the present time with almost identical habits. This other force is undoubtedly heredity, which has frequently proved stronger than the modifying effect of the environment.

9. Beetle larvæ cannot be classified by the same characteristics used in classifying adults. The shape of the antennæ has no significance in the classification of larvæ since it is almost uniform throughout the order. The shape of the legs, the number of tarsi, the shape of the coxal cavities, are of not much more value. The mouth parts seem to be of a little more value, and are of far less value in classification than they are in the adults.

10. The mouth parts of beetle larvæ, even in the typical Campodeoid form, are not Campodeoid in type, but approximate rather closely to those of the adult beetles. No traceable similarity can be found between the mouth parts of any particular family of larvæ and those of the adults of the same family, beyond the general similarity sometimes produced by like habits. It is true, however,

that the mouth parts of all beetle larvæ are more like those of adult beetles than they are like those of any other order of insects. This is probably an example of what Hyatt and Cope call concentration of development, and which is elsewhere called precocious inheritance. It is an instance where the characters of the adult have been impressed on the larval stages.

11. In beetle larvæ we have quite a number of cases in which a similar larval type has been acquired independently in two or more families.

The above conclusions apply only to the group of Coleoptera, and while some of them will doubtless be found equally true of other orders of insects, some of them are probably peculiar to beetles.

This paper was discussed by Professors Hyatt, Putnam and Fernald, and by Messrs. Sargent and Jackson.

Dr. Fewkes called the attention of the Society to models of animals which were made by Mr. S. F. Denton. These models are made of an elastic material and in many respects were much superior to any which he had yet seen. He congratulated Mr. Denton on his success in the preparation of these models.

The several models were passed about the hall and Mr. Denton replied to questions by Prof. Hyatt, Mr. Emerton and others.

Professor Putnam exhibited Gordian-like worms found four feet below the surface, near the "Serpent Mound."

Dr. Fewkes exhibited a specimen of Hexactinellid Sponge allied to *Rosella antarctica*, found in shallow water near Monterey, California. He said that Rosella is ordinarily considered a deep-sea sponge and its discovery in shallow water was an interesting fact. This, he said, is the first record of it from Californian waters.

The following papers were presented by title:

AN INTERESTING PALEOZOIC COCKROACH FAUNA AT RICHMOND, OHIO.

BY SAMUEL H. SCUDDER.

SINCE the publication of my paper on paleozoic cockroaches (Mem. Bost. Soc. Nat. Hist., III, 23–134), a considerable number of new forms have been found and referred to me for study by different parties in different parts of the country. Most of them have come in a scattered way, but in two instances very considerable collections have been made at special localities, one by Mr. R. D. Lacoe (to whom science is so deeply indebted for his persevering efforts in the field) at a locality in West Virginia, and a second at Richmond, Ohio, where the barren coal measures have been worked by Mr. Sam. Huston in a very successful way. The two deposits have much in common, in that they evidently carry a later fauna than those which in this country have previously yielded blattarian remains. Not a single species of Mylacridæ has been found in either of them. Not having at present sufficient time at my disposal to work up the entire collection, I have thought it worth while to bring together here descriptions of the earliest species which were found at Richmond, of all of which drawings have been made, previously to the publication of a more extended illustrated paper in which they will all be discussed in full.

The subjoined species all belong to the genus Etoblattina, and they are very similar to each other, but differ considerably from other species of the genus found heretofore in this country. Several of them are banded along the line of the nervures like the species described by me under the name *Gerablattina balteata* of the permocarboniferous of West Virginia. Etoblattina, though the most abundant in specific forms in Europe, has been known in this country by only three published species, though a fourth has long been known to me, and the species mentioned above, *balteata*, is to be looked upon also as an Etoblattina. These Richmond species, however, seem to form a section apart, characterized by the great length and slenderness of the internomedian area and by the frequent straightness of the internomedian vein; and they are no nearer the other American (excepting *Etoblattina balteata*) than they are to European species. Apparently they represent a rather younger fauna than our hitherto described American Etoblattinæ.

Etoblattina tenuis, nov. sp.

A single well preserved wing, complete except at the base; it is long and slender, tapering uniformly on both sides to the slightly produced but rounded tip, both borders being very gently arcuate, the surface uniformly and distinctly reticulate throughout. The mediastinal vein is preserved only apically, but it appears to terminate at the middle of the front margin, to be more than half as far from the border as the scapular and to have a few simple branches as distant as those of the scapular. The scapular and externomedian veins run down the middle of the wing in a nearly straight course with oppositely diverging branches, to beyond the middle of the wing, when the scapular curves upward, terminating above the tip of the wing; it emits several branches, the basal ones of which are compound, the middle ones forked and the apical simple. The externomedian vein forks once near the middle of the wing, each of the forks being compound, the branches curved slightly downward apically and occupying but little more than the tip of the wing; for the internomedian vein reaches far out toward the tip, its branches longitudinally oblique, the proximal ones simple, arcuate, their convexity toward the base, the distal ones forked, sinuate. The anal furrow is scarcely impressed, very little arcuate, reaching out over a little more than the basal third of the wing.

The wing was apparently nearly three times as long as broad; its length having been probably 24 mm. (though the fragment is only 21 mm.) and its breadth is 8.5 mm. It was discovered by Mr. Sam. Huston in the barren coal measures of Richmond, Jefferson Co., Ohio.

Etoblattina fasciata, nov. sp.

A single and rather fragmentary wing has some characteristics which are so clearly different from the others that it may be described, though imperfectly, as distinct. It shows the greater part of the apical half of the wing, in such a way that the main veins can be clearly separated. The mediastinal vein terminates at a point which is evidently more than half-way and probably two-thirds way down the wing, enclosing a rather narrow area and emitting simple, straight, moderately distant, oblique branches. The scapular is peculiar, being very straight and apparently terminating above the tip of the wing; it emits its first branch only a little before the end of the mediastinal at what must be about the middle of the wing; this branch runs parallel to the mediastinal vein and forks just before the tip of the same; the second branch arises very shortly after the first, runs parallel to the main vein and emits several very oblique straight branches (their tips are lost) running parallel to the mediastinal branches; on account of the closeness of this second branch to the main vein, the third branch only arises a long distance out. The externomedian vein branches opposite the termination of the mediastinal, and the forks or at any rate the lower again divide some distance beyond. The internomedian vein in the portion seen, which includes neither the basal half nor the extreme apex, is gently and regularly arcuate, its concavity towards the costal border, but also gently declivent, and probably terminates only a little below the tip of the wing; its branches are mostly simple (the apical ones apically forked), tolerably numerous, all but the apical ones arcuate with their concavity outward and upward.

Broad bands of black follow the principal veins, in the scapular and externomedian veins of greatest breadth, enveloping the branches as well, until they part widely from the parent stem; in the mediastinal and internomedian veins narrow, but compensated for by broad belts which border the costal and inner margins and envelop at least one-half the length of the branches of these veins.

This species most nearly resembles in neuration *E. tenuis*, but differs from it in the greater stoutness of the wing, the fasciated veins and the structure of the scapular vein.

Length of fragment 14 mm.; probable length of wing 27–28 mm.; breadth of wing 10 mm.

Barren coal measures, Richmond, Jefferson Co., Ohio. S. Huston.

Another specimen, apparently belonging to this species, comes from a different horizon. It shows only the tip of a wing (apparently smaller than the other), but agreeing essentially in neuration and having the same bands accompanying the main nervures and bordering the wing, it may be regarded the same. If so, it would show that the main scapular vein curved downward apically, as one would expect it to do, and terminated some distance before the tip. The externomedian vein, however, seems to fork a little later than in the other wing and with its veins to occupy the whole breadth of the tip of the wing.

Length of fragment 9 mm.; width 6 mm.

Cassville, W. Va., from the Waynesburgh coal seam, looked upon as permocarboniferous. R. D. Lacoe, No. 2066.

This is the second cockroach found common to the upper carboniferous and permocarboniferous, the other being another closely related, formerly described as *Gerablattina balteata*, but which should be referred to Etoblattina, as stated.

Etoblattina marginata, nov. sp.

Although only a fragment of this wing is preserved, it is so characteristic and contains so much of the most important parts of the wing that it may be described. It is not so slender as *E. tenuis* and tapers more rapidly, but still equally beyond the middle, the tip being more produced but still rounded. The mediastinal area is much more important than in that species, the principal vein being farther removed from the costal margin and extending probably to the end of the middle third of the wing, its branches distant, simple, arcuate, with the convexity inward. The scapular vein is almost exactly straight to beyond the tip of the mediastinal and then curves gently upward to the margin, terminating only a little before the tip and having about five equidistant, mostly simple branches, the first one not originating far before the middle of the wing. The externomedian vein is peculiar; it first forks opposite the basal fork of the scapular vein, the upper gently sinuous fork only branching near the tip; the lower, curving rather conspicuously downward, emits close together several long, mostly simple, arcuate branches. At about the middle of the wing, the internomedian vein changes a declivent for a longitudinal course, thus more than halving the width of the interspace above it when it approaches the downward curve of the externomedian vein, and making a half-closed cell of this interspace, resembling somewhat a similar feature in Spiloblattina of the Coloradan Trias; by this means it reaches far out toward the tip of the wing and its branches, which before had been rather distant transversely oblique, and strongly arcuate with the convexity inward, become less arcuate, and nearly longitudinal. The anal area is not preserved.

A feature of the wing which it shares in some degree with other species from the same locality, but which is absolutely wanting in *E. tenuis*, is a broad piceous banding of the principal veins and branches. This does not, however, follow the veins implicitly, but is based upon the neuration. It forms a black belt following the entire course of the internomedian vein and edging the lower margin of the wing; another broader belt follows the externomedian as far as the second branch; here it divides into two, one merging into the internomedian belt, the other into a still broader one which has embraced both the scapular and mediastinal stems. Or, the wing might be described as piceous with pale gray streaks, one short one in each interspace between the internomedian nervules, one in the main externomedio-internomedian interspace, one in the scapular-externomedian interspace (each of the last two terminating with the narrowing of the interspace), one running obliquely across the externomedian branches almost in continuation of the one last mentioned, one across the base of the apical scapular branches and one across the base of the mediastinal branches.

The fragment is 17 mm. long; its probable complete length may have been 22 mm.; it is 8.5 mm. broad.

Barren coal measures of Richmond, Jefferson Co., Ohio; discovered by Sam. Huston.

Etoblattina stipata, nov. sp.

A nearly complete wing, with the apex broken and the anal area within the furrow missing, but all the important neuration preserved, and enough to determine pretty clearly the entire form of the wing. Like nearly all the others from this locality it is of a slender form, the probable proportion of breadth to length being nearly three to one.

The costal margin is scarcely convex, and the whole wing must have been nearly equal with a rather broadly rounded tip. The mediastinal forms a band of nearly equal width throughout, and extends to a little past the middle of the wing with rather numerous and close straight and oblique branches. The main scapular vein is rather strongly and very regularly sinuous, terminating a little above the tip; some distance before the middle, as it begins to curve downward, it emits close together a couple of forked branches, at the middle a single compound branch and some distance beyond the middle four or five simple equidistant branches, all of which curve gently upward. The externomedian is less sinuous than the preceding, terminating at about an equal distance from the tip which it covers with its six or seven inequidistant, longitudinal, nearly straight branches which only fork, if at all, near the apex, and the earliest of which arises scarcely before the middle of the wing. The internomedian vein is nearly straight, gently oblique, and emits seven or eight subequidistant, mostly simple, gently curved branches, whose wide distance apart is in somewhat striking contrast to the crowding of the veins in the scapular and externomedian areas. The anal furrow is strongly arcuate, faintly impressed and terminates probably at about the end of the basal third of the wing. The wing is covered in places and probably was throughout with fine interlacing cross lines, making a delicate but indistinct and imperfect reticulation.

Length of fragment 22 mm.; probable length of wing 27 mm.; its breadth 9.25 mm.

Barren coal measures, Wills Creek, Richmond, Jefferson Co., Ohio. Sam. Huston.

Etoblattina variegata, nov. sp.

Although both base and apex of both specimens referred here are lost, the most complete one has so much preserved that we can determine almost all the essential features of the neuration and restore with much probability the form or at least the proportions of the wing, which could not have been much less than three times as long as broad, and was remarkable for the extraordinary straightness of the main veins. The mediastinal vein terminates scarcely beyond the middle of the wing and has numerous straight, gently oblique, simple branches. The scapular runs in a nearly direct course to a point scarcely above the apex of the wing, but curves upward slightly toward the tip, begins to branch before the middle of the basal half and emits half a dozen long, longitudinally oblique, gently curved branches most of which fork midway to the margin. The externomedian runs in an even straighter course toward the lower portion of the apex and throws off beyond the middle only a few nearly longitudinal and straight, and so far as can be seen, simple branches to the apex. The internomedian vein runs in a perfectly straight course parallel to and rather distant from the externomedian and emits distant, nearly straight, mostly simple, oblique branches to the border. The whole wing is piceous, but there are streaks of light brown which enliven the wing, falling in the interspaces between the principal veins and between the internomedian interspaces, *i. e.*, in all the widest intervals. No anal area is preserved but it must be unusually short, or the wing even longer than has been estimated.

The second fragment contains scarcely more than most of the internomedian area and does not differ from the larger fragment except that it is proportionally larger.

A third specimen from the same place and person showing only a bit of the front central portion of the wing apparently belongs here; and, if so, indicates that the branching of the scapular may commence later and the mediastinal area preserve a greater breadth near to its termination.

Length of largest fragment 18.5 mm.; probable length of wing 26 mm.; its breadth 9 mm.; length of second fragment 18 mm.; indicating a wing about 30 mm. in length.

Barren coal measures, Richmond, Jefferson Co., Ohio (Wills Creek). Sam. Huston, collector.

Etoblattina strigosa, nov. sp.

A single specimen represents this species, the form of which was probably as slender as the others, but the tip and lower outer portion is lost, which is the more unfortunate that they appear to have been peculiar. The costal margin is as convex as in *E. hustoni*, but the wing, to judge by the neuration, was much slenderer than in that species. Presuming it to have been about three times as long as broad, the mediastinal area must have extended over nearly two-thirds of the wing, as a tolerably narrow belt with numerous straight and oblique veins. The scapular vein must have terminated just above the apex of the wing, and commencing to branch near the middle of the basal half of the wing emitted numerous rather crowded, long and very longitudinal, generally forking branches to the margin. The externomedian vein, so far as it can be traced on the fragment, which must include more than two-thirds its course, is an undivided vein, so that it must in any case be insignificant; while on the other hand the internomedian vein plays a very important part. Shortly after it parts from the immediate proximity of the anal furrow it sends out an inferior branch, which runs in a nearly straight course parallel to the main stem and to the externomedian vein, and terminates at some considerable distance beyond the mediastinal vein; from it, and not from the main vein, arise the usual oblique offshoots, which are few in number, distant, nearly straight and oblique; the main vein again forks at about opposite the tip of the mediastinal, but, by emitting a superior vein which parts rather widely from the parent stem, evidently continues the course of the internomedian vein to an unusual distance toward the apex; but here the wing is unfortunately broken. The anal furrow is very strongly arcuate, not deeply impressed, and terminates before the end of the basal third of the wing; the area is filled with subparallel, mostly simple veins, near the furrow parallel to it, farther from it less so, until they are somewhat crowded and nearly straight next the lower inner angle.

Length of fragment 23 mm.; breadth of same 10 mm.; probable length of wing 30–33 mm.; probable breadth 11 mm.

Barren coal measures between coal 7 and 8, Wills Creek, Richmond, Jefferson Co., Ohio. Collected Sept., 1884, by Henry Crewthen of Johns Hopkins University, to whom I am indebted for the opportunity of studying it.

Etoblattina hustoni, nov. sp.

This species is represented by a single wing, rather more obscure than the others described here but differing conspicuously from them. It is the least slender wing of all, having certainly been not more than two and one-half times longer than broad. The costal margin is noticeably convex and the inner margin probably nearly straight. The mediastinal area narrows slightly beyond the middle, extends nearly to the end of the middle third of the wing and has many simple, straight, rather strongly oblique veins. The scapular vein is peculiar in that it is divided before the middle into two compound branches which do not act similarly, the upper being sinuous and supporting oblique, mostly simple branches, somewhat resembling the mediastinal, the lower straight with longitudinally dichotomizing forks like the externomedian branches; the lower must terminate scarcely above the tip of the wing, approaching it more closely than is usual in Etoblattina. The externomedian vein is again peculiar, for it divides in the middle of the basal half of the wing into two main branches which do not again fork until beyond the middle of the wing and then with few longitudinal branches. The internomedian is very narrow and straight throughout, leaving the centre of the wing with very wide interspaces notwithstanding the early division of the externomedian vein; the internomedian vein appears to terminate far out toward the tip; its branches are frequent, simple, oblique, gently curved, with the convexity toward the base; anal area unknown.

Length of fragment 19 mm.; probable length of wing 25 mm.; its breadth 10.5 mm.

Barren coal measures of Will's creek, Richmond, Jefferson Co., Ohio. Collected by Sam. Huston.

CANADIAN GEOLOGICAL CLASSIFICATION FOR THE PROVINCE OF QUEBEC.

BY JULES MARCOU.

Several late publications by Mr. Alfred R. C. Selwyn[1] and Sir J. William Dawson[2] call for an exposition of the classification and nomenclature used in that part of the Canada Dominion, which has been known successively under the names of "La Nouvelle France," Eastern and Lower Canada and Province of Quebec. We shall review only the different résumés published at intervals in connection with the issue of "Geological Maps" and "Palæozoic Fossils," by the Geological Survey.

LOGAN'S CLASSIFICATION OF 1855.

In August, 1855, Logan published, in Paris, his "Carte géologique du Canada," with an explanation entitled, "Esquisse géologique du Canada," written by Mr. T. Sterry Hunt.

The province of Quebec, with the exception of the vicinity of Montreal, and a narrow band extending north of the river St. Lawrence from Montreal to Quebec, both of which are referred to the Champlain system (Chazy, Trenton and Utica), is colored as belonging to the Hudson river group and the Oneida sandstone. The eastern limit of the province is covered by a large band of Niagara limestone extending from Gaspé to lake Memphremagog, and then crossing through the whole of New England. The original Taconic area from the boundary line of Canada to Poughkeepsie is colored as belonging entirely to the Hudson river group, with spots, now and then, of Trenton and Oneida.

In the text by Mr. Hunt, in all the "Bassin oriental"—east from an anticlinal axis (line), which divides the "terrain" Palæozoic of Canada—we have the lower part of the Hudson river group called

[1] "The Huronian of Canada," "The Taconic of Quebec" ('American Geologist,' Vol. II, pp. 61–62 and 134–135).

[2] "Some points in which American geological science is indebted to Canada," in a presidential address, read before the Royal Society of Canada, by Sir J. William Dawson, May 26, 1886, in 'Trans. Roy. Soc.,' Canada, Vol. IV, Section IV, p. 1, 4to, Montreal, 1887; and "On the Eozoic and Palæozoic rocks of the Atlantic coast of Canada in comparison with those of western Europe and of the interior of America," in 'Quart. Journ. Geol. Soc.,' London, Vol. XLIV, p. 797, May, 1888.

slates of Lorraine or Richelieu on which lay, in concordance of stratification, a series of strata forming the upper part of the Hudson river group, and which forms all the heights (*hauteurs*) of the city of Quebec and Pointe Lévis. Then above that series called "formation de Québec," we have another series of red and green slates with sandstone, called by Logan " groupe de Sillery" which he regards as the equivalent and the homataxis of the Oneida conglomerate of New York.

Mr. Hunt says that he found at Ouelle river, in the " Sillery formation", what he calls " fragments d'os !", while in the slates of Pointe Lévis he found " coprolites !"

Here is the classification of 1855, as recorded on the map :

FORMATIONS.	SYSTEMS.
Calcaire de Niagara.	Silurien superieur.
Grés d'Oneida, or Sillery formation.	Silurien inférieur.
Groupe de la Rivière Hudson, or Quebec formation.	
Schistes de Utica.	
Calcaire de Trenton.	
Calcaire de Black river.	
Calcaire de Birdseye.	
Calcaire de Chazy.	
Grés Calcifère.	
Grés de Potsdam.	
Huronian	Cambrien.

LOGAN'S CLASSIFICATION OF 1861 TO 1865.

The " Geology of Canada," a bulky volume in 8vo, appeared at intervals from 1861 to 1863 and 1865. In 1861, I received the first 400 pages ; then, in 1862, 400 more pages, bringing the volume to chapter XXII, called "Supplementary", and, finally, in August, 1863, the whole volume was distributed, with a notice that the atlas containing geological maps and sections would not be ready before the end of 1863. That atlas, however, was not issued until 1865 or 1866.

During the printing of the volume and the engraving and coloring of the reduced " Geological Map of British North America," the classification was changed on account of the publication in December, 1860, in the 'Proceedings of the Boston Soc. of Nat. Hist.,' Vol. VII, p. 369, of the joint paper of Barrande and Marcou, " On the Primordial Fauna and the Taconic System."

The printing had reached p. 224, when Barrande and Marcou's paper was issued. An alteration was an absolute necessity, and although the "Quebec group" was allowed to follow the "Utica and Hudson formation" and consequently above it, as it has always been placed by Logan, he explains the new position which he intends to give to that group in the following words: "although from their geographical position apparently superior to the Hudson river formation, these rocks belong in reality to an older group, which is developed to a great extent in eastern Canada, and presents somewhat different characters in the various parts of its distribution. The rocks of this series are still under examination, and the descriptions now given may hereafter require to be somewhat modified" (Geology of Canada, p. 225, 1863).

So in the volume, the Quebec group is placed above the Lorraine shales (Hudson river group) and directly below the Oneida and Medina sandstone (called Anticosti group by Logan). In the introduction on p. 20 (which has been reprinted with alterations), the Quebec group in the geological nomenclature, is placed between the Potsdam and the Birdseye formation, as the equivalent of the Calciferous and Chazy, a transfer passing over the whole Champlain system, forced upon the geological survey of Canada by the publication of J. Barrande and J. Marcou's paper. Here is the classification of the Geology of Canada in 1863.

FORMATIONS.		SYSTEMS.
Guelph formation		Middle Silurian.
Niagara "	Anticosti group.	
Clinton "		
Medina "		
Hudson river formation		Lower Silurian.
Utica "		
Trenton "		
Birdseye and Black river formation		
Chazy=Sillery? "	Quebec group.	
Calciferous=Lévis "		
Potsdam group:		
Huronian series		Azoic.

On the "geological map of Canada, 1864, atlas," we have the Quebec group as the equivalent of the Calciferous and Chazy, marked by the same colors, only the number 5 used for the Calciferous is replaced in some cases by 5*a*. The Chazy is colored yellow with the number 6, is indicated everywhere without double meaning, and the map is absolutely confusing in regard to what Logan intends by Quebec group, 5*a*, Calciferous 5, and Chazy 6, or his idea whether the Quebec group is equivalent to the Calciferous and Chazy.

All the province of Quebec south of the St. Lawrence river is colored on the map: first, as Hudson river, a large band extending from Missisquoi Bay (Lake Champlain) to Quebec city with three large patches of Oneida and Medina (Middle Silurian); second, we have a large band, occupying all the county from St. Armand to Lake Memphremagog, and extending from New York city and Albany to Gaspé, the so-called Quebec group; and third, the eastern townships are entirely covered by a broad belt of Upper Silurian, called Oneida, Medina, Clinton, Niagara and Lower Helderberg, with a few spots of Devonian. Logan extends the Upper Silurian through Vermont, New Hampshire and Massachusetts.

The original area of the Taconic system, colored on the geological map of 1844, by Dr. Emmons, is referred by Logan to his Quebec group (Calciferous and Chazy) and to the Upper Silurian (Oneida, Niagara and Lower Helderberg).

The large map of 1866, scale twenty-five miles to one inch, called a *chef d'œuvre* by Mr. Charles H. Hitchcock, contains the same classification, nomenclature and colors as the reduced map of 1864. In both, the Potsdam is still the lowest and oldest group of fossiliferous strata, lying directly above the so-called Huronian or Primitive rocks; both ignore completely the Taconic series with their three faunas, Infraprimordial, Primordial and Supraprimordial and their enormous thickness of 25,000 feet.

BILLINGS' CLASSIFICATION OF 1865.

In 1865, Billings published a palæontological classification of the Province of Quebec on p. 64 of the first volume of his "Palæozoic fossils." The object was to show the generic relations of the trilobitic fauna.

$$\left.\begin{array}{ll}\text{Trenton} & \text{fauna.}\\ \text{Chazy} & \text{"}\\ \text{Lévis} & \text{"}\\ \text{Calciferous} & \text{"}\\ \text{Potsdam} & \text{"}\end{array}\right\}\text{Lower Silurian.}$$

Although a strong partisan of the Taconic system and an admirer of Dr. Emmons' discoveries, Billings was not allowed to use the name Taconic by his superior and not knowing exactly what to do, he extended considerably and out of all safe proportions the Potsdam formation, placing in it two-thirds of the Taconic system. As regards the Upper Taconic or Supraprimordial fauna, Billings was constantly in error. However, he goes so far as to admit that the "physical evidence" is against his classification at least for the Calciferous and Lévis, and he records the important fact that "the localities in Canada where organic remains abound (in the Lévis formation), are of limited extent, and widely separated from each other, although they occur in the same line of outcrops;" admitting the sporadic character of that fauna and its special apparition so different from any fauna yet known in the world, except the colonies described by Barrande in Bohemia.

Billings in all his palæontological works has too often referred groups of strata to the Potsdam, Calciferous, Chazy and Trenton, on very slight indications of similarity of fossil forms, and he had included under those names all the Georgia group, the Phillipsburgh and Lévis group, and the Swanton and Citadel Hill of Quebec, which are six and seven thousand feet thick, with all their colonies and centre of apparitions of the second fauna forms which is so characteristic of the upper part of the Taconic system in Canada and the United States.

BILLINGS' CLASSIFICATION OF 1866.

In November, 1866, Billings gave another palæontological classification on p. 81 of his "Catalogues of the Silurian Fossils of the Island of Anticosti."

	FORMATIONS.	SYSTEM.
	Chazy.	
Break	———	
	Sillery.	
	Lauzon (in writing on my copy).	
	Lévis.	
Break	———	Lower Silurian.
	Upper Calciferous (Newfoundland).	
	Lower Calciferous (Philipsburgh).	
	Upper Potsdam (Wisconsin).	
	Lower Potsdam (Georgia, Vt.).	
	St. John Group (New Brunswick.)	

Billings makes a great break between the Lévis and Calciferous below, and another great break between the Lévis and the Chazy above, dividing what he calls "the Lower Silurian in America" into two principal groups, "one above the break at the base of the Chazy and the other below. The former includes the Chazy, Black river, Birdseye, Trenton, Utica and Hudson formations. The lower comprises a series of formations, which are only now beginning to become known."

To be consistent with his own views of great breaks, Billings ought to have made *three* "principal groups" instead of *two* in order to use his great break between the Lévis and Calciferous. But he was quite at a loss, in trying to harmonize what he thought was the succession of fauna with the stratigraphy used by the Director of the Canada survey, without paying any attention whatever to colonies and apparitions of prophetic types. Billings was not a sufficiently able practical geologist; and the true relations of the great mass of strata in the province of Quebec escaped him entirely. With such confused stratigraphical notions, it was materially impossible for him to make any reliable and good comparisons of the formations in Canada with those of England, and finally he gives up the attempt to correlate the English series with the Canadian, except that in a general way they may be compared without a perfect parallelism of the minor groups.

LOGAN'S CLASSIFICATION OF 1866.

In 1866, Logan "found it convenient to divide his Quebec group into a lower, a middle and an upper part" ("Report of Progress" from 1863 to 1866, p. 4, Ottawa). The lowest division is his "Lévis formation" comprising the "Phillipsburgh limestone," and is the "equivalent to a position about the summit of the Calciferous formation." The middle division is called the "Lauzon division." According to Logan this is a local deposit, and not "met with much westward beyond Point Lévis." The upper division is called "Sillery." Consequently we have the following table:

Quebec group	Sillery division.
	Lauzon "
	Lévis or Phillipsburgh division.
Upper Calciferous.	
Lower Calciferous.	

It differs from Billings' classification, in regarding the Lévis as the equivalent of the Phillipsburgh group, which Billings places as Lower Calciferous. At that time Logan regarded the Quebec group as simply the homotaxis of the Chazy Limestone.

LOGAN'S CLASSIFICATION OF 1870.

In the following "Report of Progress from 1866 to 1869" published in 1870, we have a remarkably detailed geological "map showing the distribution of the Lower Silurian rocks between the Chaudière and Trois pistoles rivers, on the south side of the river St. Lawrence, province of Quebec," by James Richardson. The celebrated Pointe Lévis and all the country between the Chaudière, the state of Maine, Madawasca and Trois pistoles are represented.

The classification used is:

Sillery division Lauzon " Levis "	Quebec group.
Upper division Middle " Lower "	Potsdam group.

This geological map, so far as classification is concerned, is the most extraordinary imaginative map, on a tolerably large scale, ever published. The geographical distribution is made wholly without stratigraphic, paleontologic or lithologic facts to sustain it; it is all imagination. If published fifty years ago, this map, would have been hardly acceptable. It is on a par with the "Geological map of the vicinity of Quebec" by J. J. Bigsby ('Quart. Journ. Geol. Soc., Vol. IX, Pl. VI, p. 82, London, 1853'). However, Richardson is less responsible for it, than Logan, who made the classification and directed the whole work.

Richardson says in speaking of some fossiliferous rocks of Bic harbor and other places: " these rocks have heretofore been classed with those of the Quebec group, but they appear to underlie them unconformably, and being in some places marked by fossils which Mr. Billings considers to be of Potsdam age, they are now placed in the upper part of the Potsdam group. (Report of Mr. James Richardson, p. 120)." This new classification shows first that the original Quebec group of Logan, included the Georgia slates formation, for in these rocks at St. Denis, and Bic harbor, we have the fauna of the Georgia slates, viz.: *Olenellus Thompsoni*, *Conocoryphe*, etc.; and also at the same time we see that Billings has changed the stratigraphic position of the Georgia formation from the *lower* part of the Potsdam group, as he had it in 1886, to the *upper* part of the Potsdam — a strange error for a palæontologist.

The Quebec group is placed above the Potsdam, which is not really the Potsdam, but the Georgia formation, being far below the true Potsdam of New York and the vicinity of Montreal.

These divisions and denominations are artificial in the extreme and the classification is entirely imaginative. The Potsdam does not exist anywhere in the whole province of Quebec, except near Montreal and perhaps at St. Armand. But we have the Georgia formation, well developed from Bic harbor, St. Denis, St. Rock, St. Jean, St. Pierre to Livaudière and the road from Pointe Lévis to Arlaka which is there in its right and proper place; below we have the St. Albans group of strata containing diorite dikes in the area of the Chaudière and Etchemin rivers; and above, the Georgia is succeeded by the Pointe Lévis and the Philipsburgh group, forming the whole of Pointe Lévis and the greatest part of the island of Orleans.

As to the Citadel hill and city of Quebec group, we have also to cross the St. Lawrence to find it in its proper place; but that division has nothing to do with the Sillery division of the south side of the St. Lawrence, as it is recorded in Richardson's geological map.

It is possible that the dioritic-diabase eruption existed as well during the Georgia formation deposit as during the St. Albans group; and if so that is why we do not find any fossils in the area of the Chaudière and Etchemin rivers, the arrival of such material from the interior of the earth's crust having prevented the existence of marine animals in that region.

SELWYN'S CLASSIFICATION OF 1879.

Mr. Selwyn having succeeded Logan as Director of the Canada geological survey, has proposed some alterations and changes in the stratigraphy of the province of Quebec. It was during the years of 1876, '77 and '78, that Mr. Selwyn made explorations on the southern side of the St. Lawrence river, and in 1879 he published his " Report of observations on the stratigraphy of the Quebec group, etc." In it, he refers all the slates, or shales, dolomitic limestone, sandstone and quartzites extending from Vermont to Gaspé, a distance of 500 miles, and on an average of twenty-five miles broad, to the Lower Silurian (Champlain system) because "these strata hold a large number of genera and species of characteristic Lower Silurian fossils" (no name or list of fossils of any kind given). That classification is made on what Mr. Selwyn calls "purely stratigraphical considerations," for he deprecates "palæontological stratigraphy." Notwithstanding his "principle," his classification is based solely on the "large number of characteristic Champlain fossils," and is contrary to lithology and stratigraphy, and certainly also against a well digested palæontology.

The structure of "this fossiliferous belt" is "a broad, crumped and folded synclinal," with "the characteristic Pointe Lévis limestone conglomerates and associated graptolithic shales coming up near the base on both sides." He admits, however, "a number of local and unimportant overturn dips, but there seems to be no evidence whatever of a general inversion of the strata."

Then Mr. Selwyn speaks of the St. Lawrence and Champlain fault or overlap, bounding this belt on the northwestern side, which places in contact what he calls "the even-bedded shales and limestones of the Lorraine shales' group with the crumped and twisted strata of" the Quebec group of Logan. "The line of this dislocation or unconformity— whichever it may be— has been supposed to pass to the *rear* of the Quebec citadel. This I hold to be a mistake, and I think it can be distinctly shown that it passes from the southwest end of the Island of Orléans *under the river* and between Pointe Lévis and Québec; it appears again on the north shore of the St. Lawrence about one mile north of Pointe Pizeau, passes north of St. Foy and then in a direct course to where it again crosses the river southwest of Cape Rouge."

As stratigraphy is the strong point claimed by both Logan ("the most able stratigraphical geologist of the American continent") and Mr. Selwyn ("a stratigrapher of forty years standing"), it is important to show the divergence of opinions between such experts and the character of the proof used by them.

Logan says: "from the physical structure alone no person would suspect the break that must exist in the neighborhood of Quebec, and without the evidence of the fossils, every one would be authorized to deny it . . . There must be a break;" and he points out its course and its character, calling it "an overturn anticlinal fold with a crack and a great dislocation running along the summit." Logan makes it pass "just north of the fortress; then it coasts the north side of the island of Orléans" ("Remarks on the Fauna of the Quebec Group, etc., addressed to Mr. Joachim Barrande," Montreal, Jan. 3, 1861, pp. 3 and 4).

Mr. Selwyn disagrees with Logan, first, as to the character of the break, calling it *synclinal*, where Logan finds an *anticlinal*, and he is not certain whether it is a *dislocation* or an *unconformity*. As to the so-called fault or overlap passing *just north of the fortress*, Mr. Selwyn holds that it is a mistake of Logan, and that instead of passing in the *rear* of the Quebec citadel, it passes in *front*, but *under the river*.

I have explored all the cliffs from Mountain street and the Saut du Matelot (City of Quebec) to the Diamond harbor or Cove fields and farther west as well as the rear of the citadel at the old French works and actual rampart, and nowhere did I find any trace of fault or overlap. The strata present that fan-like structure, so common in the Alps, with the greatest development of the fan on the north side of the city itself; and at the same time on the south side of the citadel, the cliff shows a fold of arched form with a long rise, recalling the splendid arch of the citadel of Besançon in France, but less accentuated as regards the arch and the steepness of the rocks.

Now, Mr. Selwyn places that so-called fault or unconformity — he is not sure which — in the bed of the St. Lawrence river, and regards it as passing under water on the south front of the citadel, instead of the rear. Of course it is impossible to know the true condition, and it is simply a supposition without any basis to rest upon. Then Mr. Selwyn makes it reappear on the north shore of the St. Lawrence, one mile north of Pointe à Puizeau, without giving the exact locality of the cliff, leaving in doubt whether he saw it somewhere at the cliff of Sillery cove, or elsewhere on the plateau at Benmor, Kirkela or at Cataraqui. As I have explored the whole cliff from Quebec city to Cape Rouge, I can say that I have not seen a single fault or overlap anywhere.

From one mile north of Pointe-à-Puizeau, Mr. Selwyn carries his so-called fault across the whole plateau to the north of St. Foy and then due west to Cape Rouge, where he runs it again into the River St. Lawrence and keeps it under water. All that bayonet-shaped fault over the Sillery plateau is pure imagination and can be classified with the bayonet-shaped fault of Logan just north of the citadel.

On the evidence of fossils claimed by Logan to place the Citadel hill and city of Quebec into his Quebec group, Mr. Selwyn declares that there is an " entire absence of characteristic Lévis fossils in the citadelle rocks." This fact was well known to me and recorded sixteen years before, when in 1862 I classified the Citadel hill and city of Quebec rocks as resting above the Pointe Lévis group (Letter to M. Joachim Barrande on the Taconic Rocks of Vermont and Canada, pp. 12–13, Cambridge, 1862). But the great difference between Mr. Selwyn and myself is, that he considers the Citadel hill strata as resting *above* the Trenton and belonging to the Utica-Lorraine group, when I put them far *below* the Trenton, just above the Lévis group and without any fault or overlap in the middle of the bed of the River St. Lawrence, between Quebec and Pointe Lévis.

Mr. Selwyn considers the Lauzon division of Logan as identical with the Lévis and Sillery divisions and the so-called Potsdam formations of St. Jean, St. Rock, St. Denis, Bic harbor, etc., as belonging to the Pointe-Lévis group, retaining all that portion of the Potsdam formation of Logan, Richardson and Billings, which contains the Georgia formation fauna in his Lower Silurian (Champlain) system. Although he deprecates " palæontological stratigraphy," Mr. Selwyn is a little embarrassed with the fauna at Bic harbor, Trois pistoles and St. Denis (*Olenellus Thompsoni*, *Conocephalites*, *etc.*) ; and in order to dispose of the difficulty he has recourse to boulders ! some, according to him, contain Georgia fossils, others Potsdam fossils, and still others calciferous fossils ; and the whole set of boulders kept together by a matrix almost contemporaneous with, but a little *above*, the Calciferous. Thus in Mr. Selwyn's opinion the Levis group is the equivalent of the Upper Calciferous and Chazy, called by him first Lower Silurian, afterward Cambro-Silurian, and colored on his great geological map of 1883 as true Cambrian, a series of blunders seldom seen.

That the Lauzon and Sillery divisions of Logan "have no definite or definable existence apart from the Lévis group" is true ; and I have never admitted those unnatural divisions. But that "the trilobites of primitive types" of the southern shores of the St.Lawrence from Pointe Lévis, island of Orleans, St. Denis, Bic harbor, Trois pistoles, Metis and Matanne are" in the pebbles or slabs of the conglomerates," and that Mr. Selwyn can almost point out what part of the northern coast of the St. Lawrence and Labrador they came from as boulders, is an imaginative supposition, added to the many so freely used by Logan and Mr. Selwyn in all their dealings with Canadian geology. At Pointe Lévis, where I have examined every outcrop and almost every large stone found there, the trilobites, brachiopods, cephalopods, etc., are not in boulders, nor in conglomerates, but in the lenticular masses of magnesian limestone inclosed in the graptolitic slates.

As a *résumé*, Mr. Selwyn claims to have "eliminated from the Quebec group (of Logan) the metamorphic older series, and also considerable areas of Trenton, Utica and Hudson river," and he prefers to use the name of Lévis instead of Quebec group because he has shown the non-existence of Sillery and Lauzon apart from Lévis. Still more, sixteen years after me, he has revived, without referring to my observations, another group, the Citadel hill of Quebec which he considers as Utica-Lorraine, but a special Utica-Lorraine enormously thick, containing a graptolitic fauna about the age of which he disagrees with his palæontological adviser Professor Lapworth, deprecating as he says "palæontological stratigraphy."

All the alterations proposed by Mr. Selwyn are neither important, nor of any permanent value. His classification of some strata of the Logan Quebec group into his so-called Cambrian had been anticipated by me sixteen years before; his transfer of Logan's Potsdam formation from above the Lévis, into it, is an error replaced by another, for the formation of St. Denis and Bic harbor is neither Potsdam nor Lévis, but older, being Georgia. And finally his opinion that the Citadel hill strata, regarded by Logan as a part of his Quebec group, and the homotaxis of the Calciferous-Chazy, are the equivalent of the Utica-Lorraine and consequently transferred from the base of the Champlain system to its uppermost part, is untenable and contrary to stratigraphy, palæontology and lithology. Since 1862 I have referred all the strata of the city and Citadel hill of Quebec, to their proper place in the classification, as the equivalent of the Swanton slates of Vermont, which are a part of the Black Taconic slates of Dr. Emmons, just above the Lévis group and far below the Utica-Lorraine, Trenton, Chazy, Calciferous and even the Potsdam which is wanting round Quebec.

SELWYN'S CLASSIFICATION OF 1884 TO 1887.

In 1884, Mr. Selwyn published with a descriptive sketch a large "Map of the Dominion of Canada geologically colored from surveys made from 1842 to 1882." The province of Quebec is comprised in what he calls "the southeastern palæozoic basin." He colors it, first with a large belt of Cambro-Silurian (Champlain) as far as Montmorency falls; then southeast of it another large band of Cambrian, but a special Cambrian of his own comprising the Lévis formation which he continues to regard as the equivalent of the Chazy and Calciferous, placing then the Lower Champlain in the Cambrian; then follows a belt of Pre-Cambrian, composed of metamorphic feldspathic schists and gneiss, and finally a belt of true Silurian (the old upper Silurian of Logan, etc.).

Here is the order which he gives:

Silurian (third fauna).
Cambro-Silurian (Champlain in part).
Cambrian (Taconic and Lower Champlain).
Pre-Cambrian (Lower Taconic of Emmons).

The Silurian (Upper Silurian and even Middle Silurian of Logan) occupies a very broad belt covering all the country from Lake Memphremagog to the United States boundary lines of New Hampshire and Maine, and extending to cape Gaspé. Besides Mr. Selwyn has colored three patches of Silurian, close by the southern shores of the St. Lawrence, in Yamaska, Artabaska, Nicolet and Lotbinière counties. Later observations made by Mr. R. W. Ells had limited considerably the upper Silurian, which is reduced to one line of small patches, instead of a broad belt, extending from lake Memphremagog to lake Massawipi, Stoke, Dudswell, lake Aylmere, Famine river towards Gaspé, and resting unconformably upon what Mr. Ells calls Cambro-Silurian and the so-called volcanic belt, and even over Pre-Cambrian rocks of the eastern township; in reality the line of Silurian patches lies unconformably over the Taconic system, which the Canada geological survey has always completely passed over unnoticed. The exposures of Silurian are small bands or rather patches left by erosion and denudation of a deposit which once covered an area, three or four times larger. As to the three large patches indicated on the map near the St. Lawrence river between Yamaska and Lotbinière, there is a mistake.

The Cambro-Silurian, although differently limited on the map as in the different papers published by Mr. Selwyn, covers large areas on the south side of the St. Lawrence river and even on the north side, which are truly Taconic and have nothing to do with the

Champlain system or Cambro-Silurian. There is a want of harmony between the map and Mr. Selwyn's expressed views, for he says that the Lévis group belongs to the Lower Silurian (Champlain) while on the map he colors all the localities of Pointe Lévis, St. Denis, Bic harbor, etc., as Cambrian. In fact we do not know with any degree of certainty what Mr. Selwyn intends by using the English names Cambro-Silurian and Cambrian. He regards the Lévis group as superior to the Potsdam, and contemporary with the Calciferous, perhaps even the Chazy, while on the map Pointe Lévis and the island of Orleans is colored as Cambrian.

There were confusions enough brought us by the extraordinary classification and nomenclature of Logan, without adding new causes of error and new misunderstanding by the importation of English names and classifications, which are used a little too freely by Mr. Selwyn, often without explanation and against plain facts.

The geological map of Mr. Selwyn has a band of Cambro-Silurian at the northern part of the Gaspé peninsula, between Marsouin river and Griffin cove, which is referred by him to the Utica-Lorraine ; while Professor Lapworth declares that there is no trace there of that group.

The map "southeast quarter sheet," which accompanies Part J, "Annual Report, 1886," differs entirely from the general geological map of 1884. In it three large bands of Cambro-Silurian extend from New Hampshire to Artabaskaville and St. Albert replacing the Silurian and even the Cambrian of 1884. The so-called Cambro-Silurian strata of Mr. Ells' report and map are mainly slates of considerable thickness, with now and then lenticular masses of magnesian limestone and sandstone inclosed. They are for the most part barren of fossils ; graptolites only are found, and some microscopic examinations have revealed the existence in some of the limestone of organic remains, which are very rashly regarded as an indication of the Trenton group, or upper part of the Chazy. The graptolites, found in the slates at Magog and Stanstead, indicate the third zone of graptolites, or the Swanton and Citadel hill group of the upper Taconic.

It is evident that Mr. Selwyn and his associates are calling Cambro-Silurian (Champlain) the Upper Taconic of New York, Vermont and the vicinity of Quebec, as well as all those graptolitic slates of the eastern townships of the province of Quebec. On Mr. Selwyn's map the Cambrian occupies first an area south and west of Montreal, which is the old Potsdam original area of New York extended into Canada. Then we have a large belt extending from Phillipsburgh to Pointe Lévis and inclosing those two most important localities, then the island of Orleans and the whole south shores of the St. Lawrence river to Cape Rozière, with the exception of a small band between Marsouin and Griffin. This belt is quite broad; it corresponds mainly to what Logan had colored on his map of 1864, as the Quebec group of the Lower Silurian. It is separated from the Cambro-Silurian by what Mr. Selwyn calls the "great St. Lawrence and Champlain fault," which from the south of Quebec city is kept constantly under water, about the middle of the St. Lawrence river, and which stops in the middle of the gulf of St. Lawrence, south of the island of Anticosti. It is a theoretical and invisible fault without any facts to sustain it, and is only put there to explain and sustain the positions taken at different times by the geological survey of Canada, in regard to their ever-changing and confused classification and nomenclature.

In the eastern townships, the Cambrian does not contain fossils. Mr. Ells thinks that the slates, sandstones and conglomerates which compose this system are "apparently uncomformable" with the Cambro-Silurian above and the Pre-Cambrian rocks below. It is a question which demands more accurate researches before admitting the unconformity with either.

On the St. Lawrence river the fossils found belong to a well characterized primordial fauna; Mr. Selwyn is the only one who continues to maintain that the primordial fossils of Pointe Lévis, island of Orleans and Bic harbor, are found in boulders inclosed in what he calls a conglomerate limestone, contemporaneous with, but a little above, the Calciferous, surrounded by the celebrated graptolite-bearing shales, which he and Mr. Walcott regard as Utica-Lorraine or "clearly the Hudson river group."

The truth is, that we have from Swanton and Highgate in Vermont, the belt of Georgia slates, about five or six hundred feet thick, containing the typical primordial fauna, *Olenellus Thompsoni*, *Conocephalites*, etc., which enters into Canada east of St. Armand, and goes right up to St. Denis and Bic harbor. Until now that most important belt of Georgia slates has not received the proper attention to which it is entitled, in the whole province of Quebec. No fossils have yet been found on the line indicated, except, I think, but I am not sure, only at one point in Artabaska county. Near the Chaudière and Etchemin rivers the flows or sheets of dioritic-diabase interbedded with the slates have prevented the existence of animals in that part of the belt, and it may be also in some other parts between the Chaudière and St. Armand; but after reaching the counties of Lislet and Kamouraska the belt is quite fossiliferous, and we have a fine development of the Georgia formation of the Middle Taconic.

As to Pointe Lévis and the main part of the island of Orleans, I have already had occasion to say that the strata there are the lower part of the Upper Taconic and belong to the Phillipsburgh and Pointe Lévis group, containing the supra-primordial fauna. The graptolite bearing shales of Pointe Lévis form the second zone of graptolites, just above the first zone existing in the Georgia slates; and the other graptolite bearing shales of Citadel hill, and on the northern part of the island of Orleans they belong to and form the third zone of graptolites of the Swanton and Citadel hill group of the Upper Taconic.

MARCOU'S CLASSIFICATION OF 1860–1888.

Now that I have given the ever-changing classification and the numerous contradictions and confusions of the Geological Survey of Canada from 1855 to 1887, I shall describe in a few words the great outlines of the stratigraphy of the province of Quebec. As far back as 1849, after a reconnoissance of the vicinity of Quebec, I recorded in my note book, a part of which was published in 1860, in my joint paper with Barrande (Proceed. Boston Soc. Nat. Hist., Vol. VII, pp. 376, 377, 378 and 379), that we have there two distinct formations: one of very small extent, almost horizontal at the top of Montmorency and Indian Lorette Falls, belonging probably to the Trenton, and another one, an extremely thick development of slates forming the hill of the city of Quebec, Pointe Lévis and la Chaudière falls, which has been strongly upheaved and broken before the deposit of the almost horizontal Trenton limestone. My first impression was correct; and all my subsequent researches in the province of Quebec during the years 1861, 1862, 1863, 1873 and 1874 have confirmed my views.

The province can be divided into two very unequal parts. The first, by far the smallest and less important geologically, is the country round and more specially south of Montreal. Its stratigraphy is simply the continuation, on the other side of the boundary line between New York and Canada, of the geological formation of the second district of the state of New York, so well described and classified by Dr. E. Emmons, as far back as 1842. Following the excellent work made by Emmons in Clinton, Franklin and St. Lawrence counties of New York, Logan simply extended the Champlain system into Canada from Rouse's Point, St. John, Cornwall, Vaudreuil, to Montreal island, Argenteuil and Ottawa. His detailed "Geological map" of that area published in 1852 (Quart. Journ. Geol. Soc. London, Vol. VIII, pl. IV, p. 324) is good and is really the only commendable work made by the geological survey in the province of Quebec; the only objection being the insertion of an important band of tertiary in the eastern part, which does not exist. Chazy and Potsdam villages being close by the boundary line, it was an easy task to extend into Huntington, Beauharnois, Chateaugay, St. John, la Prairie, etc., counties, the typical groups and divisions of Potsdam, Calciferous, Chazy, Trenton and Utica. It will seem, to any practical geologist who visits the country, that it would have been as easy to see, that as soon as we have left the Alburgh peninsula, the strata, on the east side of Lake Champlain and farther north, have absolutely nothing to do with the Calciferous, Chazy, Trenton and Utica of Chazy village, Chazy landing, Isle la Motte and Alburgh, and that we have there another and older system; but such was not the case with the members of the geological survey of Canada.

The second, and by far the largest portion of the province of Quebec, extends from the northeastern end of Lake Champlain to New Hampshire and Maine and comprises the whole country north as far as Labrador.

The stratigraphy is quite simple. We have, at first on the northern part of the St. Lawrence river, a narrow band of blue-black limestone covered by black slates varying from 300 to 600 feet in thickness, which follows the foot of the Laurentine mountains from the northeast of Montreal toward Industry, St. Cuthbert, Trois Rivières, St. Ambroise, Charlesbourg and Montmorency Fall, as far as St. Joachim, the Bay of St. Paul and Murray Bay. Then it disappears entirely under the St. Lawrence river, or very likely has been destroyed entirely by denudation. Two patches of it exist still on an affluent of the Saguenay river and at Lake St. John. No other traces of it are found until the Mingan islands and perhaps the northern shore of Anticosti, and finally it ends at Long Point, Port à Port Bay in Newfoundland.

That long narrow band is formed of Trenton and Utica with their characteristic fossils, as they are found at Trenton Falls and at Utica in New York. Its lithology also is the same as that of the formation in New York state. By Trenton group, I mean all the strata from the lowest bed of the Calciferous to the top of the Trenton, for the deposits in that narrow sea of the actual valley of the St. Lawrence have all the characters of a littoral formation, with local variations, more or less, limited to small areas. At St. Ambroise and even at a part of the top of Montmorency Falls, there are about twenty feet of sandstone and conglomerate, which have been referred to the Potsdam without any palæontological proofs, and which very likely represent there the Calciferous-Chazy. After we pass Industry and the Chicot Creek in Joliette and Berthier counties, it is impossible to recognize the Calciferous and Chazy with the normal characters which they bear in the village of Chazy. They may be represented by the most inferior part of the almost horizontal strata of what is called Trenton, or those twenty feet of sandstone and conglomerate, or they may not have any representatives at all. However, at the Mingan islands, the Calciferous-Chazy seems to exist with a thickness of almost 500 feet; although it is not certain that those strata of the Mingan represent either the Calciferous or the Chazy, being so different lithologically and even palæontologically. They may represent the whole lower and middle divisions of the Champlain system.

That narrow and very long Champlain band lies to the north over the primitive and crystalline rocks, and to the south on the strongly upheaved and broken Taconic slates. Erosion and denudation, continued without interruption from the time of their upheaval above the sea until now, have reduced them to extremely limited dimensions. Near their contact with the Taconic slates, landslides have often occurred; and some patches of Trenton limestone are seen hanging down, almost at a perpendicular angle, on asperities of the primitive rocks, or inclosed in gorges and gullies; and also some tongues of Utica slates have slipped over the Citadel hill slates of the upper Taconic and are found now and then, but always close by the normal line of Champlain outcrops. For such examples of landslides, I shall refer to the Montmorency Falls and its vicinity, and that at the foot of the lowest fall of the river Ste. Anne near the mouth of the river à la Rose.

Directly south of the narrow band of almost horizontal Champlain system, we have an enormous thickness of strongly elevated, broken, twisted and folded slates extending as far as the boundary line of Vermont, New Hampshire, Maine and New Brunswick. Those slates inclose in some places diabases, granite, gneiss, mica-schists, serpentines, talcose conglomerates, etc., and on a very narrow line from lake Memphremagog to Gaspé they inclose more or less, in their folds, some patches of another system, much younger, of which we shall speak presently.

That great slate system, older than the Champlain, is the Taconic system of Dr. Emmons. The groups made out by me in Vermont are easily recognizable in Canada, and the classification and nomenclature published by me in 1862, for the vicinity of Quebec city in the tabular section accompanying my "letter to M. Joachim Barrande, on the Taconic rocks of Vermont and Canada," answer all the wants for the whole area of the province of Quebec.

The youngest group, directly below the Champlain system, is the "Citadel hill and city of Quebec group," containing in Canada and in the United States (at Quebec, Swanton, near Bald mountain, Normanskill near Albany, etc.) the third zone of graptolites. It has an average thickness of 3,000 feet.

Then comes the "Phillipsburgh and Pointe Lévis group," also 3,000 feet thick, with a fauna containing mixed forms of the Primordial types and second fauna types, as at Hoff in Bohemia, in Norway, Sweden and Wales. In it the graptolites are very numerous and form the second zone of graptolites in America.

In both these two groups which belong to the Upper Taconic system, the fossils are always found, now and then; never in a continuous line of outcrops as in the Champlain system. They are sporadic, like the colonies in Bohemia.

Directly below the Lévis group, we have the "Georgia group," with a thickness of five or six hundred feet, containing in Canada a purely primordial fauna.

Below the "Georgia group" belt we have the "St. Albans group" with its quartzites or granular quartz, slates and argillites extremely poor of fossils in New England, as far as known, entirely devoid of fossil remains in Canada, and in which very likely, we may find an extension of the Olenellus zone. It occupies large spaces in the province of Quebec southeast of the Georgia group belt.

These divisions of the Taconic system may be repeated in two or three places; but until now only the band of the "Citadel hill group" has been found repeated in the eastern townships.

The whole system has been overturned, as in the original Taconic area in Massachusetts, New York and Vermont.

OLENELLUS BEDS IN SCANDINAVIA AND IN NORTH AMERICA.

Messrs. Linnarson, Brögger, Holm, and Nathorst[1] have shown and proved beyond a doubt, that in Scandinavia the *Olenellus beds* are invariably found underneath and in contact with the *Paradoxides beds*, and consequently an older horizon. Messrs. Walcott, Ford and even Matthew incline to consider the Olenellus beds of Georgia as younger than the Paradoxides beds ; and more they have expressed doubts whether the Scandinavian Olenellus is a true Olenellus. Unhappily the confusion created by the determination of the Georgia trilobites as belonging, first, to the genus Olenus, then to Barrandia and afterward to a new genus Olenellus showing by its very name a greater affinity and closer relationship to Olenus than to any other primordial tribolites, weighs heavily against a clear conception and definition of the question.

The great geologists and palæontologists, Emmons and Barrande, were very careful to keep their discoveries of the oldest fossils and of the creation of the primordial fauna, in the limit of exact determination of *genera;* showing both the close relationship of the Georgia tribolites with the Paradoxides and Ellipsocephalus. Dr. Emmons was very fortunate in creating in 1844 the name Elliptocephala, so near Ellipsocephalus then unknown to him ; and afterward, in 1859 and 1860, he did not hesitate to refer, first, his *Elliptocephalus asaphoides* to the genus Paradoxides and secondly, to regard the Georgia trilobites as belonging to the genus Paradoxides, instead of being an Olenus as referred by the palæontologist of New York. We have there a remarkable example of his great sagacity as a palæontologist. Barrande did not hesitate to refer at once in his memoir of 1861 the trilobites of Greenwich and Georgia to the genus Paradoxides, as Dr. Emmons had done, instead of using the name Olenus, for he thought these trilobites have the greatest affinities and closest relationship with Paradoxides ; and if they are not allied to Paradoxides, he thought that on account

[1] On the Brachiopoda of the Paradoxides beds of Sweden, by G. Linnarson, pp. 7, 28, Stockholm, 1876. Die silurischen Etagen 2 und 3 im Kristiania-gebiet und auf Eker, by W. C. Brögger; 4to Kristiania, 1882. Annexe explicative à la carte géologique de la Suède; feuille méridionale, par A. G. Nathorst, p. 21, Stockholm, 1884. Om *Olenellus Kjerulfi*, by Gerhard Holm, p. 5, Stockholm, 1888.

of furrows on the glabella showing differences with those of Paradoxides, they may belong to and form a special American group of trilobites. Mr. Matthew, whose last works on American trilobites are so important says: " of its (Olenellus) close relationship to Paradoxides there can be no question."[1]

It is plain from these remarks that, (1) Olenellus is a name which ought to be dropped, on account of the priority of the name Elliptocephalus, and of the misleading notion that it is closely allied to Olenus, when on the contrary its nearest relationship is with Paradoxides of an older horizon; (2) Elliptocephalus, if not retained for the Georgia trilobites, on account of its great similarity with Ellipsocephalus, ought to be replaced by Ebenezeria in honor of Dr. Ebenezer Emmons; (3) the horizon of the Georgia trilobites cannot be confounded with the Olenus beds of Europe, but is older, being the homotaxis and equivalent of the Paradoxides horizon.

The genus Olenellus is comparatively rare in Conception Bay, in Eastern Newfoundland, where it was pointed out by Mr. Billings as far back as 1870, and by Mr. Matthew in 1886.[2]

Mr. Matthew insists upon the distinction between the two faunas of the Olenellus beds and of the Paradoxides group. He says that they do not mingle anywhere, and that the fauna of the St. John group is entirely absent in the gulf and valley of the St. Lawrence, where the Georgia fauna is well and typically developed from Western Newfoundland to Georgia and southward. Mr. Matthew with great sagacity says: "The trilobite (Paradoxides? of Conception Bay) is a primitive form of the Paradoxides family, which has points of resemblance to *Parad. Kjerulfi.*" But he hesitates in regard to the horizon of that primitive form of the Paradoxides family, and expresses the view that "its range elsewhere [which means evidently

[1]On the classification of the Cambrian rocks in Acadia (reprinted from the Canadian Record of Science), p. 75, 1888.

[2]Both Billings and Matthew were in doubt in regarding the trilobite of Topsail Head, as belonging truly to the genus Paradoxides: having only small fragments at their disposal, they regarded them as "supposed" Paradoxides. Alexander Murray in his section from Topsail Head across Great Bell Isle (Report upon the geological survey of Newfoundland for the year 1868, pp. 27 and 28, St. John's) shows the green slates with *Paradoxides Bennetii*, underlain by strata containing Lingulæ, etc., representing the Olenellus beds. In the report for the year 1870, at pp. 37 and 38, Murray is even more explicit having recognized and found at Fortune Harbor and Langlois Island the *Paradoxides Bennetii*, *Concephalites*, etc., and at Trinity bay and Topsail Head "a small fragment of supposed Paradoxides," a *Bathyurus gregarius* Bil. and an archæocyathus, all below the green slates with Paradoxides. The stratigraphic position of the Olenellus beds of Newfoundland has been known since 1868 and 1870, and corresponds harmoniously with the Olenellus bed of Scandinavia.

in Scandinavia] is not sufficiently known" ("On the Cambrian faunas of Cape Breton and Newfoundland" in 'Trans. Roy. Soc., Canada section IV, 1886, p. 148, Ottawa'). The *Paradoxides? Kjerulfi* is referred to Olenellus by Linnarson, Brögger and Nathorst; and lately (1888) Dr. Gerhard Holm is inclined to make a new genus for it, intermediate between Paradoxides and Olenellus.

Palæontologically, as well as stratigraphically, there is no doubt that the Olenellus beds of Conception Bay, eastern Newfoundland, are older than the Paradoxides beds of Trinity and Ste Mary's bays, and that we have there the same succession of trilobitic fauna as in Scandinavia. Lately (September, 1888) Mr. Walcott after opposing in strong terms Alex. Murray's observations, saying that Murray placed the Topsail Head strata beneath the Paradoxides shales of Ste Mary's Bay "without palæontologic or stratigraphic evidence that authorized him to say more than that a supposed connection is indicated" (Second contribution to the Cambrian faunas of North America, p. 49, Washington, 1886), has found out in a recent visit to Newfoundland that after all Alexander Murray and J. P. Howley, the two geologists of the Newfoundland geological survey, were right in their "palæontologic and stratigraphic evidence." This ends the perplexity and conflicting views put forward by the adversaries of the Scandinavian stratigraphic and palæontologic tabular view of strata for the Middle Taconic system.

But in Scandinavia (Scania) the Olenellus bed is a very limited one, very thin, and simply a subdivision of the fifth order or bed, lying below the great group of Paradoxides slates and above the Eophyton sandstone and the Fucoid sandstone. On the contrary, the Paradoxides slates form a division of the third order or well developed *étage*, of considerable thickness, with a quantity of subdivisions or special fossil horizons — ten, according to Dr. Nathorst, and Mr. Tullberg's tabular view.

In America the Olenellus bed of the eastern part is also a subdivision, rather thin, of the fifth order; and there is no doubt that the Scandinavian and Eastern Newfoundland Olenellus horizon is the same and absolutely identical in all respects showing, beyond any reasonable doubt, that those two widely separated countries were in direct communication by an uninterrupted sea.

But in the western part of Newfoundland and perhaps in the valley of Mira river (Cape Breton), and all over the valleys of the St. Lawrence, of Lake Champlain, of the Hudson river and in the

Rocky Mountains regions, we have another Olenellus horizon, with an immense development. In some places, as in Vermont and New York, Olenellus exists not only in the five or six hundred feet of the typical localities of Georgia and Swanton, but in a range of strata having a thickness of three or four thousand feet at least. And at the same time the Paradoxides so abundant at Braintree, St. John, Cape Breton and Eastern Newfoundland are entirely wanting, showing that a barrier of some sort existed between the Scandinavian, Eastern Newfoundland sea, and the Western Newfoundland, St. Lawrence, Champlain, Hudson, etc., sea.

The conclusion seems almost certain, that the Paradoxides horizon, with its Olenellus bed at the base of Scandinavia and Eastern Newfoundland, is contemporaneous with the Georgia, St. Albans and granular quartz strata of the St. Lawrence, Champlain and Hudson valleys, which are rich in Olenelli. By a difference in the geographical distribution, two great genera of Trilobites, the Olenellus and the Paradoxides, have developed parallel, mingling only in the eastern sea. And we may regard the Georgia formation of the Middle Taconic as the homotaxis of the St. John formation, instead of being younger and placed above it. The two formations being separated by dry land, which extended from Labrador to central Newfoundland, New York city and very likely farther south,[1] we have on the two sides of that barrier, two primordial, contemporaneous faunæ, one containing very few Olenelli and a great development of Paradoxides ; while the other, on the contrary, shows an immense and remarkable development of Olenellus, without until now, a single example of Paradoxides. This is another case of what Mr. Barrande has called the great localization of the different primordial faunæ, which seem to be as numerous and as well marked, as the faunæ actually existing in the different parts of our present oceans.

POTSDAM NON-EXISTENCE.

In that part of the province of Quebec under consideration, we have nowhere the Potsdam sandstone, except perhaps for one or

[1] During the Middle Taconic and Upper Taconic time, an arctic continent existed, from the Scandinavian primitive rocks to Scotland, Greenland, and Labrador (that continent may have extended farther east and west), and was united with an equatorial continent, by a narrow region, somewhat similar to the isthmus of Darien or Panama which connects the continent of North America with the continent of South America. That Taconic isthmus formed the barrier between the Atlantic and the Pacific ocean of that remote period of our globe.

two miles east of the village of St. Armand, near the Vermont line. It was not deposited in the whole valley of the St. Lawrence beyond Chicot creek and Caché river in Berthier county, while near St. Cuthbert it is seen to be represented by a white sandstone, as at Keeseville, containing marks of Protichnites. There the Trenton lies in discordance of stratification against it, showing the existence of the break between the Potsdam and the Champlain system. There is no trace of Potsdam east of St. Cuthbert, nor in Newfoundland, Cape Breton, Nova Scotia, etc. In fact, the Potsdam is a local group deposited round the Adirondack mountains, and its extension westward demands careful researches before being accepted.

BREAKS IN THE PROVINCE OF QUEBEC.

In the eastern part of the province of Quebec, all was dry land and *terra firma* after the great break and overturn of the Taconic slates. I do not mean to say, that there were no breaks before; very likely several breaks, more or less important, occurred during the deposition of the Taconic rocks, but further researches are necessary to determine their position and make a proper classification of the breaks and upheaval, some of which, as at Quincy and Braintree, near Boston, at St. John, New Brnnswick and at Ste Mary's bay, Newfoundland, are already known.

After the deposition of the Potsdam sandstone a break — on a much smaller scale than the great Taconic break—occurred on the coast line with a crack entering the dry land at the contact line of the Primitive rocks of the Laurentine mountains with the Taconic slates; a part of the land subsided on that crack and the Champlain sea extended a narrow arm or gulf, like the Adriatic sea or the Red sea, along the actual valley of the St. Lawrence, as far as Western Newfoundland. At the end of the deposition of the Champlain system rocks, another break occurred, the result of which was an upheaval movement of all that narrow gulf, where lay the Champlain strata; while at the same time a corresponding depression and subsidence, local and very limited, brought the Silurian sea into a very small part of the Taconic land area from Gaspé to Lake Memphremagog. This part of the Silurian sea did not communicate — at least directly—with the sea of the state of New York and the province of Ontario, where typical deposits of the Silurian system exist. The Silurian strata of Quebec possess all the characters of a littoral formation deposited in a narrow gulf, with a quantity of corals and coral reefs and a thickness rather small if we judge from what remains of the formation at Lake Memphremagog and elsewhere on the line of outcrop.

I do not mean to say that the Silurian sea of the province of Quebec had no communication at all with the Silurian sea of Ontario and New York; but only that it had no direct communication. The west and all the south was occupied by a continent, cutting the communications, but it may very well have communicated, by an indirect and very long way, through New Brunswick, the Gulf of St. Lawrence, the North Atlantic, the Arctic region and then down the great lakes of the Hudson bay territory and the upper Mississippi.

After the deposition of the Silurian, another break occurred which resulted in an upheaval of the whole original Taconic dry land, with some additions of new lands; and afterward the sea was excluded from the province of Quebec, except from an insignificant corner of the southern part of the peninsula of Gaspé.

I close with this remark: The Champlain system and the Silurian system in the eastern and northern area of the province of Quebec are represented by narrow bands, one situated northwest of the province and the other southeast, enclosing between them the great and most important Taconic system. They may be compared to two parallel sides of the frame of a grand natural geological picture, which were produced by two great fissures or crevices of the earth's crust; the weakest first giving way on the line of contact of the overturned strata of the Taconic with the crystalline rocks of the Laurentine mountains; and the second crevice, by a sort of reaction or counterpoise, giving way in turn at the end of the Champlain deposit, forming a line of depression close to the crystalline rocks of the White mountains. In a word, those two narrow bands of Champlain and Silurian strata are due to a *bascule* (rocking) movement.

Following is the tabular view of the strata in the second part or area of the province of Quebec, as I understood it.

STRATIGRAPHY OF THE PROVINCE OF QUEBEC.

		Break. Unconformity.
Silurian system.		Some patches of Silurian deposits exist from Memphremagog to Gaspé.
		Break. Unconformity.
Cambrian or Champlain system.		UTICA, from Rouse's Point to St. John lake. Fourth zone of graptolites. TRENTON, including Chazy and Calciferous not distinguishable as subdivisions from Chicot creek (St. Peter's lake) eastward to Montmorency and Western Newfoundland.
		Break. Unconformity, at Chazy and Beauharnois.
Taconic series.	Upper Taconic.	POTSDAM, does not exist round Trois Rivières nor the city of Quebec, nor farther east. It exists only round Montreal as far northeast as St. Cuthbert in Berthier county. Break. Overturn of all the strata and strong unconformity. CITADEL HILL AND QUEBEC CITY OR SWANTON SLATES. Third zone of graptolites and colonies. POINTE LÉVIS AND PHILLIPSBURGH. Second zone of graptolites with compound graptolites. Colonies.
	Middle Taconic.	GEORGIA, from Highgate (Vermont) to St. Denis, Bic Harbor, etc.; first zone of graptolites. Olenellus belt. The homotaxis of the Paradoxides belt of northeastern America and Scandinavia. ST. ALBANS, much developed on the Chaudière river and around Actonvale and Richmond. A few Olenelli exist east of St. Albans, west of Shelton, and in the granular quartz. This formation represents the Olenellus bed of Cape Breton, Eastern Newfoundland and Scandinavia.

The doctrine of colonies has been established by Barrande on practical facts, studied most carefully in the field, without any regard to and indeed against the uniformitarian rules established too hastily by the palæontologists. Barrande reminded palæontologists, that stratigraphy comes first, and is the foundation on which lies the whole structure of geology. His discoveries in Bohemia have the great merit of placing facts before theories.

The adversaries of the Taconic system have constantly placed their theories first, and facts have been explained by suppositions, or guesses and arbitrary use of palæontology and dynamic stratigraphy, never losing sight for a moment of mathematical rules, established according to their views without a possible doubt. They have applied carelessly and inexactly all their empirical palæontological laws, without any regard whatever to the actual state of things on the ground putting entirely aside stratigraphy and lithology. But even, when their own rules of palæontology to determine the age of strata are against them, they have not hesitated to make either erroneous identifications of species, or transfer an entire zone of primordial fauna, in order to suppress the whole or at least a good portion of the Taconic.

As to stratigraphy and lithology the adversaries of the Taconic have constantly erred ; and we have the rare and singular spectacle of observers claiming to know only stratigraphy and lithology, making classifications entirely in opposition to all the principles of those two branches of geology, submitting very tamely, all their views and conclusions to the decision and advice of palæontologists, and of palæontologists all of whom are opposed to Barrande's doctrine of colonies. They seem to have closed their eyes to the facts, and endorsed by the majority they are satisfied. Such a spirit is contrary to modern science, and recalls the orthodox and official science of the middle ages at the time of the adversaries of Galileo.

CONCLUSIONS.

As a conclusion, we can say that the geological survey of Canada, from its beginning until the present time, has been a constant, and unfair, adversary of the Taconic, for it has never used nor ever mentioned anywhere in its official reports and publications the researches, discoveries and classifications of Dr. Emmons and Marcou. The right of priority has been entirely set aside. Not being successful in their undertaking of giving local names, which were never accepted to any extent by geologists at large, the Canadian geologists have lately substituted for their Quebec, Acadian, Anticosti, Guelph and Gaspé formations and groups, the English nomenclature of Cambrian, Cambro-Silurian, Siluro-Cambrian, and Silurian.

It is true that at the beginning of the survey, Logan tried to follow the classification and a part of the nomenclature of the state of New York; but he was unfortunate in choosing for his adviser the palæontologist of the geological survey of New York. After Barrande and Marcou's interference in 1860, he did not accept his defeat, and instead of using Dr. Emmons' observations he preferred to create another classification and a new nomenclature without any regard to priority.

Billings tried hard in his subordinate position to sustain the right of Dr. Emmons, showing as well as he could, the great value of his discoveries of the system of rocks containing the oldest fossils and the primordial fauna on this continent. But he was overruled by his chief in the survey, who not only did not allow him to use the name Taconic, but also obliged him to use at all times the names, Lower Silurian and Quebec group.

Logan was almost as much of an adversary of Professor Sedgwick and the Cambrian, as he was of Dr. Emmons and the Taconic; and the award of the Wollaston medal of the Geological Society of London, at a time when Murchison was all powerful, was due mainly to his extension of the name Silurian to all the fossiliferous rocks of the Lower Palæozoic of Canada, as it will be seen from the following extract of a letter of Murchison, to me, dated London, March 3, 1856: "At our last anniversary I received the Wollaston medal for my friend Sir W. Logan of Canada, and I took special care when Mr. Henry D. Rogers was sitting opposite to me to express publicly (and it will be printed), that I had peculiar pleasure in receiving the distinction offered to so eminent a geologist who had laid down over such very large areas of North America the Lower Silurian as well as the Upper Silurian rocks and had shown that they were underlain by enormous masses (the Laurentine rocks) to which he restricted the term Cambrian. I added that he (Logan) did so as well as all American and other geologists up to this day; thus leaving Mr. Henry Rogers *stans pede in uno*." In the same letter, Murchison adds: "I do complain that Mr. Rogers is the first American who has ventured to restrict the term Silurian (in his geological map of the United States and British North America, and explanation, published in 1855, in Keith Johnston's "Physical Atlas," Edinburgh), to the upper group and not even to insert the words or Lower Silurian, so that the unlearned might understand. Still more was I offended with his writing Cambrian above my own formation of Llandeilo. I believe he is going to try to take out some of these misnomers. He has, however, made an absurd mistake in coloring all the region north of the Laurentine Mountains (Arctic circle) as *Cambrian!* while every one knows it is Upper Silurian."

As Dr. Emmons expresses it in one of his letters to me: "placed as he was, he (Billings) must have run great risks in the course he took" (The Taconic system and its position in stratigraphic geology by Jules Marcou, Proceed. Amer. Acad., Vol. xii, p. 189, Cambridge, 1885). However near the end of his life Billings published in 1872, two papers entitled: "On the Taconic controversy" ('The Canadian Naturalist and Geologist,' April and July), in which although he disculpates and excuses as much as he could, the errors committed by Logan, he stated fairly and in undoubted terms his opinion on the Taconic system and Dr. Emmons' discoveries.

The result of the rejection of Emmons and Marcou's classification and nomenclature for the eastern part of the province of Quebec is an accumulation of errors without a precedent in historical geology. Confusion in stratigraphy, confusion in palæontology, confusion in lithology, confusion in dynamic geology, confusion in geological maps and confusion in their explanations, confusion in classification, confusion in nomenclature; confusion everywhere.

Some groups of strata have travelled all over the different steps of the stratigraphical palæozoic scale; others have received duplicate, triplicate and even quadruplicate names. Faults have been created without being able to show a single locality, where they can be seen as incontestably existing; changing their places at will, in order to explain changes in the classification; and finally in despair putting them under water, as a last resource to stop criticism and demand of proofs.

It will take years of hard and minute work to extricate the geological survey of Canada from its endless errors, and to put in their right places strata, fossils, faults, folds, anticlinal, synclinal, etc.

As this may be my last contribution to the Taconic controversy, I beg permission to thank the Boston Society of Natural History, for having allowed me to defend the most important discovery ever made in geology by a son of Massachusetts, Dr. Ebenezer Emmons. This discovery was made on Massachusetts soil, around Williamstown and Williams College in the Taconic range of mountains. It was in the hall of this Society, that I read the letters of Barrande addressed to me in 1860; and it was there that those discussions and publications which have changed the whole American classification and nomenclature were begun. Without the help of this Society, I have no doubt that the Taconic question, which is now so prominent a topic and of such great value to geologists all the world over, would have been retarded for at least fifty years.

I shall add, that we are only at the dawn of the study of that question, for we have entombed in the strata of the Taconic system all the secrets of the beginning of life on our planet.

ON SOME DATES OF THE "REPORT ON THE GEOLOGY OF VERMONT."

BY JULES MARCOU.

VERMONT REPRINT OF MR. BILLINGS' PAPER DATED NOVEMBER 21, 1861.

In a paper entitled, "Date of the publication of the report upon the geology of Vermont," recently published by C. H. Hitchcock (Proc. Boston Soc. Nat. Hist., Vol. XXIV, p. 33, 1888), we read, p. 36, "in reference to the reprint of Mr. Billings' paper" (in the report on the geology of Vermont with the suppression of a long footnote, extending over two pages, without any notice), "If Mr. Marcou will consult the volume entitled 'Palæozoic fossils,' Vol. I, of the Canada survey, where the pamphlet which afforded the descriptions copied into the Vermont has been reprinted, he will discover that *Mr. Billings has also suppressed this footnote.* Perhaps it will appear in the next memoir upon the Taconic rocks, that Mr. C. H. Hitchcock suppressed this footnote in the Canadian volume!"

Mr. Hitchcock also says: "It will be a favor to me if Mr. Marcou will furnish the proof that I had any concern in the omission of this page in the Vermont reprint." I will give with pleasure the proof asked for. All the numerous copies of Mr. Billings' paper distributed or sold from 1861 to 1865 contain the long footnote on pp. 11 and 12; while the text and figures contained in those twenty-four pages are without a single change or alteration of any sort, *ne varietur.* The same is true in the Vermont reprint except the omission of the general title of the pamphlet and the suppression without any notice of a footnote, containing a letter by Mr. C. H. Hitchcock with remarks by Mr. Billings, not complimentary to those who had made use of palæontological evidence, in working on the Vermont stratigraphy. Mr. Hitchcock, in quoting " Palæozoic fossils," Vol. I of the Canada survey, does not give the date of printing and publication, which is 1865 ; that is to say, four years later than Mr. Billings' paper of the 21st of Nov., 1861, making it a material impossibility for Mr. Hitchcock to use that volume in his Vermont reprint. Besides, Mr. Billings has taken care to state in one place in the volume, which has escaped entirely the attention of Mr. Hitchcock, that " the first twenty-four pages were reprinted with the following alterations. The notes on pages 10, 11 and 12 of the original are withdrawn." In fact those twenty-four pages have been so altered, that it is a new paper entirely different from the pamphlet of 1861, with new names, new figures, suppression or additions of many paragraphs, changes in the synonymy of species, and finally an addition of a new species.[1]

Mr. Hitchcock will find the notice referred to on p. 419, appendix. So Mr. Billings, although suppressing the footnote in 1865, has taken great care to notice it; while four years before Mr. Hitchcock suppressed it in his Vermont reprint without any notice, showing the truth of what I have said, "we see that the Geology of Vermont cannot be quoted as priority for the papers of Barrande and Billings nor even as an exact reprint, being both defective in regard to titles and contents."

VERMONT HISTORY OF THE TACONIC SYSTEM.

Mr. Hitchcock takes exception to what I say about his history of the Taconic system as being " full of reticence and even opposition." A few quotations will sustain my remarks. *Geology of Vermont*, p. 436 : " But throughout Canada, where Professor Emmons finds many Taconic rocks, Logan finds nothing lower than lower Silurian. Many have supposed that great aid was given by these discoveries (numerous primordial forms at Pointe Lévis) to the advocates of the Taconic system ; but there is surely little comfort to them in Sir William's conclusions. Prof. Jas. Hall op-

[1]The addition of *Archæocyathus profundus*, and the suppression of *A. Minganensis*, with additions of whole paragraphs to *Protozoa* and to genus Archæocyathus obliged Billings to make room; and he suppressed the obnoxious footnote. But unwilling to lose such an important document as the letter of Mr. C. H. Hitchcock, he retained it and has it reprinted in his "Remarks on the Taconic controversy" ('Canadian Naturalist,' April, 1872, page 11 separate).

posed these conclusions of Sir William E. Logan, holding that the stratigraphical evidence was in favor of regarding the Quebec group as middle Silurian, just as Logan had held it." *Op. cit.* page 435: "If the Georgia slates are Primordial, then the upper part of the Taconic system must be Silurian according to the definition (a curious interpretation of Charles H. Hitchcock). Perhaps Prof. Emmons will not hesitate to grant this." "The latest aspect of the controversy rests upon the age of the red sandrock and Georgia slates. These were both regarded as middle Silurian by Prof. Hall and others. The descriptions of the *Oleni* (Barrande) from the Georgia slates called out M. Barrande's views, who unequivocally pronounced the rocks containing such fossils to be equivaalent to those containing the primordial zone of life in Bohemia, that is, to the Potsdam sandstone of America." This is an erroneous interpretation, for M. Barrande never said that the Georgia slates were the equivalent of the Potsdam sandstone.

"This does not agree with Emmons' views, for he distinctly places the Georgia slates (Taconic slates) unconformably below the Potsdam sandstone. Yet M. Barrande supposes that his views will support the Taconic system."

Yet Mr. Hitchcock says that his "sketch is a more truthful exposé of the Taconic system of Emmons than the writings of Jules Marcou." Adding "if one were inclined to be humorous he would inquire if it were not possible that Mr. Marcou was trying to suppress the Taconic system;" because "Mr. Marcou makes the Potsdam a part of the Taconic;" saying "it is my belief that he (Emmons) would have abandoned the Taconic system rather than have incorporated the Potsdam with it." If Mr. Hitchcock will consult the 'Proc. Amer. Acad. Art and Sc.,' Vol. XII, p. 189, he will discover in a letter of Emmons addressed to me the following remark: "as it regards the Potsdam sandstone I think you are right, so far as Owen's discoveries are concerned. It is a point I have not thought of, and is new to me. The suggestion is a good one, and must be met."

DATE OF THE PUBLICATION OF THE REPORT OF VERMONT.

Although the title of the paper of Mr. Hitchcock seems to imply that he will give the exact date of publication of the Report of Vermont, he does not; but he speaks only of a circular bearing the date Jan. 28, 1862. The distribution was not made in Boston until two months later, on March 21, as it is recorded in the library of the Boston Society of Natural History; and as I have said in my paper "The Taconic of Georgia and the Report on the Geology of Vermont." I continue to maintain that the date of publication of the Geology of Vermont instead of being Oct. 1, 1859, or Oct. 22, 1860, or 1861, is the end of March, 1862.

The errors of dates of the Messrs. Hitchcock's geological publications, on which Mr. Charles H. Hitchcock bases his claims of priority against me, are obvious. I shall give one more example. The book and geological map of E. Hitchcock entitled: "Outline of the Geology of the Globe and of the United States in particular," is claimed by Mr. C. H. Hitchcock in his paper "The Geological Map of the United States" (St. Louis, Oct., 1886) to have been published January 1, 1853 (date of the Introductory), which is the day when "the manuscript and maps were delivered to the publishers." On the back of the title-page, we read: "Entered according to Act of Congress, in this year 1853, by Phillips, Sampson and Co., in the clerk's office of the District Court of the District of Massachusetts." Having applied to the Librarian of Congress, at the copyright office where the registers are kept, I have received the following answer.

Library of Congress, Washington, June 27, 1888 — Sir: In reply to your communication of the 25th inst., I have to advise you that Hitchcock's "Outline of the Geology of the Globe and of the U. S." does not appear to have been entered for copyright by Phillips, Sampson and Co., in the District clerk office, District of Mass., in 1853.

Very respectfully,

A. R. Spofford, *Librarian of Congress.*

THE TWO EDITIONS OF THE GEOLOGICAL MAP OF VERMONT.

Mr. Hitchcock tries to make me say that because I have spoken of two editions of his geological map of Vermont, I adopt the principle that the date of publication of a volume "does not depend upon the issuance of the volumes in bound form. Excerpts that have been distributed or exhibited to scientific men before the appearance of the bound volume, are regarded as having been published. Thus he (Marcou) says of the general map in volume 2, 'The map had two editions. The first one, distributed in December, 1861, contains, etc.' He (Marcou) allows that this map was published in 1861. Then the whole of Part II (Report of Vermont) must have been published as early as September, 1861, since it had been distributed and exhibited to scientific men just as much as the map had been."

It is an explanation of principles entirely inaccurate, and an application of which I never was guilty. A geological, like a topographical map, is a complete work which always stands by itself. The geological map of Vermont can be used, and is used without the report, which does not even contain a single paragraph of description or explanation of it. On the contrary, a part of a volume gives only an incomplete portion of a work, and its exhibition and distribution to scientific men do not involve as a consequence its issue at that date; it can only be regarded as a private communication of an incomplete work.

This is so true that Mr. C. H. Hitchcock exhibited this same map alone, before the Boston Society of Natural History, without reading or showing any part of his report, being satisfied with the announcement "that there is no foundation for what Mr. Emmons called his Taconic system (a mixture of the Silurian and Devonian)." (Proceed. Boston Soc. Nat. History, Vol. VII, p. 239, 1860.)

PRIORITY OF THE SUGGESTION, DEFINITION AND DESCRIPTION OF THE "GEORGIA SLATES."

Mr. Hitchcock contests my right of "priority of the proposal of the name Georgia slates." Here are the dates and facts.

October 17, 1860.—Mr. Marcou uses for the first time the name slates of Georgia in a communication made before the Boston Society, in a joint paper with Barrande, and he refers them to the Taconic system of Emmons (Proc. Boston Soc. Nat. History, Vol. VII, p. 375, published November 23 and December 24, 1860).

July 20, 1861.—Accepting Mr. Hitchcock's date, as given in his late pamphlet of July 20,[1] or August 10, or September, 1861, for the printing, distribution and exhibition to scientific men of Part II, Vermont report; it will make no difference for his claim of priority of the proposal of the name Georgia slate; for Mr. Hitchcock's knowledge at that date was a complete blank of everything relating to the question; as well as to the exact position of the locality where the primordial fossils have been found, and as to the stratigraphic place they ought to occupy in the classification and nomenclature of American geology. A few quotations and explanations

[1] The note added does not "indicate that everything up to that point, including the account of the Georgia slate, had been printed by July 20;" but only that at that date the author thought proper to add a note to his manuscript, which is very different. Printing and adding a note are two things entirely distinct.

are necessary. Mr. Hitchcock says "The Georgia group was proposed by me to embrace two other terranes (*sic*) as well as the one under consideration, and the name of Georgia was employed because the whole group was exhibited within the township with characteristic fossils, and its use did commit the report to any one of the three views that had been proposed for its age." Let us examine the value and correctness of that definition. In the Vermont report there is no trace that the Georgia group embraces three groups called terranes (*sic*) and it is classified as Upper Silurian, being between the quartz rocks and the talcose conglomerate. The definition given in the report, p. 358, is: "We use the term Georgia group to designate this terrain,[1] from the town of Georgia in Franklin county, where it is developed in its full proportions, and where the most interesting fossils have been found." Everyone would suppose from that definition that a good description of the Georgia group in the town of Georgia would follow as the typical place and original area of that group. Not at all; there is not a single word about the rocks covering the whole township of Georgia nor a single section local or general, of that township. All the lithology, range, extent and thickness, are taken outside of Georgia. The celebrated Parker's quarry is ignored completely, and its name is not even once given. It seems as if Mr. Hitchcock did not know from what part of Georgia township the fossils he spoke of came. If we consult his geological map, we see that he has not colored the original area of the Georgia fossiliferous slates, as belonging to his "Georgia group;" it being colored and referred to instead, as his "Oneida conglomerate." All the strata, which constitute my original *Georgia slates* group round Parker's quarry and those on Parker's farm, and even one mile farther east, on the western side of a brook which flows north and empties into St. Albans' bay, are not included by Mr. Hitchcock in his so-called "Georgia group." Nothing can show better the value of his "original suggestion" for the correctness of which he wants to be credited. His absolute want of knowledge had led him hopelessly astray in dealing with the original area and locality "where the most interesting fossils have been found," for he excluded the whole area from his "Georgia group." It is hardly possible to imagine a stratigraphy so extraordinarily erroneous. Mr. Hitchcock in his pamphlet "claims that the essential points of his definition of the

[1] In one paper Hitchcock uses terrane and in another terrain.

Georgia rocks have been accepted by Mr. Walcott to the detriment of those of Mr. Marcou."

For priority of suggestion and correctness of date of early publications, my claim contained in my joint paper with Barrande before the Boston Society, preceded Mr. Hitchcock by at least ten months.

As to the descriptions and sections of the typical and original fossiliferous area of the Georgia slates, Mr. Hitchcock has never published anything about it, even to this day ; and the only ones we have are (1) my description in the Proc. Boston Soc. Nat. History, Vol. VIII, December, 1861, and (2) a more complete description with all the details and figures of the celebrated Parker's quarry in 1880 ('Bulletin Soc. geol. France,' tome IX, pp. 23–24, Paris), and in 1887 " The Taconic of Georgia," etc. ('Memoirs Boston Soc. Nat. Hist.,' Vol. IV, pp. 112–113). In 1886, Mr. C. D. Walcott also published a description of the Georgia slates, at Georgia township, with a figure of a section on pp. 15–16, in his paper entitled : " Second Contribution to the studies of the Cambrian faunas" ('Bulletin U. S. Geol. Surv.,' No. 30).

The priority of suggestion, as well as of description of the "Georgia slates" at their original and typical area, belongs to me and not to Mr. Hitchcock.

Mr. Hitchcock ends his paper by saying : "The writer has no desire to disparage the value of Emmons' observations." This is a great change and a complete revolution of the opinions previously expressed by him ; for, until now, he has opposed Dr. Emmons' observations in all his writings, and in all his geological maps. Even his last geological map of the United States, of 1887, prepared to illustrate the "nomenclature recommended by the International Geological Congress," is hostile to the Taconic system, using in place the name Cambrian system, against the decision of the Berlin Congress of 1884, which has recommended the use of No. 1 only to designate the system containing the primordial fauna of Barrande and Emmons, until the meeting of the Congress in London, in September, 1888, shall decide about the name.[1]

[1] The International Congress, at London, was unable to come to any decision; and at its meeting of September 18, it was decided that no vote should be taken, either on the division of the Lower Palæozoic rocks into three or only two systems, or on the names to be used; so it remains an open question, leaving every one at liberty to use the nomenclature which he prefers. I shall add only that the general secretary of the committee of nomenclature, Prof. Dewalque, has accepted and recommended for adoption the report of the American committee, dividing these rocks into: Taconic (Primordial), Cambrian (second fauna) and Silurian (third fauna).

General Meeting, Nov. 21, 1888.

The President, Prof. F. W. Putnam, in the chair.

Dr. J. Walter Fewkes read a paper entitled "Observations on certain European Zoölogical Gardens and Aquaria," in which he considered certain representative Gardens and Aquaria which he had studied last summer on his visit to Europe.

Mr. S. H. Scudder followed with remarks in relation to the proposed Natural History Garden in Boston. He spoke of his observations of European gardens made many years ago, and although he had not the notes which he had then made, he remembered to have observed several things mentioned by the speaker.

Dr. Gardiner called the attention of the Society to the success of certain European zoölogical gardens in breeding dogs and of the revenue from the sale of these animals. The income derived in this way is considerable and in a way compensated the loss from death.

Professor Putnam spoke of a beaver dam which formerly existed in the neighborhood of the Museum of Comparative Zoölogy, at Cambridge. He commented on the popular interest in a garden which should exhibit animals in their native habits surrounded as nearly as possible by native conditions.

Professor Hyatt said that the paper of the Secretary should be published, and suggested the columns of the Sunday paper as a means of reaching a large number of those interested in the subject.

Miss Isabel Johnson thought some methods ought to be devised to increase popular interest in the subject and advocated small subscriptions from school children for the Natural History Garden fund.

Mr. H. D. Ross said that as the chairman of the sub-committee on conference he had taken some steps in regard to the house on the land at Franklin Park offered to the Society for a Zoölogical Garden. The Park Commissioners had promised to put it in thorough repair. He thought if the house could be used by the members of the committee in connection with raising the necessary subscriptions, for the exhibition of plans of the garden, and for other legitimate purposes, it would be very advantageous to the Society.

Professor Putnam thought that the plan suggested by Mr. Ross for having the house on the grounds an excellent one. It could be made use of in social meetings of the Society and meetings of the Natural History Garden committee.

Dr. H. P. Bowditch spoke of certain features of the Zoölogical Garden in Antwerp. He had found that the sale of animals had at this garden equalled the loss by death. He also said that citizens of Antwerp cannot visit the garden unless they are ticket holders, by which the Society is able to compel them to become members.

Professor Putnam called the attention of the Society to the nest and egg shells of a quail found within twenty feet of the Serpent Mound. These eggs were hatched on the 19th of September, much later than is ordinarily the case. The nest was taken immediately after the young left it and the egg-shells were now in their natural position; each egg shell showing how the young quail had cut its way out, leaving the larger end attached by a "hinge" to the rest of the shell.

General Meeting, December 5, 1888.

The President, Prof. F. W. Putnam, in the chair.

The following communication was presented :—

THE GEOLOGY OF NAHANT.

BY ALFRED C. LANE.

[ABSTRACT.]

Nahant has as a rocky basis three islets of igneous rock, which are connected with each other and the mainland by barrier beaches.

The main rock of Great Nahant is normally a coarsely granular diabase with a granitic structure. Beside a labradorite feldspar and augite, the rock contains constantly dark mica and magnetite, in microscopic quantity, together with the various minerals known as viridite (such as amphibole, chlorite and serpentine), also apatite, pyrite, etc. It is well exposed at the foot of Summer Street.

Opposite Pea Island, we find also a variety containing pseudomorphs of olivine, and at Black Mine a brown hornblende, attended by relatively little bastite, forms so much of the rock that it might be called a hornblende picrite. This is perhaps the rock sold in 1690 at three shillings a ton for an iron ore. It is not an independent rock, but merely a local facies.

The mica appears as one of the later cystallized components, and is probably due to the resorption of olivine by a residual magma containing potash, which thus formed biotite instead of or in addition to augite, as described by Rosenbusch.[1] The analysis of the Medford diabase, which, as described by Hobbs,[2] resembles that of Nahant in many ways, strengthens this supposition.

Along slickensides and veins and where the diabase is crushed, prehnite is developed. The intertwined structure described by Bentell[3] and Mallard[4] is often seen in thin section. The ready fusibility of prehnite to a blebby glass distinguishes it from feldspar. It is generally in radiating groups.

Near Saunder's ledge the rock is puzzling, being differentiated into more and less basic portions mutually inclusive. Occasionally feldspar is developed here in crystalline form.

The syenite of Little Nahant, although in many ways akin to the main mass, contains orthoclase and, microscopically, quartz as well as microliths of zirkon.

The brightly banded altered sediments at the east end of the peninsula, from Bennett's Head to the Shag Rocks, are the most striking feature to visitors.

The darker bands are a lydite or indurated quartziferous slate, in which the microscope reveals, besides a ground mass of minute quartz grains, rusty flecks of ilmenite and mica.

The lighter bands are largely made of microscopic garnets, to which calcite, epidote, quartz and other minerals of less importance are added. Chlorite tinges the rock green, hematite turns it red. The black lydite is a good touchstone. The lighter bands take the streak of minerals well. Both are good whetstones when of sufficient size and of even grain. The light bands are much like the Belgian whetstone. They are normally irregularly tubular or nodular, but are often confluent.

Small beds of diabase are intercalated in the sediments, which are not of themselves sufficient to produce such alteration as described. This is due to the great diabase sheet, whose upper limit is not known (the well at Mr. Schlesinger's shows that it is over two hundred feet thick). Under this sheet the sediments dip in every case,— at Nahant Head and also at Black Rock and John's Peril, where are also obscure outcrops. Between Dorothy's Cove and Pond Beach, boulders of nodular slate are found, the origin

[1] Mik. Physiog., II, 485.
[2] Bull. Mus. Comp. Zool., 1888.
[3] Neues Jahrbuch, 1887, p. 89.
[4] Bulletin Soc. Min. Francais, 1882, p. 195.

of which may perhaps be from the gap between Little and Great Nahant. On the northwest side of Little Nahant is another outcrop of sediments — seams of quartzite,— in some of which clastic grains of sand may yet be seen, and green slates of a waxy lustre like semifused specimens from the Oetzberg in Hesse.

Upward of five hundred dikes have been noted. They form probably from three to six per cent of the rock. They are mostly dike forms of diabase. The exceptions are, first, a few small dikes of diorite porphyrite (one such occurs on the east side of Bailey's Hill), which contains much reddish orthoclase or microcline in the ground mass. Secondly, there is a dike running about east across John's Peril, which is light green and dense. It weathers white, when the otherwise scarcely noticeable porphyritic crystals of feldspar make pits. It contains zirkon and gives a very strong sodium flame. It is a felsyte or more precisely, perhaps, a keratophyre.

The diabase dikes differ widely in looks, but all have a fine or coarse lattice of lath-shaped feldspar. Two or three hundred feet east of the steamboat wharf, there is a dike in which the laths are at times an inch long and very glassy. The southeast corner of Bailey's Hill is formed by a very large dike of what has been called labradorite porphyrite. The French name plagiophyre is simpler and more inclusive. The metalloids here and in many not ultra basic dikes occur in tree-like forms.

Just southwest of Pulpit Rock, striking northwest, is a good example of another class of dikes which have some of the bisilicates in porphyritic crystals. Besides augite, this particular dike has cavities where was once olivine. They are now filled with amphibole needles. I suggest the extension of the name lamprophyre for these dikes.

A transition to the lamprophyres, according to Rosenbusch's original definition, is made by a dike at Black Mine, which has a strike N. 12° E., in which case porphyritic crystals of diaclasite and olivine pseudomorphs lie in a base containing much ruddy mica and olive brown hornblende. This dike stands near the kersantites, but I suspect it is affected by a solution of inclusions.

The dikes are altered not only by atmospheric weathering, but also dynamically, a schistose structure being produced with well known mineral metamorphoses. This effect may be especially well studied at Bailey's Hill.

Robinson's history of Lynn gives the following list of minerals from Nahant: prehnite, chlorite, dolomite, calcite, epidote, quartz and lignified asbestus (metaxite, found near Maolis), prase, chert (probably an erroneous determination of the garnet bands), datolite (which I have not found) and corundum (which must have been from an erratic).

The main structural feature is the synclinal indicated by the sediments, which dip 47° N.W. (str. 40° N.E.) at Nahant Head, and at Little Nahant dip 70° S.E. (str. 52° N. E.).

Signs of this basin structure are also seen in the great diabase sheets, and to a certain extent in the petrographic varieties, but most especially in the joints and dikes.

One set of joint planes are always far more nearly perpendicular to all the rest than any other. They have generally less dip than the others, though near the contact with the sediments they are parallel to it, and they are seldom or never used by dikes, even where, as at Little Nahant, they stand at a high angle. They are the original horizontal joints of the sheets, of diabase allowing them to fold as do bedding planes—only with difficulty, as sharp flexures, crush-lines and numerous small faults show. The average strike and dip of dikes show the effect of folding plainly.

The faults are mainly parallel to the axis of the synclinal and up the hade, as the way they throw the dikes shows (the two parts being moved each toward the acute angle of intersection). A few, of generally greater throw, are in other directions, *e. g.*, one 450 feet east of Pulpit Rock. Most of the faulting seems to have taken place since the intrusion of the dikes, as the youngest set (strike N. 7° W.) is much affected thereby.

The separation of the dikes into groups is difficult, as dikes of like petrographic character have come in at different times, and the same set of joint planes has been repeatedly used. Good illustrations of complication are seen along Canoe Beach. However, the N. 7° W. joints seem to have been the last used, being injected mainly with very fine grained trap. Next older, are dikes along the N. 80° W. joints, not generally very basic. Still older are dikes whose strikes bisect the angle between the strikes of the first two sets, and a set, consequently, about parallel and perpendicular to the synclinal axis. This in connection with Daubree's[1] experiments lead us to look on the younger dikes as filling joints

[1] Dana's Geology, 3d ed., p. 802.

produced by a torsion perpendicular or parallel to said axis. There are yet older dikes which follow no joints.

Turning now to unconsolidated formations, we find that the coating of boulder clay is but scanty, and that the bed rock has glacial polish and striæ (N. 30° W.).[1] The outjutting points, as, for example, Cedar Point, often show the shock and lee structure well, even where it could not be long preserved while the water was at its present level. These points show that the ice could not have profoundly affected the topography; and, in view of the symmetrical position of the contact beds, one is tempted to suppose that the island may have been preglacially a hill preserved from erosion by a trap capping.

Signs of postglacial oscillation of the sea level are seen in elevated gravels (*e. g.*, back of the Union Church) and in tree stumps below high tide mark. A number of stumps have been recently removed from the marsh back of Pond Beach, and they are reported from various other points. The local impression is that the present motion is one of submergence. The two swamps,—one fresh and one salt water,—will soon be redeemed.

The beaches range in slope from 2 : 100 to 30 : 100, and vary accordingly in coarseness. Lynn, Little Nahant and Pond are well developed barrier beaches. A curious feature is the scalloped crests produced by high storms. The breaking waves act like a row of fountains. The breadth of these scallops is to their depth as 3 or 4 : 1.

Since 1860 the east end of Lynn beach has increased much in breadth and height. This is due to the binding action of grass then planted on the blown sands. The beach is said to be losing on the west side.

The deposit of blown sand extends up on to Little Nahant. Trenches dug in 1855 by Mr. Simmons passed through three feet of sand before striking a black soil which dates from the time Nahant was forest clad. In 1704 penalties were enacted for cutting trees.

Part of Little Nahant is reserved for a sand pit, whence twenty tons were sold in 1887.

Mr. J. H. Emerton made a few comments on the meetings of the Society, which led to a discussion of some of the points mentioned.

The following paper was then read:

[1] The strikes are referred to true north, and a magnetic variation of twelve degrees is assumed.

ON THE SERIAL RELATIONSHIP OF THE AMBULACRAL AND ADAMBULACRAL CALCAREOUS PLATES OF THE STARFISHES.

BY J. WALTER FEWKES.

The skeleton of the actinal region of the starfish is made up of two series of paired plates, one of which is called the ambulacral, the other the interambulacral, or adambulacral.[1] These plates occupy a definite relation to each other, and are ordinarily given a different name and a different homology.

They have, it is true, in adult forms of the starfish very little resemblance in general character, for they differ in shape and position, one from the other, and while the members of one set, or series, extend across the ray of the arm and join on the median line, those of the other are limited to the border of the ray and do not approach at this line. One series bears no spines; the other is spiniferous. The members of one series alternate with the legs; those of the other lie on the sides of these organs, and although, at first sight, these plates differ so much that they are regarded of different morphology, they seem to be homologically the same.

It is the object of the present paper to consider the question of the serial relationship of these plates. An answer to this question is thought to have a very important bearing on the morphology of all Echinoderms, especially the homology of the calcareous plates which form the ambulacral areas of sea-urchins and starfishes.

It would appear that the pentagonal starfishes are nearer the Echinoids than the stellate genera, and it is possible that we can discuss the relationship of the starfishes and sea-urchins better if we know more of the manner of development of the calcareous plates in some pentagonal genus[2] of Asteroids. Asterina[3] is chosen as such a representative pentagonal genus and we may arrive at a better conception of the relationship of the ambulacràl and interambulacral

[1] I use these two terms interchangeably in this paper. The term interambulacral is not only the oldest but is embryologically more accurate.

[2] In the younger form stellate genera are pentagonal.

[3] The rich collecting grounds near the marine laboratory at Roscoff, France, furnished me abundant material to consider these and some other questions connected with the development of Echinoderms and I readily availed myself of an invitation to visit there for the consideration of this subject.

I take pleasure in expressing my thanks to Prof. Lacaze Duthiers for his kindness in opening the resources of the laboratory to me and granting me many facilities for work.

plates of starfishes by a study of the development of these structures in it as compared with Asterias, than by a study of stellate genera alone. This study and comparison are particularly desirable as far as the oral plates are concerned from the fact that it is supposed that the ring of plates surrounding the mouth in this genus (Asterina) is said to be formed on another plan from that in Asterias.

The following observations are published to support certain theoretical considerations which seem to indicate that, although so different in form and position, ambulacrals and adambulacrals are morphologically the same. It is held that in their origin and in younger conditions of their growth they are identical, and that in each we have the same structure now modified into an ambulacral rafter, now into an adambulacral. We may, in other words, regard the skeleton of the starfish arm on the actinal side as composed of a number of somites the alternate members of which are calcified so as to approach each other and to join on the middle line of the arm. It is theoretically supposed that typically in Echinoderms the calcification of each somite may be thought to surround the water tube of the arm, but that in the starfish the ambulacrals have the external half aborted and not represented, while in the adambulacrals both external and internal parts of the calcification are missing, the lateral portions only of the ring remaining.

In the sea-urchin, however, the plates corresponding with the internal ambulacrals of the starfish are wholly lost, while the lateral ends of the interambulacrals remain, and form the external so-called ambulacrals. In the mouth plates of both starfishes and sea-urchins we have plates, however, more closely approaching the theoretical type than any of the plates of the arm.

It is thought that a study of the mode of development of the plates of the body and arms of the pentagonal starfish, Asterina, ought to throw some light on the homology of the plates of sea-urchins and starfishes. Since we do not know how the plates of the sea-urchin form[1] we cannot yet build any very substantial fabric of homology on embryological grounds, but from what is known of the anatomy of the adult starfish and that of the adult sea-urchin we find many difficulties in our acceptance of the commonly taught homologies.

A primary difficulty in homologizing the ambulacrals of star-

[1] In the young Echinarachnius the plates in this area are very late to form.

fishes and sea urchins will at once be recognized when I mention the fact that many morphologists consider the ambulacral plates in Asterias, which are above or internal to the water-vascular system, as homologous to plates of the sea-urchin which are outside the same. An homology of plates in such morphologically different positions, one set external, the other internal, presents many difficulties, and it is thought that the morphology suggested in the following pages offers a better solution of the whole question of the relationship of these calcifications than that commonly given. A key to this solution is found in a study of the plates of the mouth.

In the oldest form of the Asterina young which Ludwig has figured (Pl. viii, fig. 106) we find that there are represented on the abactinal side of this starfish the following plates:

1. Dorsocentral.
2. Five terminals.
3. Five genitals, or basals.
4. Five first dorsals.
5. Ten marginals.

In a more or less schematic figure of a similar stage (p. 72), given in his text we have in addition:

6. Five unpaired "Intermediäre" (odontophores).
7. Thirty ambulacral rafters.
8. Thirty adambulacrals (interambulacrals).

In the latter figure, which is diagrammatic, the oral plates are represented together with the aboral and are affixed to the ends of the rays.

It will be seen from the list of plates mentioned that Ludwig has traced the origin of the majority of the primary plates of the body. There are, however, several remaining plates of the origin of which nothing is yet published. Let us take up the subject of the growth of these plates where he has left it, and trace the origin of certain other late formed calcifications which play an important role in the form of the adult of the Asterina. Our account especially concerns the adambulacrals, the dorsals of the arm, the sub-basals, the marginals and some others.

Two divisions of the Asteroids have been made, based upon other characters than the morphology of the oral plates, yet although other features, as the number of rows of legs, and the character of the pedicellariæ are also used in combination with the character of the mouth parts, still the homology of the mouth parts is the most important feature in this classification which is based on the character of these oral plates.[1]

Asterina belongs to that group of starfishes which is said to have an adambulacral mouth, while Asterias has the calcifications around the mouth formed by an ambulacral and adambulacral oral ring. It is, therefore, an object of this paper to show that the mode of origin of the mouth plates[2] in both these genera is similar, and that such a division does not hold good in younger stages of two representative genera.

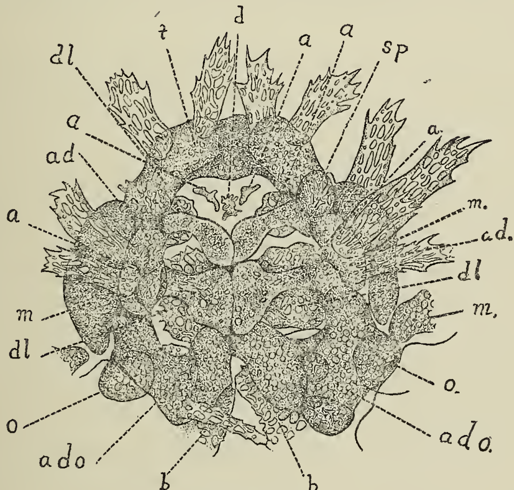


FIG. 1. *Asterina gibbosa.*

View of one arm of Asterina from the actinal side showing the relation of the calcareous plates; *a*, Ambulacrals; *ad*, Adambulacrals; *ado*, Orals; *b*, Genitals; *dl*, Dorsolaterals; *d*, Dorsals; *m*, Marginals; *o*, Odontophores; *t*, Terminal; *sp*, Spines.

The above figure represents an arm of an Asterina older than Ludwig's (fig. 106) in which we have represented the oral adambulacrals, *ado*, two pairs of ambulacrals, *a*, or ambulacral rafters, and the beginning of a third pair of these last mentioned calcifica-

[1] The Asteriæ Ambulacrariæ are said to have ambulacral mouth plates, pedunculate pedicellariæ, and ambulacral pores in two rows.

The Asteriæ Adambulacrariæ are said to have adambulacral mouth plates, sessile pedicellariæ, and ambulacral pores in a single straight line. See Viguier (Ann. Zool. Exp. et Gen. VII, 1878).

[2] I refer to the plates which surround the mouth and not to the odontophores alone, which are sometimes homologized with the orals.

tions. We have in addition, a terminal plate, *t*, and a single marginal, *m*, on each side of the arm. A single interbrachial, *o*, (odontophore) is also represented. This stage in the growth of the Asterina arm differs considerably from the oldest figure by Ludwig. Several of these differences are worthy of special mention.

Fig. 1 is believed to be the first correct representation of the relation of the actinal plates in an Asterina of this age. Some of the differences between it and a similar stage of Asterias are as follows:

The oral adambulacrals of Asterina.—The so-called oral adambulacrals, *ado*, extend from the interradii to the medial actinal line of the arm.

These extensions are regarded as the adambulacrals and not separate calcifications, but are thought to be the same as similar calcifications in Asterias, where they are, as elsewhere[1] shown, simply the ends of the ambulacrals.

They differ here, as in Asterias, from other ambulacrals, and seem to form like the spoon-shaped plates of Amphiura. These ambulacrals are believed to be homologous with the first formed oral ambulacral plates of Asterias, although in this genus they take on the form of ambulacral rafters, which they never assume in Asterina. These oral plates of both genera are thought to be the same plates differently modified in form, but it is not necessary to suppose that any new plates are thus far introduced in the formation of the calcifications of the mouth. In other words it is believed that the mouth plates of two representative starfishes are built essentially on the same plan, and that a division of starfishes into those with adambulacral and those with ambulacral mouths is not found in nature. A second character of starfishes with an ambulacral mouth is that the feet have a biserial arrangement. This is an adult character of Asterina, although a larval feature of Asterias as several naturalists have already shown.[2]

It can then be shown that the plates of the mouth of Asterias and Asterina are essentially similar in mode of formation but it is more difficult to say whether these oral plates are homologous with the other ambulacrals or adambulacrals of the arm. I believe that they are homologous in both cases with ambulacrals, and that they may be regarded as the distal extremities of the ambulacrals

[1] In my paper on the calcareous plates of Asterias, *op. cit.*

[2] Bull. Mus. Comp. Zool., Vol. XVII, No. 1.

and homologous with so-called adambulacrals, which are themselves simply modified[1] ambulacrals. It may be remembered that adambulacrals always follow ambulacrals of the same arm joint in their time of development. The oral mouth plates are the first formed plates of the actinal region of the body and no adambulacrals antedate them in time of formation. As ambulacrals ordinarily precede adambulacrals we may regard them as ambulacrals.

A second fact which looks as if they are ambulacrals is that in Asterias they have in the adult a resemblance to ambulacrals and have the same relation to the feet. Adambulacrals of the body bear, however, both in Asterias and in Asterina, spines which are wanting on ambulacrals, but which are present on adambulacrals of the arm. This would look as if they might be adambulacrals in both cases.

The time of the relative appearance of plates in Echinoderms is not ordinarily regarded as an evidence of homology, and it might well be said that the fact that the first orals are the first actinal plates to form, while adambulacrals always follow ambulacrals, does not prove that the first-formed plates are ambulacrals.

As far as their resemblance to ambulacrals in Asterias goes, we might also say that they also resemble adambulacrals but this argument is not conclusive. The objections to both views are important, and while there seems no good reason for calling them one or the other it appears that we might regard them the same, and that they are calcifications which might well be given a new designation for convenience, rather than as an expression of a belief that they are morphologically different. I should therefore not accept the designation of adambulacrals, given by some naturalists to these plates, and I think the mode of their development does not justify our accepting the classification of Viguier, who divides starfishes into those with an adambulacral and those with a combination of ambulacral and adambulacral mouth plates.

There are other facts to which attention is called in connection with those illustrated by fig. 1. The first interbrachial, *o* (odontophore), is in the same position in the young Asterias and the young Asterina; the first interbrachial lies between the distal ends of two successive ambulacrals, not at the extremity: the first marginal bridges the interval between the edges of the terminal and the odontophore. These common characters of both genera are

[1]The modification is the result of partial calcification, or rather of calcification now in one region, now in another, of a supposed primitive calcareous ring.

thought to show the close likeness of the young of Asterias and Asterina. If we should consider the aboral side of the body we should notice other resemblances. The terminal is cap-like in both, and in both Asterias and Asterina shields the last formed ambulacral rafters as represented for Asterina in fig. 1.

Evidently thus far in the growth of the two genera there is perfect accord as far as the oral plates are concerned and we may conclude that pentagonal and stellate asteroids arise from a starfish with these characters.[1] Prior to this stage there is nothing to indicate that one is to have a pentagonal, the other a stellate form.

On the aboral side we find another common feature in these two genera. We find in both the medial row of dorsals formed in the same sequence and with the same prominence. In both genera this prominence is lost in later stages, but in early forms they are identical. Moreover, we notice that dorso-lateral plates of the arms begin in the same way, but soon they lose their resemblance, one genus passing into a pentagonal, the other into a brachiated asteroid.

The adambulacrals, *ad*, of the arm of Asterina form *between*[2] the marginal ends of the ambulacrals as in Asterias. They follow the same law in the time of formation and those nearest the mouth are developed first. They originate in pairs, while the ambulacrals are well formed before the intermediate adambulacrals appear.

It would be interesting to turn to the origin of these plates in these typical genera in order to discover how far back in the history of these starfishes this difference, if any, extends, and to note any variation in growth of the two forms. It would seem as if embryology ought to throw considerable light on this basis of classification. Are these plates in the mouth parts of Asterina formed in a different way from the plates of an Asterias, or are the components of the circle of mouth plates simply the same, only differently modified in each case?

I believe that in both genera they are the same, and that the same plates in one instance assume the form of adambulacrals,

[1] In order to determine the sequence of plates in another pentagonal starfish, I undertook the study of the development of Palmipes, but was unsuccessful. I was able, however, to observe a novel fact in regard to the ova of this genus. A mature female Palmipes laid strings of yellow eggs in my glasses. I am not familiar with any Echinoderm which drops the ova in strings as in this genus. Ova were deposited at Roscoff in August.

[2] While this is their primary position, it becomes ultimately, however, more or less lost, and as in Asterias in the adult it is almost impossible to make out.

in the other of ambulacrals and adambulacrals, but that they are really in both cases homologous.

The marginals of the pentagonal starfishes, as we might expect from their relation to sea-urchins, reach a much greater development than the same plates in stellate genera. This is what we should find if these are nearer the Echinoids since I look to the marginals for the homologues of plates in the urchins formerly regarded as adambulacrals. In the starfishes these plates form along the sides of the arms although, as in Asterina, and other pentagonal starfishes, the interval between them is often filled up by a number of interbrachial plates. In sea-urchins, however, the interbrachial plates fail to form between marginals, and the marginals of adjacent rays are not separated but always remain in contact. The formation of interbrachials in starfishes of a pentagonal form is manifestly necessary on account of the rapid growth of the arm in stellate directions. In Palmipes, the interbrachials are enormously developed while in Asterias they are small in number and rudimentary. In Echinoids, as a general thing, they are wanting.

The later stages of formation of the pentagonal form of Asterina result frequently from the interposition of new marginals placed outside the marginals already formed. These originate between those already formed and the interambulacral, and the first pair arise near the interbrachial ends as represented. The second interbrachial originates as in Asterias. The marginals are centripetal *i. e.*, the younger are nearer the axis than the older, not as is the case in the ambulacrals and dorsals, centripetal, *i. e.*, those nearest the terminal being the latest found.

In Asterias I have shown that the body plates between the terminals and dorsocentral form before those which lie between the genitals and dorsocentral. In Asterina the plates between the genitals, *b*, and dorsocentral, form before those on the radial lines. I expressed a doubt in my paper on Asterias whether these plates ought to be called underbasals. In Asterina we might call them underbasals and suppose that they are belated in Asterias. We may say, considering the fact that the pentagonal form is that to which the development of the young Asterina is tending by virtue of the growth of the plate of the actinal region, that we may thus explain the early appearance of these plates.

From what has been given it follows that the so-called interambulacrals or adambulacrals originate in Asterina as in Asterias between the marginal extremities of the ambulacral rafters, and differ from other plates of the body and arms. I think we can associate them together and regard them as serially homologous, and suggest the following explanation for their difference in form. They are different parts of a supposed ring, surrounding the water vessel, and are calcified in different regions. While in the case of the ambulacral rafters the portion above the tube is calcified, in the adambulacrals the lateral regions are formed into plates.

It has been shown that the oral plates of Asterina are formed like those of Asterias and that there is no fundamental difference between them great enough to base a classification upon. As we have seen, the manner of development of the mouth plates of both Asterias and Asterina, is similar and we may conclude that in both the mouth parts are homologous and that in the one case they assume the form of adambulacrals and in the other of ambulacrals, but that in both instances they are serially homologous calcifications.

It will be noticed that in both Asterias and Asterina the adambulacrals form between the distal ends of the ambulacrals. While they are serially to be compared, the adambulacrals simply differ from ambulacrals in their time of development and their limitation to the border of the ray. They have spines which ambulacrals want, but there seems no good reason to regard their homologies as distinct. We have, in other words, in the starfish arm, alternate pairs of ambulacral plates on the under side of the arms. Some of these extend to the median line and form the true ambulacrals, while others remain on the periphery and form the so-called adambulacrals, or interambulacrals, of authors.

If now we turn to the sea-urchin we find the case just reversed. The alternate plates which in the starfish are on the periphery are here extended to the median line below or outside[1] the water-vascular system, while the ambulacrals of the starfish are wanting in the adult sea-urchin. The marginal plates in both instances are largely developed and in the sea-urchins form the so-called interambulacrals. It seems, therefore, since ambulacrals of starfishes,

[1]It may of course be asked, How do you know that the ambulacrals, so called, of the urchins, are not simply the lower (outside) half of the ring of which the ambulacrals of the starfishes are the inside ring? We do not know that such is not the fact, but it is thought the spherical development of the urchin can best be explained on the supposition that the ambulacrals of the urchin are homologous with the adambulacrals of starfishes.

and interambulacrals of sea-urchins are homologous, that the difficulty is very much lessened in our comparisons of sea-urchins and starfishes.

The former may be known as echinoderms in which serially homologous plates in one case grow externally to, in the other internally to, the water system.

In the starfish we have ambulacral rafters joining at the middle line, while the so-called interambulacrals retain an embryonic condition and in that they do not approach the middle line, remaining at the border of the starfish ray as the adambulacral. In the sea-urchin, however, the condition is just reversed, for the ambulacral rafters are here wanting, and are only represented in a mouth plate known as the auricle, while the alternate ambulacrals have grown to join at the middle line outside the water-vascular system of tubes. It will thus be seen that I regard the ambulacral rafters of the starfishes as unrepresented in the sea-urchin, while the adambulacrals are homologous to those plates which are ordinarily called the ambulacrals. The adambulacrals in the starfishes are only ambulacrals, which alternate with ambulacral rafters, and are serially homologous with them. From the fact that they lie at first between the ends of the ambulacrals the old name of interambulacral is a convenient one by which to designate these plates, remembering, however, that they are the same as the ambulacral.

The plates in the Echinoids called adambulacrals which lie between the system of plates generally known as ambulacral are regarded as the same as the marginal plates of the starfish. An Echinus-like condition of these plates is seen in the pentagonal larva of Asterina.

We know from Ludwig's paper the early form of the oral plates in Asterina. Although my studies of later larvæ differ somewhat from his, yet still they agree as to the place of formation of the earliest formed plates. We know also the history of the growth of the oral plates in Asterias.[1] We have enough observations to compare the manner of growth of these plates in genera widely different and representatives of the two great groups into which starfishes have been divided.

The mode of development of the oral plates of both Asterias and Asterina seem to me to show that both adambulacrals and ambulacrals are simply modifications of the same elements, and that in

[1] The relationship of these plates in Asterias will be seen in a paper on the plates of this genus. Bull. Mus. Comp. Zool., Vol. XIII, 3.

these plates we find one and the same plates with the characters of both. Farther out on the arms this common calcification either appears as an ambulacral rafter, or an interambulacral, and assumes very different forms; but in the oral plates we have structures which partake of the character of both, or rather of our supposed calcareous ring surrounding the water-vessel.

A comparison of the calcifications of starfishes and sea-urchins[1] may be seen in the following table:—

Starfish.	Sea-urchin.
1. Ambulacral rafters.	1. Wanting.
2. Peripheral ambulacrals, generally called adambulacrals.	2. Ambulacrals.
3. Marginals.	3. Adambulacrals.

The mouth parts of both starfishes and sea-urchins take the form of both ambulacral rafters and adambulacrals.[2] The condition of the mouth plates in the young starfish is similar to that of the sea-urchin for the ambulacrals of the starfish resemble in position the auricles of the sea-urchin.

If now we compare calcareous plates of the body of the starfish and sea-urchin we find this interesting fact. All the plates of the abactinal region of the starfish are practically unrepresented in the sea-urchin. The interbrachials of starfishes are wanting in Echinoids.

The following may show in a tabular form the relation between certain plates in these groups:

Starfishes.	Sea-urchins.
1. Dorso-central.	1. Dorso-central.
2. Underbasals, radials.	Wanting.
3. Connectives.	
4. Genitals.	4. Genitals.
5. Terminals.	5. Oculars?
6. Interbrachials.	6. Wanting.

The failure of the underbasals and radial body-plates to form in the sea-urchin has brought it about that the genitals and radials

[1]The homologies here presented are essentially the same as those already published by Ludwig as far as the relationship between the ambulacrals of the starfish and the adambulacrals of the sea-urchin is concerned.

[2]Or more accurately speaking we may say that the elements of an ideal calcareous ring surrounding the water vascular system is in the case of the mouth plates almost wholly consolidated into a ring.

still adjoin the dorso-central, and the whole abactinal region of the body of the starfish is represented in Echinoids by that small area which lies within the circle of the oculars. In this area there are several small plates (periproctal plates, Sladen), which are simply rudiments of the plates of the starfish in the same region.

Of the plates of the arms we have the following calcifications of the starfish arm unrepresented in the sea-urchin.

1. Dorsals.
2. Connectives.
3. Dorsolaterals.

The bearing of the above comparisons and their theoretical importance are explained by the following supposition. It is supposed that the ray of the starfish is composed of a number of rings or joints strung together. These joints may be composed of two parts ; one enclosing the water vascular and nervous system, the other the digestive, forming the body cavity. The part related to the water vascular system forms the calcification of the actinal region of the arms. Each typical segment of the actinal region may be regarded as a calcareous ring formed of two halves, found one on each side of the medial line. These halves may or may not join. In the primary somites of the starfish the parts of the ring above (inside) the water system are developed and join. In the secondary segments, lateral parts are represented in the starfish. In the sea-urchin these latter form outside plates which join on the middle line.[1]

From this it appears that while the so-called adambulacrals of the starfish are homologous with the so-called ambulacrals of the urchin, the exact comparison should be with different regions of the ring in the two groups, for the ambulacrals of the starfish belong to the primary, those of the sea-urchin to the secondary segments.

In the mouth plates we find the nearest approach to a complete ring of calcification in both sea-urchin and starfishes, or we have,

[1] The term "primary segments" of the starfish arm may be used to apply to those segments, when the calcifications of the ideal ring inside the water system are developed and those outside the same are wanting.

The term "secondary segments," on the other hand, refers to the adjoining somites, each of which lies between the primary in which neither the portion of the calcareous ring above the water tube nor that below it is calcified, but only those on either side.

The primary and secondary somites are alternate segments of the arm.

In the primary ambulacral the portion of the calcareous segment inside the water system is developed in the starfish and the outside portion is wholly wanting in the Echinus. In the secondary ambulacrals the lateral parts of the ring are represented in the starfish and the outside in the urchin.

in other words, a segment formed of both the primary and the secondary somites of the arm united.

In conclusion it may be said that observations have shown that the oral plates of Asterina form like those of Asterias, and that the so-called adambulacral (secondary ambulacral) form between the ends of the ambulacral rafters (primary ambulacrals). From these observations we may conclude that the oral plates of Asterina, and Asterias, once supposed to be formed on an entirely different plan, so different in fact that this supposed difference has been made one basis of classification, resemble each other in an embryological point of view, and best illustrate our hypothetical calcareous ring.

Summary.

1. There is no difference in the way the mouth parts of a typical representative of the group of starfishes known as Asteriæ Ambulacrariæ and Asteriæ Adambulacrariæ form in the development of the two groups.

2. The arm of a starfish is made up of somites or segments, and the water vascular system of vessels may be supposed to be primarily surrounded by a calcification. The theoretical ring of calcification is most closely reproduced in its typical form in the plates surrounding the mouth.

3. Ambulacrals and adambulacrals are portions of the annular calcification of successive segments and are serially homologous.

4. The ambulacrals of starfishes are not represented in sea-urchins except about the mouth where they appear as auricles.

5. The adambulacrals of starfishes represent the ambulacrals of sea-urchins, and complete the external portion of the problematical ring of calcification which is absent in Asteroids.

6. The marginals of Asterias are homologous to the so-called adambulacrals of sea-urchins.

Primary Spines of Echinoderms.

Anyone who studies the young of our common starfish, Asterias, will be struck by the relatively large size of those structures called spines which are appendages of the early formed calcareous plates. These spines are not only relatively much larger than those later formed but also differ somewhat from them in shape. They begin to form before the larval starfish passes out of that condition in its development which is known as the brachiolaria, and they preserve their relatively large size after the Asterias has taken on a stellate form.

Among true starfishes these spines are not peculiar to Asterias, but occur also in Asterina, in the genus Leptasterias, which does not have a true free-swimming brachiolaria, and in one or two others.

Among young ophiurans also, as in Ophiocoma, Ophiothrix and Ophiopholis the first-formed spines are relatively very large and in the genera mentioned have a peculiar shape which differs very considerably from that of later formed appendages of this name.

Nor is this fact of the relatively large size of the primary spines confined to the starfishes and ophiurans, for in the sea-urchins we find a similar condition. In the "sand dollar," Echinarachnius, where the spines of the adult are very small, we find that the first formed spines are very conspicuous and relatively of monstrous size. Here as in Asterias also these appendages are very early formed in the development of the animal, and before the arms of that larval condition known as the pluteus are absorbed, the beginnings of these structures can readily be seen in the body of the growing sea-urchin.

In Arbacia also the first-formed spines are very different in form from the adult spines and have relatively a larger size. In this genus the first-formed spines are spatulate and form a ring about the rim of the disk.

In the ordinary starfish, as pointed out by other investigators these early formed spines are more or less fan-shaped, while in Ophiocoma they have a hook-shaped form. In Asterias they are flattened and spatulate. In all cases they differ in form markedly from the later-formed appendages, found on the body of these genera. None of the spines which appear in the late larval stages of starfishes approach them in relative magnitude, and none have the characteristic shapes peculiar to those first formed.

It is believed that the form and size of these early formed spines are so characteristic that we are justified in regarding them as embryonic in their nature. What the fate of these structures is, whether they become permanent body spines losing their predominance by the increase in the size of the plates to which they are connected, or whether they are absorbed and their place taken by others, observation has not yet taught us. In some instances, probably the latter; in others probably the former, is the case. At all events their predominance in size and their early appearance would seem to invite us to regard them as of some importance in the morphology of the echinoderms, and they possibly tell some story of the phylogenetic history of the groups to which the genera belong.

It is an interesting and significant fact that in the genus Amphiura, an ophiuran which does not have a free pluteus stage, but in which the young are carried in brood sacs until they are quite well advanced, these spines are not developed. Unfortunately, the young of the starfish, Pteraster, which also carries the young in similar but not homologous sacs, is so little known that we are unable to say whether these spines are present or not, and the same is true of the so-called viviparous sea-urchin, Hemiaster. We cannot state whether these large early formed spines are limited to genera where the young stages are nomadic, and have plutean or brachiolarian stages. Nor has the physiological function of these appendages been discovered. It is probable that the uses which they perform may be different in different genera.

The physiological role of the flattened primary spines of Asterias is probably not the same as that of the hook-shaped primary spines of a genus like the ophiuran, Ophiocoma. In the former case we are tempted to regard them as connected with locomotion and possibly as survivals of similar structures in an ancestral form where they played an important part in the swimming of the animal. A somewhat similar function of modified spines is to be found in the "fins" of a genus of ophiurans, Ophiopteron, lately described by Ludwig.[1] It seems not impossible that in an ancestral form of Asterias now unknown, there existed organs not unlike those preserved in Ophiopteron which served as flappers by which the starfish was propelled through the water. I have carefully watched the young starfish in its varied movements but have never seen any flapping of these paddle-like spines in this genus. It is possible that the highly developed brachiolaria has vicariously performed the function of these organs so that in Asterias at least they are functionally useless although they still preserve somewhat the fan-shaped form of the ancestral organs where they may have served as flappers for propulsion of the animal.

In connection with the possibility that the flat, fan-shaped spines of Asterias may be in some way connected with propulsion one

[1] Zeit. f. wiss. Zool., Vol. XLVII.

naturally recalls the paddle-like spines of certain deep-sea echinoids. The flattened spines are well shown in the genus Dorocidaris (*D. Blakei*), and as far as their form is concerned they seem admirably suited for serving as paddles.

It is by no means necessary that we should suppose that these flattened spines serve in the young starfish or in the sea-urchin in which they are now found, for a locomotion of the animal from place to place. They may not, as the ctenophore combs, the homologous position of which with the spines is suggestive, serve as the only means of locomotion. We may suppose that they *assist* in the movements of the animals. The body of the echinoderm loaded with its heavy skeleton of calcareous plates cannot be raised by these organs serving by their action to offset the increased weight, but in conjunction with the legs they help in the onward movement. It is no new proposition that echinoderms move from place to place by means of flapping of parts of the body. Comatula can be seen to propel itself by a simultaneous movement of the arms and certain ophiurans are capable of a considerable onward movement by a rowing motion of their arms. In both these cases the amount of motion is limited and brought about by movement of the arms, while in neither case have the spines any particular modification in form fitting them for a greater resistance upon the water. In the genus Ophiopteron, however, it would seem that these spines have developed paddle-like structures well adapted to assist in the propulsion of the animal in combination perhaps with movements of the arms.[1]

It appears that we might then interpret the peculiar, fan-shaped[2] spines characteristic of the young starfish as survivals of a swimming organ, which has become functionless in the modifications of the body. While the body of the adult starfish, loaded with heavy calcareous plates, cannot be moved by these bodies, they still preserve a fan-shape which in an ancestral genus may have been of value in locomotion. While this problematical ancestral free-swimming echinoderm is yet to be found this fact does not certainly show that

[1] These " fins " of Ophiopteron, following Ludwig's description, are membranes supported on ten rods, so that they might be regarded as compound bodies and not single spines. This would seem to prevent their homology with the solid *single* spines of Asterias. If we consider them homologous to the spines which support the "net of Pteraster may they not be regarded as simple spines very much branched at the distal end?

[2] I suggest the name nectospines for these structures to distinguish them from the older spines which are of uniform diameter.

my theory is impossible. The evidence afforded by the form of the spines that they are adapted for paddles seems to render it plausible that in some ancestor they may have served for propulsion. Nor is the fact of the early appearance of these structures without a bearing on the subject of their phylogeny. Consider the fact that these nectospines form very early in the development of the starfish. When they first appear there is no indication of the stellate form of the body. The brachiolaria has not begun to be absorbed and there are but eleven of the calcareous plates of the future starfish formed. If the early appearance of structures means anything in ontogeny, certainly these early formed bodies have some story to communicate in regard to the relationship of the starfish. I suggest that they are homologous with structures which, if we knew the ancestry of the starfishes, would be found to exist as organs for swimming in some now unknown genus. This interpretation of the function of structures with which these primarily formed spines are homologous is but a suggestion, but as far as I know it is the only one yet proposed.

While we may possibly interpret these early formed spines of Asterias as survivals of swimming organs we certainly cannot suppose that certain hook-shaped structures early developed in certain ophiurans play the same physiological role, nor have they the same forms. The common features which they share are simply their early appearance, their large size, their limitation as a general rule to young larvæ, and their differences from the permanent spines of the adult. Before we consider these spines in ophiurans, let me call attention to a significant difference in the manner of origin of the primary spines and the true spines of Asterias, which points to a radical difference in these two structures. It has been recorded that some of the spines of the starfish originate as extensions from the plates already formed, when the starfish spine is not formed from a separate centre of calcification. This seems to be the only way certain immovable spines on the abactinal surface of the starfish could form *a priori* when they simply appear as tubercles from the plates. There are, however, many spines on the abactinal plates, as for instance those found on the dorsals which are formed from separate calcifications. The primary spines always arise from separate calcifications as Ludwig has shown in Asterina[1] and as I have described in Asterias.[2] We may then suppose

[1] *Op. cit.* [2] *Op. cit.*

that there are at least two kinds of spines in asteroids, one kind formed as papillæ from the plates with which they are solidly connected from the very first, the other formed from a separate centre of calcification which is later articulated with the plate. We must either suppose the spine homologous with a plate, or that these two kinds of spines are not homologous. It seems to me that the latter hypothesis is the better one, and that we can recognize two kinds of spines on the external surface of the Asterias. The former are the true spines, the latter simply extensions of the plates. Some of the former have fan-shaped bodies, others are simple shafts of uniform diameter. To the former or movable kind of spines belong those early formed in the young starfish.

Consider also the character of certain of the first formed spines of the echinoid genus, Arbacia. The first formed spines of this genus are paddle-shaped structures totally different in form from the permanent spines of the body. They form spatulate bodies around the rim of the young Arbacia long before the true spines appear. They are very prominent and can be well seen in the published figures by A. Agassiz and those by Garman and Colton.[1]

The first formed or spatulate spines of Arbacia resemble organs of locomotion both in form, in position and in general character. It would seem as if we have here a young echinoid with a likeness to the free swimming ancestor demanded by my hypothesis.

The spatulate spines of Arbacia are thought to be homologous with the ten early formed spines on the terminals of Asterias. Their position is the same as regards the abactinal surface, for in the Arbacia they are situated on the rim of the disk, while in Asterias they lie peripherally to the terminals. Moreover they occur in groups separated by a radius in which lies the primary water-tube. Calling this radius the radial axis, of which axes in both genera there are five, and the intermediate radii the interradials, each member of a pair of the spatulate spines of Arbacia and the fan-shaped spine of the terminal of Asterias lies between a radius and an interradius on the border of the circular disk, which limits the actinal and abactinal surfaces of the two genera. However my interpre-

[1] Garman and Colton (Stud. Johns Hopkins Laboratory, vol. 2, p. 253) have called attention to the fact that the young Arbacia aids its movements by pushing downward and laterally with its spatulate spines. They say nothing of the use of these organs in swimming. They find these spines cannot be bent upwards "owing to the projecting rim at the base of the spine above the obliquely inserted pedicle."

tation of the possible function of these bodies as motor organs may be modified, the homology of these structures in the young Arbacia and the young starfish Asterias seems to me well founded.[1]

In Echinarachnius also we have primary spines corresponding to the spatulate spines of Arbacia and the fan-shaped spines of Asterias, originating very early in the development of the young sea-urchin, as I have already elsewhere shown. These spines never take on the spatulate form which they assume in Arbacia, but they form before the absorption of the pluteus and while there are but five[2] plates around the apical area. Their mode of formation is identical with that of the terminal fan-shaped spines of Asterias. They originate in both instances as nodules or triangular spicules forming the base of the spine from which the shaft grows as a calcareous extension. Their trifid shape, their relative position as regards the radii, their predominance in size when a little older, are identical in Asterias and Echinarachnius. It seems not a mistake to regard them homologous. The same is true, as far as we know, in regard to the relationship of these early formed spines of Echinarachnius and Arbacia. They also are homologous.[3]

Accepting now the homology of these peripheral spines in Arbacia, Asterias and Echinarachnius, is there any observation to show that any one of these have free-swimming larvæ after the absorption of the brachiolaria or pluteus? I believe there is, and it is just in that genus which has the primary spines the most spatulate, and the best suited for flappers that we have an observation of great importance in this regard.

I have repeatedly taken, the young Arbacia, *free swimming*, *in the stage with spatulate spines*. I do not recall a large number of Echinarachnii after the absorption of the pluteus as found in the nets used in the capture of swimming animals, but I have repeatedly taken the young Arbacia *after it has absorbed its pluteus*, along with free-swimming pelagic organisms. From the mode of fishing with the "Müller net" it is of course possible that these young Ar-

[1] The origin of these spatulate bodies in Arbacia has not been traced, nor do we know, as already elsewhere stated, the relative homologues of the terminals in the young sea-urchin. Discovery in this line of work, however, will not change the fact that the relation of the spines to the radii is the same in Arbacia as in Asterias.

[2] I can only make out five; possibly there are ten.

[3] It may seem as if I have magnified the importance of a self-evident proposition. I believe it is of the utmost importance to recognize the fact that the first formed peripheral spines in Asterias, Arbacia and Echinarachnius are the same.

baciæ may have fastened to some floating body, but why not Echinarachnius in the same way? It looks as if Arbacia may be free swimming even after the absorption of the pluteus. In those Arbaciæ which were raised in aquaria I have never seen one rise in the water from the bottom of the glass, after absorption of the pluteus, and I have never seen a flapping motion of its spatulate spines, but the fact that in confinement it clings to the bottom is offset by the observation that I have often found it in numbers in pelagic fishing where the soundings were very deep.

The larval Arbacia is thought to resemble the ancestral form from which have sprung the stellate and echinoid groups of echinoderms. This problematical ancestor (Archiarbacia) may be supposed to have a disk-shaped body on the periphery of which are placed spatulate or lappet-like flaps supported by a calcareous axis. These marginal flappers are separated into five zones by the water tubes which extend beyond the margin of the disk in the form of embryonic tentacles. The calcareous spines which support the lappets are articulated with calcifications in the body. The mouth is situated in the centre of the under side.[1] Motion is produced by a flapping of the marginal lappets. While this problematical ancestor of stellate and echinoid echinoderms is marvellously like the Ephyra or ancestral form of the Acraspeda, it differs from it in the presence of calcifications. These calcifications become so heavy that the animal soon falls to the ocean floor, and later the likeness to the ancestor is lost. I am not prepared to defend the proposition that the problematical young of the stellate and echinoid is a direct descendant of the Ephyra. I think it is, but there are many difficulties to be explained. I suggest the name Archiarbacia for this ancestral stage.

Among other echinoderms, as in the ophiurans, we have the same primary spines as in the starfishes and echinoids, which although homologous in position have possibly another function.

It is a well known fact that the young of certain ophiuran genera bear at the tip of the rays certain hook-like spines, which differ very considerably in form from the ordinary spines of the genus upon which they are found. Such spines occur in Ophiocoma and Ophiothrix and have been well figured and described by several authors. They seem to be confined to those genera of ophiurans

[1] A primary fundamental difficulty is the cœlenterate character of the Ephyra, while this larva has a body cavity.

which have a pluteus, or at least the hooked spines do not exist on the well-known viviparous Amphiura.

It is a remarkable fact that the hooked spines, although not confined to the end of the arm, occupy a prominent position on the terminal segment of the arm. In some of the figures with which I am familiar, they are represented on the other segments, but they are not found elsewhere on the body of the ophiuran. I am also unaware that they have been detected in genera which have a direct development.

That these spines are not the same functionally as those with straight shafts ordinarily found in ophiurans seems to me not to admit of doubt, but it seems doubtful whether they are morphologically the same. I believe that in the genera mentioned they are embryonic structures. Are there any adult genera which retain these or similar embryonic hooked spines? We naturally turn in answering this question to the ophiurans from deep water, which from their habitat would seem to preserve embryonic features. Lyman describes from the rich collections made by the "Blake" a most interesting ophiuran which has similar hooked spines in specimens which may well be considered adult. The genus Ophiobrachion is remarkable in several particulars, but in none more so than in the possession, on the arms, of rows of uncinate spines. I have seen no homology of these spines with those of other genera suggested, and suppose that they are believed to be the same as ordinary ophiuroid spines, simply with hooks at the end. It seems to me, however, that they may be put in the same category as the terminal *embryonic* spines of the young Ophiothrix. In Ophiobrachion they are permanent in the adult.[1]

In Astrophyton, also, we have at the tips of the ray divisions of the adult spines which are directly comparable with the embryonic hooked spines of Ophiothrix. The resemblance of these spines to those of the adult Ophiobrachion is commented upon by Lyman in his description of the genus.

It seems therefore necessary to distinguish among the spines of ophiurans, as among starfishes, two different kinds of calcifications:

1. The ordinary spines of the adambulacral arm plates.

[1] Similar hooked spines occur in the adult Ophiothrix and in Ophiopteron, according to Ludwig. The latter has three different kinds of hyaline spines: 1, hooks; 2, rod-like spines; 3, supporting rods of the membranous fins.

2. Hook-shaped spines found one on each side of the terminals of the very young Ophiothrix, Ophiocoma and others, and on several plates in Astrophyton, Ophiobrachion and others in the adults. Both kinds of spines are movable.

In addition we have also:—

3. Fins of Ophiopteron.

4. Fan-shaped spines of Asterias.

The function of the hooked spines in Astrophyton is not doubtful to any one who studies the living animal. They are in this genus grasping organs. It is more difficult to say what function they performed in the larval Ophiothrix. Their absence in the viviparous Amphiura may possibly throw some light on this question.

A more pertinent question in our discussion is whether these hooked spines on the young Ophiocoma and Ophiothrix are homologous with the fan-shaped spines of Asterias and the spatulate spines of Arbacia. This question is a difficult one for us to answer from the fact that so little is known of their manner of development and their primary relation to the terminals and other plates. We are certainly justified in supposing that they are homologous, as far as all movable spines may be homologous, but we must wait until we have more observations to prove that these hook-shaped spines are homologues of the fan-shaped spines of Asterias or the spatulate spines of Arbacia.

General Meeting, December 19, 1888.

The President, Prof. F. W. Putnam, in the chair.

The following papers were read:

RECENT PROGRESS IN ICHNOLOGY.

BY C. H. HITCHCOCK.

The study of Ichnology in our country commenced in Massachusetts, whose legislature published the *Ichnology* in 1858 and its *Supplement* in 1865. Since the appearance of these reports excavations have been made at Turner's Falls by Roswell Field, Prof. O. C. Marsh, T. M. Stoughton and others, and very valuable slabs obtained. Other localities have been explored to a less extent. The study of the Ichnozoa, or the animals that made the tracks, naturally divides itself into three parts: first, an examination of the ichnites themselves; second, the restorations of the animals from their bones; and third, comparisons of the impressions made by living animals with the triassic imprints. I will, at present, speak only of the first.

Allow me to present, at the outset, a complete list of the triassic Ichnozoa, arranged in convenient classes. It will not be needful to state the reasons why certain species of the Ichnology are dropped. The number, after several erasures, has increased from 150 of the Ichnology to 170.[1]

ICHNOZOA OF THE TRIAS.

Marsupial.

Cunichnoides marsupialoideus E. H.

Birds, Pachydactylous.

Brontozoum giganteum C. H. H.
approximatum C. H. H.
minusculum E. H.
divaricatum E. H.
tuberatum E. H.
exsertum E. H.
validum E. H.
Sillimanium E. H.
Amblonyx giganteus (?) E. H.
Amblonyx Lyellianus (?) E. H.
Grallator cursorius E. H.
parallelus " "
tenuis E. H.
gracilis C. H. H.
cuneatus Barratt.
formosus E. H.
Leptonyx lateralis " "

(?) *Birds, Leptodactylous.*

Argozoum Redfieldianum (?) E. H.
dispari-digitatum " "
Argozoum pari-digitatum E. H.

Dinosaurs.

Anomœpus major E. H.
isodactylus C. H. H.
intermedius E. H.
curvatus E. H.
minor E. H.
cuneatus C. H. H.
minimus E. H.
gracillimus C. H. H.
Gigantitherium caudatum E. H.
minus E. H.
Hyphepus Fieldi E. H.
Corvipes lacertoideus E. H.
Tarsodactylus expansus C. H. H.
caudatus E. H.
Apatichnus crassus C. H. H.
Holyokensis C. H. H.
circumagens E. H.
bellus E. H.
Plesiornis quadrupes E. H.
pilulatus E. H.
æqualipes " "
mirabilis " "
Plesiornis giganteus C. H. H.
n. sp. " " "
Chimærichnus ingens " " "
Barrattii E. H.
Anticheiropus hamatus " "
pilulatus " "
Platypterna Deaniana E. H.
tenuis E. H.
delicatula E. H.
recta E. H.
varica E. H.
digitigrada E. H.
Ornithopus gallinaceus " "
gracilior E. H.
Tridentipes ingens E. H.
elegans E. H.
elegantior E. H.
insignis E. H.
uncus (?) E. H.
Trihamus elegans E. H.
magnus C. H. H.

[1] A catalogue of the Ichnozoa, as they were known in 1871, was prepared by me for Walling and Gray's Official Atlas of Massachusetts.

Reptiles and Amphibia.

Polemarchus gigas E. H.
Plectropterna minitans E. H.
gracilis E. H.
angusta " "
lineans " "
Triænopus leptodactylus E. H.
Harpedactylus gracilis E. H.
gracilior E. H.
crassus E. H.
n. sp. C. H. H.
Xiphopeza triplex E. H.
Toxichnus inæqualis E. H.
Orthodactylus floriferus E. H.
introvergens E. H.
Orthodactylus linearis E. H.
Antipus bifidus E. H.
flexiloquus E. H.
Stenodactylus curvatus E. H.
Arachnichnus dehiscens " "
Isocampe strata E. H.
Typopus abnormis E. H.
gracilis E. H.
Anisichnus [C. H. H.] Deweyanus E. H.
gracilis E. H.
gracilior " "
Comptichnus obesus E. H.
n. sp. C. H. H.

Batrachians.

Otozoum Moodii E. H.
caudatum C. H. H.
parvum " " "
Batrachoides nidificans E. H.
Palamopus Clarki E. H.
Macropterna vulgaris E. H.
divaricans E. H.
gracilipes " "
Cheirotheroides pilulatus E. H.
Shepardia palmipes E. H.
Lagunculipes latus " "
Selenichnus falcatus E. H.
breviusculus E. H.
Exocampe arcta E. H.
ornata E. H.
minima E. H.

Chelonians.

Ancyropus heteroclitus E. H.
Chelonoides incedens " "
Helcura caudata E. H.
Helcura surgens E. H.
anguinea E. H.
Amblypus dextratus E. H.

Hexapod Arthropoda.

Grammepus erismatus E. H.
Acanthichnus cursorius E. H.
alternans " "
alatus E. H.
anguineus E. H.
trilinearis " "
punctatus " "
rectilinearis E. H.
divaricatus " "
saltatorius " "
Bifurculipes laqueatus E. H.
scolopendroideus E. H.
Bifurculipes curvatus E. H.
elachistotatus E. H.
Copeza triremis E. H.
propinquata E. H.
punctata E. H.
cruscularis E. H.
Hexapodichnus magnus E. H.
horrens " "
Conopsoides larvalis E. H.
curtus " "
Harpipes capillaris " "
Sagittarius alternans " "

Inferior Arthropods, including larval forms and worms.

Harpagopus dubius E. H.
Stratipes latus E. H.
Hamipes didactylus E. H.
Saltator bipedatus E. H.
caudatus " "
Halysichnus laqueatus E. H.
tardigradus E. H.
Cunicularius retrahens E. H.
Sphæripes larvalis E. H.
magnus " "
Lunula obscura E. H.
Pterichnus centipes E. H.
Unisulcus Marshi E. H.
intermedius E. H.
minutus E. H.
magnus C. H. H.

Mollusca.

Bisulcus undulatus E. H.
Trisulcus laqueatus " "
Cochlea Archimedea " "
Cochlichnus anguineus E. H.
two n. sp.

Incertæ sedis.

Hoplichnus equus E. H.
poledrus E. H.
Ænigmichnus multiformis E. H.
Grammichnus alpha E. H.
Ampelichnus sulcatus E. H.
Climacodichnus corrugatus E. H.

Of lower arthropods and worms there may be half a dozen new species and two new genera.

Summary:

Marsupial,	1	Hexapod arthropods,	24
Pachydactylous birds,	17	Lower arthropods and worms,	16
Leptodactylous birds,	18	Mollusca,	6
Dinosaurs,	28	Incertæ sedis,	6
Reptiles and amphibia,	27		——
Batrachians,	16		165
Chelonians,	6		

The class of *Birds* is still retained for convenience, although the bones found in the west seem to point to reptiles as most probably the animals thus designated. It is still a fact that such special reptilian characteristics as would be exhibited in walking are absent in the genera Brontozoum and Grallator, while those creatures called Dinosaurs are thus referred, either because of the marks of front feet, heels to the hind feet or of tails. The bird group is also characterized by long legs, while most of the Dinosaurs had short legs, as indicated by their numerous steps. I do not change the reference of a group to Chelonians, though it is not satisfactory.

The Arthropoda are most likely to be referred to the lower classes ; yet the presence of only six feet in the impressions leads us to speak of them as *Hexapods*. They may not be true insects, but larval forms requiring further investigation before satisfactory references can be made out. Further statement of the reasons for referring various imprints to their lowly owners would involve a discussion of the third part of the subject which cannot be undertaken now.[1]

It will be proper to state a few facts about museums and localities before describing the new species.

THE AMHERST MUSEUM.

A few slabs have been added since 1865, and the arrangement of the rooms has not been changed since the printing of the catalogue. One slab shows a Brontozoum with two toes on one foot and three upon the other, as if the owner had lost a toe by fighting or

[1] Of modern authors, A. G. Nathorst has treated of the invertebrate tracks most fully in his *Memoir sur quelques traces d'animaux sans vertebræ, etc., et de leur portee paleontologique*, 1880. His bibliography notices several American authors, but he has evidently not seen the Ichnology of Massachusetts.

by accident. After the discovery of *Apatichnus Holyokensis*, I was able to point out several illustrations of the new species at Amherst, which had been overlooked in the preparation of the *Ichnology* and *Supplement.*

MUSEUM AT SOUTH HADLEY.

The Mt. Holyoke Seminary and College has taken great interest in Ichnology and possesses an admirable collection. Among the more important ones are the type specimens of *Apatichnus Holyokensis* and of six or eight new species from Wethersfield Cove besides *Anomœpus cuneatus* and *A. isodactylus* from the Dickinson quarry at South Hadley. The data for improved descriptions of *Brontozoum divaricatum* and *Plectropterna elegans* are present, as well as long rows of *Otozoum Moodii*, *Brontozoum giganteum* and *B. approximatum.* The slabs occupy a large room in the basement of the Lyman Williston Hall, while smaller specimens have been placed in an adjoining apartment.

The institution possesses several slabs from the Dickinson quarry about a mile north from the buildings. These are composed of a hard sandstone which preserves the impressions and casts with unusual distinctness. The marks of the heels of the hind feet, the front feet and the tails of Anomœpus are very plentiful. About sixty species of Ichnozoa are placed upon these tables and a careful description of every slab exists in the manuscript form.

This catalogue is like the one prepared by myself in 1865 for the Amherst collection, and printed in the *Supplement.*

THE WETHERSFIELD (CONN.) COVE.

This was known as a locality of footmarks fifty years since. The material is a soft fine-grained shale capable of preserving the more delicate markings. My father regretted his inability to explore this locality more fully. In his collection eighteen species are ascribed to this locality. In 1878, Miss A. C. Edwards, associate principal of Holyoke Seminary, authorized me to make explorations in behalf of her institution. The result was the gathering of thirty-five species of Ichnozoa, eight of them being new to science. The following is a list of them:

Brontozoum giganteum.	Anomœpus curvatus
divaricatum.	Platypterna Deaniana.
Sillimanium.	tenuis
Grallator cuneatus.	delicatula.
tenuis	Ornithopus gallinaceus.

Ornithopus gracilior	Harpedactylus n.sp.
Pletropterna minitans.	Comptichnus n.sp.
elegans	Corvipes lacertoideus.
gracilis.	Unisulcus minutus
lineans.	Bisulcus
Plesiornis giganteus, n.sp.	Trisulcus
Trihamus elegans	Acanthichnus cursorius
magnus.	var. trilineans
Triænopus leptodactylus.	var. alatus
Typopus abnormis	Conopsoides larvalis
Plesiornis æqualipes.	Cochlichnus, two sp.
Plesiornis n.sp.	Sagittarius, and others.

Other facts observed have led to a revision of the descriptions of *Brontozoum approximatum*, *Plectropterna elegans* and *Triœnopus leptodactylus*.

LOCALITIES IN NEW JERSEY.

Ichnites have been found at Whitehall, Milford, Plainfield, near Boonton, and elsewhere. The finest known slab came from Whitehall, and was obtained by Prof. George H. Cook for the museum at Rutgers College, New Brunswick. The rock is a fine-grained red sandstone, well fitted to preserve impressions. The following species have been observed upon it: *Tridentipes ingens*, *Brontozoum giganteum*, *B. minusculum*, *B. Sillimanium*, *Grallator formosus*, *G. parallelus*, *G. cursorius*, *Anomœpus intermedius*, *Apatichnus crassus* and *Anisichnus gracilis*.

The first species is shown in a row of five tracks and is the finest exhibition of this ichnozoan known to me. The *B. giganteum* shows a row of three tracks, the *B. minusculum* four, and the *G. formosus* seven. The *Apatichnus crassus* is a new species, based upon the illustrations afforded by this slab. The *Anomœpus* is found in a row, and shows the heels of the hind feet and the small five toed hands. I have visited the locality and find it capable of yielding other slabs after suitable excavations.

Milford.— The most novelties are furnished at Smith Clark's quarry in Milford, which has yielded *Grallator parallelus*, *G. cuneatus*, *G. gracilis*, *Chimrœichnus ingens*, *Polemarchus gigas*, *Argozoum dispari-digitatum*, *Otozoum parvum*, *Unisulcus magnus*, *Sagittarius*, and others. Most of the specimens examined are in the museum of Lafayette College, Easton, Pennsylvania. It is impossible to see much at the quarry; in fact no one knows the layer from which most of the above named species came.

I have referred to the *Chimœrichnus* two relief tracks of considerable size and representing only one-half of the foot. The front foot of *Polemarchus* may be seen on these slabs. It has four toes, and is not unlike the fore foot of *Anisichnus*. The Massachusetts locality has not yet supplied us with so much information about this most interesting animal as this slab from New Jersey.

This quarry has yielded also a small species of *Otozoum*. This is probably the same with an impression seen by me *in situ* on the Pennsylvania side of the Delaware river in 1868 and referred to Cheirotherium[1]. Except for the absence of the fifth toe, the similarity of our new species to the *Cheirotherium Barthii* of Europe is very striking. They are identical in size. The front foot is better shown than the hind one in the specimens, and is unlike the corresponding part of the *Otozoum Moodii*. The suppression of one toe gives us a trifid foot very ornithic in aspect. Another relief-track is that of a three-toed foot having the outer toes very much larger and longer than the others, such as is exemplified in the Hesperornis. Possibly this may lead us to the discovery of a true bird track in the Trias.

Prof. I. C. Russell has found tracks in Plainfield and near Boonton. Among his drawings from the latter locality I recognize *Brontozoum approximatum* and *Grallator formosus*.

LOCALITY AT YORK, PENNSYLVANIA.

Mr. A. Wanner of York, Pa., sent to the National Museum at Washington a slab showing impressions of *Anomœpus gracillimus*, *Brontozoum Sillimanium* and *Anisichnus gracilis*. He exhibited drawings of this slab and of other interesting fossils at the Cleveland meeting of the A. A. A. S. in August, 1888.

DESCRIPTIONS OF NEW SPECIES.

One of the best marked forms requiring description may be referred to the Apatichnus. The Mt. Holyoke Museum purchased a slab from Turner's Falls showing eight tracks of an animal allied to Anomœpus as respects the general form of the hind foot, the heel and the front foot, but having a fourth toe. A study of the various ichnites leads me to refer it to Apatichnus and the specimens enable us to understand better the intimate relationship of the two genera. The slab is 6ft. 3in. long, 2ft. 4in. wide, with eight tracks of the hind feet, two of the front feet and rather imperfect impressions of the long heel. The row is interrupted by a break in

[1]Amer. Jour. Sci. [2] XLVII, p. 133.

the stone and one of the impressions was made by the animal when walking across his first line of march. Handsome ripple marks also cover the slab. Following the example of the Ichnology, the more important characteristics of the animals as shown by their impressions may be specified as follows :—

Hind foot. Four-toed ; three of the toes bird-like, attached to the tarso-metatarsal bone, and the fourth placed higher up like a spur. Toes pachydactylous, joints not distinct on the type specimen, though they must conform to the usual number of three in the inner, four in the middle and five in the outer toe, in all cases including the ungual phalanx. The tarso-metatarsal bone was frequently brought to the ground, making an impression amounting to about one-half the length of the whole foot. Average divarication of the long lateral toes, 90° ; between the outer and middle and between the inner and middle, 45°. The fourth toe is usually parallel with the inner toe and divergent outwardly when not parallel. Distance of this mark from the foot, .8 inch. Length of the inner toe in advance of the heel, 2.35 inches ; of the middle toe, 3.2 inches ; of the outer toe, 2.85 inches ; of the foot, 4.5 inches ; of the fourth toe, 1 inch ; of the step, 13 to 13.5 inches ; of the stride, 26.5 inches, of the heel, 2.12 inches as exposed. Toes, .6 inch wide. Trackway from 7.25 to 8.25 inches wide. The claws of the middle toe turn slightly inward.

Front foot. Pachydactylous, pentedactylous, unguiculate, digitigrade. Phalangeal impressions indistinct. Width of foot, 1.85 inch. Length from anterior to posterior part, so far as exposed, 1.35 inch. Length of toes in order, beginning with the inner, .615, .750, .850, .750, .700 inch.

The locality is Lily Pond, Gill.

Upon slab No. $\frac{52}{4}$ at Amherst are several tracks of this species. The specific name is bestowed to commemorate the interest taken by the Mt. Holyoke institution in the subject of Ichnology and in view of the fact that the type specimen is in their possession.

Apatichnus crassus. The same genus appears upon the slab at New Brunswick from Whitehall. The inspection of drawings proves it to be a larger species, the length of the foot being 5.6 inches. The impression of the fourth toe is about one-half inch long and is removed from the foot mark itself nearly 1.5 inches.

Anomœpus isodactylus. It will not be necessary to describe the characters which this species has in common with the others of the genus, and I will therefore mention only what is distinctive. Divarication of the lateral toes, 65°; of the inner and middle, 32°; of the middle and outer, 32°. Length of step one foot; of the stride, 2 feet, not including the heel. Trackway 6.25 inches wide. Length of hind foot 4.5 inches; of the same including the heel, 8.5 to 9 inches.

Found at the Dickinson quarry, South Hadley. It may be the same with certain impressions at first called *Brontozoum isodactylum* by my father, but does not correspond to the reference by him of the most of that species to *B. divaricatum* in the *Supplement.*

Type specimens, No. 142 and its relief 128 in the Mt. Holyoke Museum. Nos. 112 and 126 represent the same species from another locality.

Anomœpus cuneatus. Divarication of the lateral toes 40°. Length of step 13 to 18 inches; of the stride 37 inches. Width of the trackway scarcely more than that of the track, except where the animal seemed to have paused in his march, as in the type specimen where the width is 7 inches. Long and distinct impressions made by the middle toe, and also by a slender tail.

From Dickinson quarry, South Hadley. Type specimen, at Mt. Holyoke Museum and the relief slab of the same in Museum of Dartmouth College. The species is recognized upon slabs Nos. $\frac{29}{1}$ and $\frac{50}{2}$ in the Amherst Museum, which came from the Lily pond quarry and the Howland farm in Gill. The foot of the animal is very like that of the *Grallator cuneatus.* At first the two were thought to be identical; but the shorter stride and length of step of the new form would seem to ally it with Anomæpus.

Plectropterna elegans E. H. The large number of illustrations of this species from Wethersfield in the Mt. Holyoke Museum enables us to perfect the description of the hind foot, the front foot not yet being known.

Hind foot. Tetradactylous, three toes directed forwards, the fourth being a spur at right angles to the heel. This genus differs from *Ornithopus* and *Tridentipes* in respect to the position of the spur, as it points backwards in the two latter. Heel narrow, tapering backwards and not wholly impressed. In this respect there is a departure from the normal character of the genus. Divarication of the front toes, 70°; of the inner and middle, 30°; of the middle and outer, 40°. Length of the spur or hind toe, .9 inch; of the inner front toe, 1 to 1.75 inch; of the outer front toe, 1.50 to 1.75

inch ; of the middle toe 2 to 3 inches ; of the heel, 1.75 to 2 inches ; of the middle toe beyond the rest 1.75 to 1.90 inch ; of the foot 5 to 5.2 inches ; of the step 18 to 21 inches. Toes slightly curved inwards. From tip to tip of the lateral toes 2 to 2.35 inches ; from tip of inner to tip of middle toe, 1.88 to 1.95 inches ; from tip of outer to tip of middle toe, 2.1 to 2.6 inches ; from tip of middle to end of spur, 3.75 to 4.8 inches. Width of trackway about three inches. Animal walks nearly in a right line. Locality, Wethersfield Cove. Descriptions based upon Nos. 53, 91, and 242 of the Mt. Holyoke Museum. Represented upon eighteen other slabs.

Brontozoum divaricatum. The Wethersfield specimens lead to a better knowledge of the species and the most important features are the following. The fractional numbers refer to the slabs in the Hitchcock Ichnological Museum at Amherst.

Type specimen No. $\frac{58}{1}$.

In the cabinet Nos. $\frac{5}{3}$, $\frac{6}{1}$, two steps, $\frac{16}{13}$, $\frac{17}{1}$, $\frac{20}{8}$, $\frac{25}{1}$, $\frac{25}{2}$, $\frac{32}{58}$, $\frac{32}{59}$, $\frac{33}{8}$, $\frac{33}{9}$, $\frac{33}{51}$, $\frac{33}{52}$, $\frac{33}{2}$, $\frac{34}{29}$, $\frac{43}{4}$, $\frac{52}{1}$, $\frac{52}{8}$, $\frac{58}{1}$.

Divarication of the lateral toes, 70° to 72° ; of the inner and middle, 25° to 28° ; of the middle and outer 45°. Length of the inner toe 7 inches ; of the middle toe, 9 inches ; of the outer toe, 7.75 inches ; of the foot 14 inches ; of the step 3 feet 6 inches ; of the stride 6 feet 6 inches. Width of toes 2.5 inches ; of posterior part of foot 6 inches ; of the claw one inch. Distance between the tips of the lateral toes 9.75 inches ; between the outer and middle, 7.5 inches ; between the inner and middle, 6 inches. Width of the trackway 18 inches. The toes are turned out slightly and deeply impressed in walking.

The smaller variety mentioned in the supplement, page 7, is reppresented upon Nos. $\frac{1}{3}$, $\frac{23}{11}$, $\frac{35}{37}$, $\frac{37}{3}$, $\frac{37}{27}$, $\frac{40}{5}$. The length of step may be stated to be 3 feet 3 inches, and of the foot 8 inches.

OTHER NEW SPECIES.

Concerning other new species I would remark briefly. *Plesiornis giganteus* is a quadruped with trifid feet comparable with *Brontozoum minusculum* in size, and related to a large Iguanodon from England, whose tracks are exhibited in the Museum of the Geological Society of London. The hind and front feet are nearly alike.

Trihamus magnus is very like *T. elegans* save in size. Its length of step is about 6 inches.

The hind foot of *Otozoum parvum* is 5 inches long besides $2\frac{1}{2}$ inches of heel. None of the specimens yet obtained show two tracks in succession. *Otozoum caudatum* was recognized twenty years ago in the Museum of Wesleyan University, the slab coming from Portland, Conn. It differs from the *O. Moodii* chiefly in the forward direction of the thumb. The marks of a tail do not necessarily indicate its presence in one species and absence in the other.

Illustrations of new varieties of the lower arthropods, worms and mollusca, will not be brought forward at this time, since our comparative studies of the tracks of living animals related to them are not yet completed.

MARINE SHELLS AND FRAGMENTS OF SHELLS IN THE TILL NEAR BOSTON.

BY WARREN UPHAM.

The fossils here described, occurring in drift deposits near Boston, and belonging wholly to species that are still living in Massachusetts bay, have been previously noticed by several observers, who have regarded them as evidence of a marine submergence within the Pleistocene or Quaternary period. Instead of this, my observations made during the past summer and autumn show that these fossils were transported from the bed of the sea on the north by the ice-sheet in the same manner as the materials of the drift, including its boulders and rock fragments, large and small, have been carried various distances from north to south, being often deposited at higher elevations than the localities from which they were brought. These glacially transported shells and fragments of shells cannot therefore be regarded as proof of the former presence of the sea at the height where they are found.

So long ago as during the Revolutionary war a fort was built on the top of Telegraph hill in Hull, near the extremity of the peninsula of Nantasket, and a well was dug inside the fort, of which the commander, Gen. Benjamin Lincoln, wrote as follows.[1] "There

[1]Geographical Gazetteer of the Towns in the Commonwealth of Massachusetts, 1785, p. 56. (Only a small part of this work was published.)

is a large fort on the E. Hill, in which there is a well sunk 90 feet, which commonly contains 80 odd feet of water. In digging the well the workmen found many shells, smooth stones, and different stratas of sand and clay, similar to those on the beach adjoining to the hill. These shells and appearances were discovered from near the top of the ground to the bottom of the well."

Again, nearly forty years ago, Dr. William Stimpson collected fragments of shells, representing fourteen species, from the cliffs of drift which form the east and west sides of Winthrop Head, or, as it is more commonly called, Great Head on the Point Shirley peninsula of Winthrop, then a part of Chelsea.[1] This peninsula has two lenticular hills or drumlins of till, namely, Great Head which rises about 100 feet above the sea, and another, a third of a mile farther south, which may be more properly called the Point Shirley hill, about 60 feet high. It seems clear, from Stimpson's description of the sections where his shells were obtained, that they belonged to the higher one of these hills, which at the present time is being undermined by the sea. The southern hill, nearer to Point Shirley, is not sufficiently high to agree with his description, and moreover its eroded eastern cliff is separated from the ocean by a low tract of beach gravel and sand twenty to forty rods wide, so that probably within the present century it has not presented any freshly exposed section.

Stimpson also reports that at some little distance from the place where he discovered these fossils, the digging of a well encountered shells in the drift at a depth of 50 feet below the level of high tide. Seventy years ago it was recorded that fragments of clam shells had been found 40 feet below the surface at Jamaica Plain, and at the depth of 107 feet in digging the well at Fort Strong, which was built in 1814 on Noddle's island, now East Boston.[2] About twenty years ago, in digging a well in Fort Warren, on George's island, shells were found 100 feet below the surface and about 40 feet below the sea level.[3]

An article published last summer by Mr. W. W. Dodge,[4] de-

[1]Proceedings of this Society, vol. iv, p. 9, January 15, 1851.

[2]Outlines of the Mineralogy and Geology of Boston and its vicinity, with a geological map. By J. Freeman Dana, M.D., and Samuel L. Dana, M.D., 1818, p. 96.

[3]Reported by Mr. W. H. Niles in the Proceedings of this Society, vol. xii, 1869, pp. 244 and 364. In commenting on this discovery, Mr. T. T. Bouvé read a letter from a gentleman in Hull, noting similar facts known to him in his own vicinity (p. 364).

[4]American Journal of Science, III, vol. xxxvi, p. 56, July, 1888.

scribing the section of the sea-cliff of Great Head, Winthrop, and noting its fossil shell fragments, specially directed my attention to this subject. An examination of Great Head and of the lower drumlin at Point Shirley convinced me, as before stated, that the former was the locality of Dr. Stimpson's earlier and widely known observations. Mr. Dodge also informed me of the occurrence of similar shell fragments in Grover's cliff on the northeast shore of Winthrop, nearly one and a half miles north of Great Head.

My observations have included these drift sections and others in Winthrop, Revere, Chelsea, and thence southwest and south around Boston harbor, on several of the islands in the harbor, on the peninsula of Hull and Nantasket, and in Hingham, Cohasset, and Scituate. In only a small proportion of the whole number of sections examined were glacially transported shells and fragments of shells observed, these being found in Grover's cliff and Great Head, Winthrop, on Long island, Moon, Peddock's and Nut islands, in Quincy Great hill, in the drumlin forming the north shore of Hull close northwest of Telegraph hill, and in Sagamore Head, which rises from the Nantasket beach. All the other sections seen failed to yield any trace of organic remains, excepting that scanty fragments of lignite were found along an extent of two or three feet in the modified drift forming the base of the drumlin of Third cliff in Scituate by Professor Crosby and Mr. Bouvé, who accompanied me in an excursion there. Without doubt, however, such transported shell fragments will be found in many other drumlins on islands in the harbor and on its eastern and southern shores, where they should be looked for in any deep section of the till, as in digging wells and in cliffs undermined by the sea.

The area where shells and fragments of shells are known to occur in the till has an extent of ten or eleven miles from northwest to southeast, reaching from East Boston and Grover's cliff to Sagamore Head, with a width of three or four miles, if not more, its eastern limit, which is the open ocean, being at a distance of four and a half miles east-northeast and eleven miles east-southeast of Boston. The fossiliferous sections are all in lenticular hills of till like the drumlins of Great Britain, which name is now adopted for them. These hills have a very fine development upon most of the country in the neighborhood of Boston, rising with smooth, ovally rounded contour to heights from 50 to 200 feet, and have been the subject of several papers before this Society.[1] Approximate elevations of the drumlins in which fossils have been found are as follows: Grover's cliff, 60 feet above the sea; Great Head, 100 feet; Eagle hill, East Boston, 120 feet; north end of Long island, 75 feet; George's island, 60 feet; Moon island, 100 feet; north end of Peddock's island, 70 feet; Nut island, 40 feet; Quincy Great hill, 100 feet; on the north shore of Hull, 80 feet; Telegraph hill, 125 feet; and Sagamore Head, 65 feet. The cliffs eroded by the sea on most of these drumlins extend from ten or fifteen feet above mean tide sea level upward very steeply or often in part vertically to near their tops.

Excepting Great Head, which contains modified drift near its base, to be presently described, these sections consist wholly of till or boulder-clay, the direct deposit of the ice-sheet, unmodified by the transporting and assorting action of water. Weathering has changed the small ingredient of iron in this deposit from the protoxide combinations which it still retains in the lower part of the till to the hydrous sesquioxide in its upper part for a depth of commonly fifteen or twenty feet from the surface, thereby giving to the latter a yellowish color in contrast with the darker gray or bluish color of the former. Both portions are very compact and hard till, an intimate unstratified commingling of boulders, gravel, sand and clay, and seem by these characters, and by their abundant striated boulders and smaller fragments of stone, to be distinctly the ground moraine of the ice-sheet. The southeast and east-southeast trends of the longer axes of the drumlins in this vicinity, coinciding at least approximately with the direction of the striation of the bedrock, further indicate that these oval hills of till were accumulated beneath the ice-sheet, this form being that which would oppose the least resistance to the glacial current passing over them. Though the till is destitute of stratification, its materials, coarse and fine, from boulders often several feet and occasionally ten feet or more in diameter to the finest rock-flour, being indiscriminately mixed in the same mass, it yet generally shows an obscure lamination in

[1]By Prof. N. S. Shaler, Proceedings, vol. xiii, pp. 198–203; by Prof. C. H. Hitchcock, vol. xix, pp. 63–67; and by the present writer, vol. xx, pp. 220–234. Also, see Geology of New Hampshire, vol. iii, pp. 285–309; "The Distribution and Origin of Drumlins," by W. M. Davis, in Am. Journ. Sci., III, vol. xxviii, pp. 407–416, Dec., 1884; and Illustrations of the Earth's Surface: Glaciers, by Professors Shaler and Davis, plate xxiv.

parallelism with the surface, having thus in the drumlins an inclination like that of their slopes. This structure is best displayed after some exposure of the section to the action of the weather. It seems to be an imperfect cleavage resulting from the enormous pressure of the overlying ice, and also indicates that the accumulation of the drumlins took place by gradual addition of till over their surface. Only a thin layer of englacial till, with its numerous large boulders, contained within the ice-sheet and allowed to fall loosely from it during its final melting, is observable upon these drumlins, its probable thickness in this vicinity being not usually more than one or two feet.

Plentiful fragments of shells, up to one or two inches in length and rarely of larger size, are embedded, like the small fragments of rock, in the dark lower portion of the till. They were found most abundant in Grover's cliff, Great Head, Peddock's island, and the northern cliff of Hull, one or several shell fragments being usually seen on each square yard of the exposed surface, so that hundreds may be gathered in an hour. In all the localities a single species, the round clam or quohog, *Venus mercenaria*, L., makes up probably ninety-nine per cent of the specimens found ; but no entire valve of this shell was obtained among the thousands of its fragments. The species next in numbers is *Cyclocardia borealis*, Conrad, which, like the foregoing, is thicker and stronger than most species and therefore better fitted to resist the grinding action of the ice. The smaller size of the latter has enabled some of its specimens to escape almost unbroken and with only slight abrasion of its margin. In no instance, however, have the two valves of this or any other species been found united. Some of the fragments show little wearing or none, their broken edges being sharp and the markings of their surface perfectly preserved ; but the majority are considerably worn, and pieces perforated by burrows, like the dead shells cast up on a beach, are frequently found. No glacial striation has been detected on any of these shell fragments, and indeed it is rarely observable on pieces of stone of so small size.

The cliff at the northeast end of Peddock's island, though not showing more of the large fragments than the other localities specially mentioned for their abundance, yet far surpasses these in its multitude of very small fragments and even minute particles of shells, from a quarter and an eighth of an inch in length down to the least speck visible to the eye. In one place, by no means exceptional, near the base of this cliff, the number of these particles and specks of shells, ground up in the process of formation and deposition of the till, averaged not less than forty to each square foot of the section. This locality, too, is the only one where the shell fragments were observed in the yellowish upper part of the till nearer to the original surface than a depth of ten or fifteen feet. Here small fragments of shells, an inch or less in length, were found in considerable numbers to a height of only one or two feet below the sod forming the surface of the hill and brink of the cliff. The highest were in a soft and crumbling condition, aud those found thence downward in the yellow till showed a gradation to the hard and strong character of the shell fragments in the dark blue till. These observations indicate that the transported and broken fossils were probably originally as plentiful in the upper as in the lower part of this drumlin, and perhaps likewise of all the others, but that they have been mostly dissolved out of the upper part by infiltrating water.

Great Head is a typical drumlin, the eastern third of which has been eroded by the sea, forming a cliff about 100 feet high. This consists of ordinary till, yellowish above and dark bluish below, from its top to within twenty or fifteen feet above mean tide, where its base, exposed a few years ago during the construction of a railroad, was observed by Mr. Dodge to be a somewhat arched bed of "loose, clean, rather fine gravel filled with small fragments of shells. *Venus mercenaria* and *Cardium Islandicum* (?) were the only shells identifiable with any reasonable degree of certainty among the fragments." This was seen to be overlain by till, which exhibited traces of an imperfect stratification close to their line of separation but above is entirely unstratified. The till contains fragments of shells up to a height of about eighty feet. A similar structure of the drumlins of Third and Fourth cliffs on the east shore of Scituate, each of which includes extensive anticlinal beds of modified drift, overlain by a thick covering of till, and in Fourth cliff also seen to be underlain by till and interbedded with it, promises to contribute much to our knowledge of the mode of deposition of these remarkable drift hills, as I shall hope to show in a future paper.

Following the nomenclature and arrangement of the catalogue of the marine invertebrate animals of the southern coast of New England and adjacent waters, by Verrill, Smith, and Harger,[1] the species represented by these fragments of shells in the drumlins near Boston are noted in the following table.

LIST OF SPECIES IN THE TILL NEAR BOSTON.

SPECIES.	1	2	3	4	5	6
Balanus crenatus, Bruguière.		*				
Chrysodomus decemcostatus, Say.		*				
Tritia trivittata, Adams.		*				
Urosalpinx cinerea, Stimpson.		*				
Lunatia heros, Adams.				*		
Lacuna neritoidea, Gould. (?)		*				
Saxicava arctica, Deshayes.					*	
Mya arenaria, Linné.		*				
Ensatella Americana, Verrill.		*				
Mactra solidissima, Chemnitz.		*				
Venus mercenaria, Linné.	*	*	*	*	*	*
Tapes fluctuosa, Sowerby. (?)		*				
Cardium Islandicum, Linné. (?)		*				
Cyclocardia borealis, Conrad.	*	*	*	*	*	*
Astarte undata, Gould.	*	*				
Astarte castanea, Say.		*				
Mytilus edulis, Linné.		*				
Modiola modiolus, Turton.		*				
Pecten Islandicus, Chemnitz.					*	
Ostrea Virginiana, Lister.		*				
Cliona sulphurea, Verrill.	*	*	*		*	*

Those marked by asterisks in the first column have been collected in Grover's cliff, the most northern section yielding these fossils. In the second column are those found in Great Head, mostly by Dr. Stimpson, to whose list Mr. Dodge has added, somewhat doubtfully, three species. An hour's search there by Mr. Q. E. Dickerman and myself was rewarded by fragments of *Venus mercenaria*, abundant; *Mya arenaria* and *Cyclocardia borealis*,

[1] United States Fish Commission, Report of 1871–72. This work and Gould's Report on the Invertebrata of Massachusetts give notes of the geographic range of our species, living and fossil, and of the situations and depths at which they occur.

frequent; *Astarte undata*, rare; and a columella, perhaps of *Chrysodomus decemcostatus*. In the third column are the species found in the cliff of Moon island; in the fourth column, those obtained from the well at Fort Warren; in the fifth, those of Peddock's island; and in the sixth, those of the northern cliff in Hull. At the other localities only *Venus mercenaria* was found in the limited time available for search.

All these species, which remain from the marine fauna that existed before the formation of the last ice-sheet upon this area, excepting one whose determination is doubtful, are found living at the present time in the adjoining waters of Massachusetts bay. Stimpson wrote of his collection: "With the exception of *Venus mercenaria*, I have obtained all of them in a living state by dredging within a mile of the locality where they are now found fossil." Nor are any noteworthy differences observable between these fossils and the living shells, excepting that the *Venus mercenaria* belongs, like most of the fossils of this species in Sankoty Head, Nantucket, to the very massive and strongly sculptured form, probably not to be regarded as a distinct variety, which still survives in the waters of Nantucket.[1]

Four species in this list attain their southern limit at Cape Cod; and one, *Tapes fluctuosa*, is not reported south of Nova Scotia and the Fishing Banks. The remaining sixteen have a southward range beyond Cape Cod. In northward range, five extend only to the Gulf of Saint Lawrence; and three of these, namely, *Urosalpinx cinerea*, *Venus mercenaria*, and *Ostrea Virginiana*, occur only in isolated colonies north of Massachusetts bay. Another, *Astarte castanea*, has its northern limits on the coast of Nova Scotia and at Sable island; while the burrowing sponge, *Cliona sulphurea*, is not reported beyond Portland. Fourteen are more boreal, of which four continue to Labrador, and ten to the Arctic ocean.

The great abundance of the round clam, *Venus mercenaria*, which is now scarce in Massachusetts bay but plentiful south of Cape Cod, with southward range to Florida, indicates that the sea here during part of the epoch just preceding the last glaciation was warmer than at the present time.[2] Similarly, the colonies of this and asso-

[1] Am. Journ. Sci., III, vol. X, 1875, pp. 369, 371.

[2] From the same evidence and the presence of other species elsewhere in the Pleistocene deposits of the eastern United States north of their present range, Desor announced in 1847 to the Geological Society of France (Bulletin, Vol. v, p. 91) and in 1852 in the American Journal of Science (II, vol. xiv, pp. 52, 53) that a warmer climate then prevailed throughout this whole district.

ciated southern species, scattered here and there northward to the Bay of Chaleurs, are evidence that since this last glacial epoch the sea has been again warmer than now along this coast, permitting these species to advance so far to the north. The intermingling of characteristic southern and northern forms in this assemblage of fossils from the till seems to be readily accounted for by the gradual refrigeration of climate which culminated in the formation of the ice-sheet. Before that time the round clam or quohog and other shells of chiefly southern range were doubtless succeeded by a wholly boreal and arctic marine fauna. In the Pleistocene beds containing fossil shells on Gardiner's island[1] and at Sankoty Head,[2] which are referable to the same epoch with these near Boston, namely, the interglacial epoch preceding the latest glaciation, the round clam occurs in abundance; but it has not been discovered fossil north of the sections here described, which indeed are the most northern yet found in northeastern America holding fossils of interglacial age. It has not been found in the plentiful fauna of the marine beds of modified drift deposited in southern Maine during the departure of the last ice-sheet, nor in the scantily fossiliferous continuation of these beds southward to Portsmouth, Gloucester, and Cambridge.

Nearly all the species of our list inhabit the shore or shallow water, from low tide to the depth of a few fathoms, though some of these also range downward to considerable depths. Three, of which two are doubtfully determined, are probably restricted to comparatively deep water; but even these are often cast ashore in severe storms. Considering the outlines of our eastern coast and the direction of the motion of the ice-sheet, it seems probable that these fossils were living along the shore and in the shallow edge of the sea on the area between the mouths of the Charles and Saugus rivers. In that interglacial epoch the drumlins of this district had not been accumulated, and the greater part of Chelsea, Revere, and Winthrop, formed of these and other deposits of glacial and modified drift, may then have been sea of similar depth with the present harbor of Boston or the part of Massachusetts bay between

[1] Sanderson Smith in Annals of the Lyceum of Natural History of New York, vol. viii, 1867, pp. 149–151; F. J. H. Merrill in Annals of the New York Academy of Sciences, vol. iii, 1886, p. 354, with sections on Plate xxvii.

[2] Desor and Cabot in Quarterly Journal of the Geological Society, London, vol. v, 1849, pp. 340–344, partly quoted by Packard in Memoirs, Boston Soc. Nat. Hist., vol. i, pp. 252–3; Verrill and Scudder in Am. Journ. Sci., III, vol. x, 1875, pp. 364–375.

Winthrop and Nahant. From this tract the southeasterly moving ice-sheet, plowing up the marine beds and their inclosed shells, with those then tenanting the sea, carried them forward to form a portion of the till of the drumlins. That the sea-bottom from which these shells were derived had been shallow is evident from the predominance of the round clam, which, according to Professor Verrill, is seldom found in any abundance below five fathoms.

Glacially transported shells and fragments of shells have been previously observed in till in Brooklyn, N. Y., where E. Desor and W. C. Redfield gathered fragments of the round and long clams, oyster, and other species, "imbedded in a reddish loam intermixed with pebbles and boulders, many of which are distinctly scratched;"[1] and in till, or at least deposits of clay enclosing numerous stones and boulders, on the lower part of the Saint Lawrence river, from the vicinity of Quebec northeastward more than a hundred miles, chiefly on the southeastern shore, to opposite the mouth of the Saguenay.[2] But the descriptions of these beds containing shells and boulders on the Saint Lawrence indicate that they were mostly, if not altogether, deposited by water with floating ice during the recession of the ice-sheet, while these marine shells lived where they are now found, being thus comparable with the fossiliferous boulder-bearing brick-clay of Paisley, Scotland.[3] In the modified drift forming Cape Cod, derived from the melting ice-sheet in which it had been contained, I collected ten years ago fragments representing sixteen species of shells, all now living, eight of which also appear in the foregoing list.[4]

Looking over the various lists of Pleistocene fossils found on Gardiner's island and in Sankoty Head under the drift of the last ice-sheet, in these drumlins of till near Boston, and in the modified drift of the glacial recession thence northward to Maine, New Brunswick, and the valley of the Saint Lawrence, we cannot fail to be surprised that all these species are still living in the adjoining ocean to-day. So recent was the glacial period[5] that none of them has become extinct, nor, with very rare exceptions, undergone any

[1] Bulletin de la Société Geologique de France, second Series, vol. v, 1847, pp. 89, 90; Quart. Journ. Geol. Soc., vol. v, p. 343; Am. Journ. Sci., II, vol. xiv, 1852, p. 51.

[2] J. W. Dawson's Notes on the Post-pliocene Geology of Canada, 1872, pp. 7, 45, and 50–53.

[3] T. F. Jamieson in Quart. Journ. Geol. Soc., vol. xxi, 1865, pp. 175–177.

[4] American Naturalist, vol. xiii, 1879, p. 560.

[5] Compare Proceedings of this Society, vol. xxiii, 1888, p. 446.

noteworthy change in form or size. But the vicissitudes to which they were exposed during the last of our two principal glacial epochs, when the ice-sheet east of the Alleghenies advanced farther than in the earlier glaciation, were doubtless well adapted to cause both extinctions and modifications of species. How vast then must be the duration of time occupied in the evolution of the complex faunas and floras of our globe, and in the formation of all the fossiliferous groups of rocks since the dawn of terrestrial life!

In various parts of Great Britain such transported Pleistocene shells are found in the till, both in its low and smooth tracts[1] and in its hilly and knolly terminal moraines traced by Professor Lewis, as well as in the associated kames.[2] Some of these fossiliferous glacial deposits occur in Ireland, northern Wales and northwestern England at heights 1,100 to 1,350 feet above the sea, and have been generally considered as proof of marine submergence to that depth. Instead of this, Lewis has shown[3] that the shells and fragments of shells found there were brought by the currents of the confluent ice-sheet which flowed southward from Scotland and northern Ireland, passing over the bottom of the Irish sea, there plowing up its marine deposits and shells, and carrying them upward as glacial drift to these elevations, so that they afford no testimony of the former subsidence of the land. This removes one of the most perplexing questions that glacialists have encountered; for nowhere else in the British Isles is there proof of any such submergence during or since the glacial period, the maximum known being 510 feet near Airdrie in Lanarkshire, Scotland.[4] At the same time the submergence on the southern coast of England was only from ten to sixty feet,[5] while no traces of raised beaches or of Pleistocene marine formations above the present sea level are found in the Shetland and Orkney islands.[6]

The occurrence of transported marine fossils in the till near Boston shows that during the epoch preceding the latest glacia-

[1] Geikie's Great Ice Age, second ed., pp. 164–185, and 337–340.

[2] Quart. Journ. Geol. Soc., vol. xxx, 1874, pp. 27–42; xxxiv, 1878, pp. 383–397; xxxvi, 1880, pp. 351–355; xxxvii, 1881, pp. 351–369; and xliii, 1887, pp. 73–120; also, Geological Magazine, II, vol. i, 1874, pp. 193–197.

[3] Report of the British Association for Adv. of Sci., Birmingham, 1886, pp. 632–635; Am. Naturalist, vol. xx, pp. 919–925, Nov., 1886; Am. Journ. Sci., III, vol. xxxii, pp. 433–438, Dec., 1886. Also, see American Geologist, vol. ii, pp. 371–379, Dec., 1888.

[4] Quart. Journ. Geol. Soc., vol. vi, 1850, pp. 386–388; xxi, 1865, pp. 219–221.

[5] Quart. Journ. Geol. Soc., xxxiv, 1878, pp. 454–457; xxxix, 1883, p. 54. Geol. Mag., II, vol. ii, 1875, p. 229; II, vi, 1879, pp. 166–172.

[6] Quart. Journ. Geol. Soc., xxxv, 1879, p. 810; xxxvi, 1880, p. 663.

tion, the North American coast in this latitude was not higher than now in relation to the sea; for in that case no marine deposits and shells could have existed here to be eroded by the southeasterly moving ice-sheet and incorporated in its drift accumulations. Conversely, we know that the land then was not appreciably lower than now, in other words, that there was no considerable submergence of the border of our present land area; for this would have led to the intermingling of such broken sea-shells with the glacial drift farther inland, where no trace of them is found. So it appears that the relative levels of land and sea here were closely the same before the last glacial epoch as at the present time.

The chief element of my interest in this subject has been a hope that its bearing thus on the oscillations of land and sea during the Quaternary period would contribute to the solution of the question whether the northward ascent of the beaches of the glacial Lake Agassiz, assigned to me for investigation in the United States Geological Survey, is to be explained mainly by northward attraction of the water of that lake in gravitation toward the ice-sheet, or mainly by a depression of the earth's crust beneath the vast weight of the ice and its re-elevation when that weight was removed. In this study of our Atlantic coast, I have therefore sought to connect these observations near Boston with the allied evidence supplied by other Pleistocene marine fossils both south and north of our latitude. Some of the conclusions to which this correlation seems to lead I will endeavor to state briefly.

As before noted, it is only toward the south that we find Pleistocene fossiliferous beds antedating the last epoch of glaciation, when an ice-sheet covered all New England. They occur in Sankoty Head and on Gardiner's island at elevations respectively about 30 and 15 feet above the sea, and in numerous localities on Long Island from the sea level up to elevations of about 200 feet. But at least the higher of these beds appear to have been "upheaved by the lateral pressure of the ice-sheet and thrown into a series of marked folds at right angles to the line of glacial advance," as shown by Merrill;[1] and he finds that this uplifting and folding is also very distinctly seen in the strata underlying the glacial drift on Gardiner's island, so that the fossiliferous layer there, though raised little above the sea level, is probably higher than its origi-

[1] Annals of the New York Academy of Natural Sciences, vol. iii, 1886, pp. 341–364, with sections and map.

nal position. To such glacial thrust and uplifting I would attribute likewise the tilted condition of the beds forming the base of Sankoty Head and the elevation of the included layers of shells. More than this, I believe that the same cause will account for the elevation and folding of the wonderful section of steeply inclined Miocene strata which underlie the terminal moraine in Gay Head.[1] It may well be true, therefore, so far as paleontologic evidence can inform us, that this part of our coast, extending south to the farthest limit reached by the continental ice-sheet, held approximately the same relation to the sea level in preglacial and interglacial time as now.[2] During the final melting of the ice-sheet, however, the land was higher, or, as I would prefer to say, the sea was lower than now, as is shown by channels of drainage, which extend southward from the terminal moraines across the bordering plains of modified drift on Long Island, Martha's Vineyard, Nantucket, and Cape Cod, continuing beneath our present sea level.[3] Nor have we any proof in marine beds overlying the glacial drift that the sea there has stood higher than now at any time since the glacial period.

Near Boston and northeast to Cape Ann the coast seems to have been submerged to a slight depth, probably not exceeding 10 to 25 feet, when the ice-sheet retreated from this area.[4] In New Hampshire this submergence amounted to 75 feet or more, and the fossils in the marine beds overlying the glacial drift, being partly of arctic and partly of temperate range, show that the severe climate of the glacial period was gradually changed until the ocean became as warm as now before it sank to its present level.[5]

[1]Hitchcock's Geology of Massachusetts, 1841; Lyell's Travels in North America in 1841–2, vol. i, pp. 203–6.

[2]The fossils in South Marshfield and Duxbury, Mass., which I once referred to the Pleistocene (Am. Naturalist, vol. xiii, p. 557), extend back to the Miocene in the Southern States, and seem more probably to be of similar age with the beds of Gay Head (Hitchcock's Geology of Mass., 1833, pp. 199–201; do., 1841, pp. 91, 427).

[3]Am. Journ. Sci., III, vol. xiii, 1877, pp. 142–146, and 215; vol. xviii, pp. 89, and 198–205. Am. Naturalist, vol. xiii, 1879, p. 553.

[4]Evidenced by layers of shells of the common or long clam, mussel, oyster, and other species at Lechmere point in Cambridge (Outlines of the Mineralogy and Geology of Boston, before cited, p. 96), and by fossils discovered by Professor Shaler at Gloucester, Mass. (Proceedings of this Society, vol. xi, 1868, pp. 27–30). In the same notice with the former of these localities, the authors mention a stratum of clam shells, observed on the side of a hill in Cambridge at the distance of a half mile from the Charles river, which seems from its description to be probably an aboriginal kitchen-midden.

[5]Geology of New Hampshire, vol. iii, pp. 165–7.

After this the ocean within recent times has held even a somewhat lower level than at present, and seems to be now very slowly rising upon this shore and indeed along the entire coast from New Jersey to the Gulf of Saint Lawrence, as is shown by submerged stumps of trees in many localities, rooted in the ground where they grew, and by tracts of marsh and peat-swamp covered by the sea.[1] During part of the time of lower level of the sea, its temperature was apparently warmer, as indicated by the range of *Venus mercenaria* with other southern species northward to the Gulf of Saint Lawrence, though now it is wanting along the shore of Maine, the bay of Fundy, and Nova Scotia.

Proceeding from Boston toward the north and northwest, the elevation of fossiliferous marine beds lying on the glacial drift increases to about 225 feet in Maine, about 520 feet in the Saint Lawrence valley at Montreal, and 440 feet at a distance of 130 miles west-southwest of Montreal; but eastward along the Saint Lawrence it decreases to 375 feet opposite the Saguenay, and does not exceed 200 feet in the basin of the Bay of Chaleurs, while these marine deposits are wanting in Nova Scotia and Cape Breton island.[2] The changed condition in the relative heights of land and sea at the time of the recession of the ice-sheet thus caused the land to be submerged in increasing amount northwestward from a line drawn through Nova Scotia, Boston, and New York. This condition, due probably in part to depression of the land and in part to uplifting of the sea level by gravitation, seems to have been caused by the ice-sheet, which had its greatest thickness, estimated by Dana to be not less than two miles, on the highlands between the Saint Lawrence and Hudson bay, where its influence to produce such changes of level would be greatest. The submergence seems to have been more than can be wholly attributed to gravitation of the sea toward the ice-sheet;[3] but it is much less than

[1] Outlines of the Min. and Geol. of Boston, p. 95; Memoirs of this Society, vol. i, p. 324; Quart. Journ. Geol. Soc., vol. xvii, 1861, pp. 381–8; Geol. of N. H., vol. iii, p. 173; J. W. Dawson's Acadian Geology, third ed., pp. 28–32, and Supplement of do., pp. 13–17.

[2] A. S. Packard, jr., in Memoirs of this Society, vol. i, pp. 231–262. J. W. Dawson in Notes on the Post-pliocene Geology of Canada; and Am. Journ. Sci., III, vol. xxv, 1883, pp. 200–202. C. H. Hitchcock in Proc. Am. Assoc. for Adv. of Sci., Portland, 1873, vol. xxii, pp. 169–175; Geol. of N. H., vol. iii, pp. 279–282; and Geol. Mag., II, vol. vi, 1879, pp. 248–250. R. Chalmers in Transactions of the Royal Society of Canada, sec. iv, 1886, pp. 139–145.

[3] Sixth Annual Report, U. S. Geol. Survey, 1885, pp. 291–300.

would be expected for agreement with the views of Jamieson[1] and Shaler,[2] that the ice-sheet must depress the earth's crust to a vertical extent approximately measured by a thickness of rock equal to the ice in weight.

Besides the testimony of marine fossils, one further observation contributes greatly to our knowledge of the relation of land and sea on the south side of Massachusetts bay while this area was enveloped by the continental glacier. On the shore of a peninsula in Cohasset Little Harbor, fifteen miles southeast of Boston, pot-holes similar to those of water-falls on rivers are found in two localities, reaching from sea level to a height of fifteen feet. The contour of this vicinity precludes the possibility of referring their origin to any stream since the close of the glacial period ; and they must doubtless be attributed to the action of a water-fall plunging down hundreds of feet through a *moulin* of the ice-sheet.[3] To Mr. Bouvé, long the president of this Society, belongs the honor of first observing these pot-holes and appreciating their significance. It was under his guidance that my visit to them was made ; and it is with his permission that I speak of them here, previous to the detailed description which he will later present before the Society. Such water-wearing of the bed-rock could not take place beneath the sea level, so that they prove that here during a part, probably the later part, of the time when this area was covered by the ice-sheet, the land stood at least as high as now, not being depressed under its vast weight.

EARLY MAN IN THE DELAWARE VALLEY.

BY HILBORNE T. CRESSON.

Special assistant of the Peabody Museum.

At Professor Putnam's request, I have prepared this brief account of work carried on for the past two years, under the direction of the Peabody Museum, and included some previous researches,

[1] Quart. Journ. Geol. Soc., vol. xxi, 1865, p. 178. Geol. Mag., II, vol. ix, Sept. and Oct., 1882; and III, vol. iv, Aug., 1887. Also, see Fisher's Physics of the Earth's Crust, and Geol. Mag., II, ix, p. 526.

[2] Proceedings of this Society, vol. xii, 1868, pp. 128–136; and xxiii, 1884, pp. 36–44. Memoirs of this Society, vol. i, 1874, pp. 320–340. Am. Journ. Sc., III, vol. xxxiii, 1887, pp. 210–221. Lowell Lectures, Nov. and Dec., 1888.

[3] Compare Quart. Journ. Geol. Soc., vol. xxx, 1874, pp. 750–771.

the results of which will shortly be arranged and exhibited in the cases of the Peabody Museum.

In studying the traces of early man that have been discovered in the lower Delaware Valley, a few hours' journey southwest of the renowned Trenton gravels, so well known by the untiring labors of Dr. Charles C. Abbott, it is well at once to introduce you to the neighborhood called Naaman's Creek, better known, however, at the present day as Claymont, a small hamlet lying just beyond Mason and Dixon's line, in New Castle County, State of Delaware. In order that you may better understand the exact geographical position of Naaman's Creek, around whose mouth and head-waters the early people of the Delaware Valley evidently found attractive hunting-grounds, among the terraces and hills of the interior and the marshes of the river shore, it will be best to refer to the map. Taking New Jersey as a point well known to all, a glance in a southwesterly direction, for a short distance, brings the eye to Philadelphia, and about twenty-two miles farther on, the line between Delaware and Pennsylvania is somewhat conspicuous from the fact that instead of the usual straight dividing line between states, we have here a semicircle, that curves around from the Delaware River in a westerly, and then southerly direction, dividing Delaware from Pennsylvania and Maryland. The position of Claymont village may then be easily remembered, for it stands within rifle shot of the Delaware, directly alongside of the state line referred to. So much for the geography of the locality.

Let me now say a few words upon the geological situation, making a few brief allusions to the Philadelphia red-gravel and brick-clay.

Underlying the city of Philadelphia, and points west and southwest of it as well, are two distinct layers of gravel easily distinguished from each other by their color: a dull yellow, and a brilliant red. Overlying the gravel deposit is a layer of boulder clay which, from its fictile adaptability, has been named the Philadelphia brick-clay. The oldest of these gravels just referred to, the yellow, does not concern us, from the fact that the fragments of coral and shell pebbles that are at times found in it suggest the probable debris of some old tertiary shore line. It cannot therefore have any connection with the far more recent conditions relating to the finds at Naaman's Creek, except, that at this last-named place it underlies the boulder clay or gravel in the same order that it does at

Philadelphia, or is replaced by schists. Just above the yellow, is a layer of red ferruginous gravel, in which quartzite predominates with a less proportion of sandstone, chert, and hornstone. These materials, it is true, are found in the yellow gravel, but in the red gravel, at Philadelphia, we have another constituent which is never found in the former, and that is pebbles of red shale.

In the brick clay already referred to, lying above the red gravel, will be found water-worn boulders of Cambrian quartzite, Silurian sand-rock, and shale from the Triassic formation, for whose origin we must look toward the north around the head-waters of the Delaware. The boulder clay and red gravel are confined to certain limits on either side of the Delaware river, and its tributary the Lehigh. At Philadelphia, the two deposits extend back from the waters of the first named stream, an average distance of three or four miles; *the clay deposit*, in some cases, mounting the slopes of a line of hills in the neighborhood of the city, to a distance of two hundred feet.

Without going into any further description of the postglacial deposits underlying Philadelphia, deposited by great floods during the periodical meltings of the great ice sheet, allow me to add that the geologist will find the same deposit running along the Delaware's banks from Philadelphia to Chester, and thence southward, far beyond the point in which we are interested — that of Naaman's Creek. Any one who will follow the numerous deep cuts of the Baltimore and Ohio railroad from Philadelphia to Wilmington, will be impressed with the truth of these statements, and be rewarded with rare opportunities for study.

In considering the remains of early man that have been found near the head-waters of Naaman's Creek, it will be well to refer to the first discovery that attracted attention to this neighborhood in 1866. It is now rather late to mention it, but, although at that time *little* was thought of the remains of the rock-shelter that I shall describe, at the present day the implements of its several layers are of the greatest interest to the anthropologist. We now have means of comparison which we did not have twenty years ago, and experience has taught us to preserve the smallest flake or sherd, no matter how uncouth it be, for each contributes its mite towards the history of early man.

The remains of the Naaman's Creek Rock-shelter luckily fell into hands that have preserved them, and thanks to the Museum which bears the name of one of America's greatest benefactors, George Peabody, the specimens will soon be arranged and exhibited for future reference. To pass on in this connection, and not mention the indefatigable efforts of the directors of the Peabody Museum in the interests of science would be a great injustice. Thanks to the energy of the staff of this great Museum, America possesses an extensive treasure-house of archæological and ethnological lore, which considering the comparatively short time that has elapsed since the first specimen was labelled is, without doubt, one of the most valuable and interesting collections ever brought together, rivalling any of like kind in either hemisphere.

To give a detailed account of *how* the Rock-shelter at Naaman's Creek was discovered, would consume too much time this evening, Let us rather consider, briefly, the nature of the rock composing it and the contents of the shelter's various layers. In all probability, the rock forming a shelter *was* a Laurentian outcrop — probability is mentioned because no exact geological survey has ever been made of the locality, so far as I am aware, up to the time of Professor Wright's visit to the spot last month. I say *was* a Laurentian outcrop from the fact that the site of the shelter has, within a few years, been cut in twain and all but one side of its place obliterated by the Baltimore and Ohio railroad company's trackway, made through the Laurentian outcrop, from which a mass of rock formerly projected, making a natural shelter that at times was used by the early peoples of the Delaware valley. The Peabody Museum possesses photographs of the spot as it appears at the present day, which may be seen by all interested in the subject. Fortunately, careful drawings of the shelter were made during its excavation, between the years of 1866 and 1867, copies of which have been presented to the Museum by William R. Thompson, Esq., of Philadelphia. Any one interested in photography will readily understand how, but a few years ago, it would have been a difficult matter, if not an impossibility, to have obtained photographs of the spot. A camera, in those days, with its appliances, would have required a horse and cart to carry them.

The profile drawing on the following page represents the outcrop of rock as it appeared above the ground line, before excavations were begun in 1866. The trees show that the ground was then covered by a thick wood. The outcrop of the rock *R*, above the ground line *G G*, is plainly indicated. From the point *P*, that

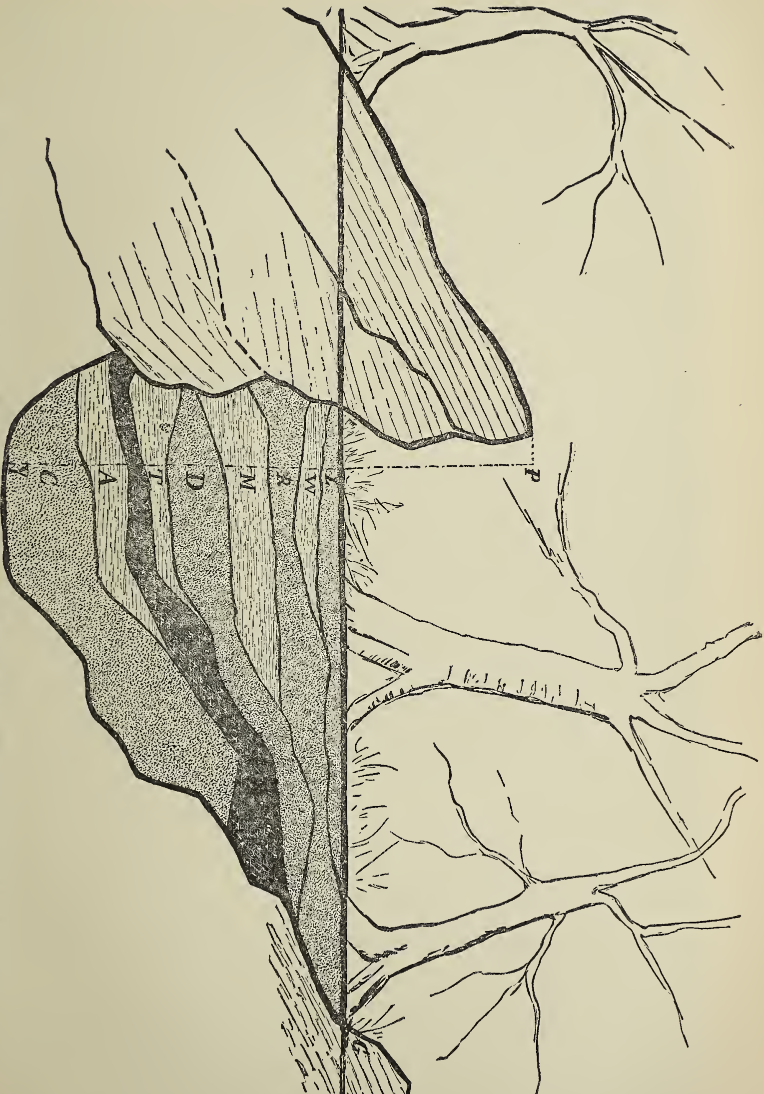


FIG. 1. Rock-shelter at Naaman's Creek, Delaware. *A*, *T*, *M* and *W* are the layers containing implements.

marks the innermost edge of the outcrop overhanging the hollow *P Y G*, a perpendicular line dropped to the intersection of the ground line[1], would measure five and one-eighth feet, the height of the projection of the rock above the ground before the excavations were commenced.

Twenty-two feet, eight inches, from the outcrop *R*, measured from its inner face *P*, there is still another outcrop of Laurentian rock, marked *G* on the diagram. This marks the opposite side of the hollow, the profile outline of which is easily made out by the thick line running from *G* to *Y*. Carrying the eye upward to *P*, the angle of projection of the rock, over the depression *P Y G*, is readily understood.

It is thus evident how admirably the place was adapted to the wants of the early hunters of the Delaware Valley, whether it be as a shelter, or as a place of defence against their enemies.

Contenting ourselves with this hasty sketch of the shelter's profile, and the suggestion that the hollow beneath the projecting rock was the result of erosion, let us consider for a moment the layers of earth, sand and gravel that filled it, these being intermingled with rude implements, broken bones, and charcoal, indicating that man at times had resorted to the spot.

Layer C.—This was composed of schist, resting on the Laurentian? bed rock (*Y*) of the shelter. A layer of aqueous gravel of the same character as that underlying Philadelphia rested on the decomposed schist. The greatest depth of the red gravel layer was 4 feet $2\frac{1}{4}$ inches, measured from the layer of decomposed schist. Least depth of gravel observed, 1 foot, 3 inches. These measurements were verified by me at the final excavations made through the shelter by the Baltimore and Ohio railroad company in 1887. New geological specimens were also obtained of the different layers, as some of those obtained in 1866 were lost during changes that have taken place in the household of the gentleman who preserved the collection until the time of its presentation to the Peabody Museum.[2]

Layer A.— This was a layer of grayish white brick-clay mixed with yellow clay similar to that underlying Philadelphia, on top of

[1] The point where the line *P* cuts the ground line *G* is here referred to.

[2] A portion of the specimens from the rock-shelter were accepted in 1884 as a consideration for my services rendered in superintending the excavations during the summers of 1866–7–8. At the earnest request of the curator they have been presented to the Peabody Museum.

which was a layer mixed with sand, shown by the black space. Stone implements were discovered in this layer. They were but few in number and very rude, exclusively of argillite, and palæolithic in type. Greatest depth of layer, 2 feet, 1½ inches. Least depth, observed, 1 foot, 4 inches. No implements of bone were found.

I should here state that the continual infiltration of water from a spring on the surface soil near by, made it very difficult to examine the layers; much of the material contained in them being so decomposed that it was impossible to save it. Here and there, however, by using great care the remains of different animals were secured; and, on a following page, I give a list of these identified by the late Dr. Shivers of Naaman's Creek.

Layer T.— This was of reddish gravel intermingled with decomposed schist, cinders, and broken bones of animals. Fragments of a human skull were found at the spot marked on the sketch in this layer. A fragment of a human rib was also discovered. The fragments of the skull are covered, here and there, by dendritic incrustations. Rudely chipped points and other implements, all of argillite, were found in this layer. Depth of layer 13 to 18 inches.

Layer D.— Composed of reddish-yellow clay. Depth, 2 feet, 3 inches. No implements.

Layer M.— In this layer were numerous implements of argillite and some of bone, intermingled with rude implements of quartzite and jasper and fragments of rude pottery with charcoal. Greatest depth, 1 foot, 1½ inches. Least depth, 3 inches.

Layer R.— Yellow clay. Greatest depth, 2 feet, 1½ inches; least depth, 8 inches. No implements.

Layer W.— This contained chipped implements, those made of jasper and quartzite predominating over those of argillite. Implements of bone and ornaments of stone, bone and shell. In the lower part of this layer were fragments of rude pottery. In the upper portion of the layer were potsherds decidedly superior in decoration and technique to those from the lower portion. Geological composition of this layer, yellow clay loam. Greatest depth, 3 feet, 4 inches. Least depth observed, 2½ inches.

Layer L.— This consists of leaf mold, 7 inches thick, converted into swamp muck by decomposing action of water from springs.[1] No implements.

[1]The position of the spring referred to was about ten feet to the right of the outcrop *G* (see plan, p. 145), and being somewhat elevated above the shelter a portion of its waters flowed into the depression between the outcrops *P* and *G*.

The following is a list of the remains of animals found in the several layers as indicated by the "cross":—

Layers.	A	T	M	W
Species.	Palæolithic implements.	Chipped Points and other implements of argillite.	Implements of argillite, quartzite, jasper and bone, pottery.	Implements of quartzite and jasper predominate over those of argillite; bone implements. Pottery of better grade. Ornaments of bone and shell, perforated stones.
Man		×		
Bear		×	×	
Deer		×	×	×
Raccoon				×
Beaver		×		
Wildcat		×	×	
Opossum				×
Rabbit				×
Turtle				×
Duck				×
Wild Goose				×
Crane			×	
Sturgeon			×	
Catfish				×
Shad				×

No remains of extinct animals were found.

Most of the materials thus briefly commented upon having been placed in my hands but a short time since, with the request to transfer the collection as soon as possible to the Peabody Museum, I have not had time to make any conclusions from a study of the specimens. Although I superintended the excavation of the rock-shelter, so long a time has elapsed that it will be necessary to go over the material slowly, hunt up old notes that have been scattered, and also try to bring together portions of the collection now in other hands.

It remains for me to explain why I have first spoken of the rock-shelter, before speaking of the palæoliths found in aqueous deposits near Darley's Road, which crosses the Baltimore and Ohio railroad track, but a short distance from the locality that we have just examined. I have stated before that I was anxious to verify the several layers of the rock-shelter, and as the stakes of the railroad survey indicated that the place was doomed to destruction, for several weeks I followed the workmen as they slowly proceeded from Darley's Road Crossing toward what is now Carpenter Station, a quarter of a mile distant. I had already seen what is called by the country people the "Indian Field" cut in twain by these invaders of nature's solitudes, and must confess that it seemed to me a strange fatality that the shelter and the old Lenape council field stood directly in the line of destruction. When the work-gang reached Darley's Road Crossing, the excavation began to lay bare the gravels. Towards Wilmington, on the southwest side of the bridge, the layers terminated in a thin skein, but a few inches in thickness, and the boulder line which Professor Wright will describe in detail dwindled away to mere pebbles. As the work progressed toward Carpenter Station, in the direction of Philadelphia, the layers of brick clay widened somewhat, and the red-gravel deposit assumed a feature which seems to be better defined as we approach Wilmington, and less so to Philadelphia. I refer to the aqueous gravel deposit being subdivided, as it were, by its difference in color; generally red above (the true Philadelphia red-gravel color), while underneath it is grayish-reddish white. This peculiarity will be apparent to you, when Dr. Wright displays his lantern slides. The boulders of the boulder line, too, seem to increase in size as Philadelphia is approached; but I must not dwell upon these points in detail, interesting though they be, but tell you where the palæoliths were found.

Toward midday of July 13, 1887, while lying upon the edge of the railroad cut, sketching the boulder line, my eye chanced to notice a piece of steel-gray substance, strongly relieved in the sunlight against the red-colored gravel, just above where it joined the lower grayish-red portion that I have mentioned. It seemed to me like argillite, and being firmly embedded in the gravel was decidedly interesting. Descending the steep bank as rapidly as possible, the specimen was secured, not too quickly, for the workmen above were just beginning to tumble down a huge mass of boulders and gravel that had been undermined beneath, and then eased off, as they say, at the top by crowbars. Upon examining my specimen, I found that it was unquestionably a chipped implement. There is no doubt in my mind about its being firmly embedded in the gravel, for the delay I made in extricating it with my pocket knife nearly caused me the unpleasant position of being covered by several tons of gravel, to say nothing of the tongue lashing that I received from my friend, the section boss of the laborer's gang. It is to be regretted that the camera was not at hand to photograph the implement *in situ*, but this was impossible.

Having duly reported my find to Professor Putnam, I began, at his request, a thorough examination of the locality and on May 25, 1888, the year following, discovered another implement,[1] four feet below the surface, at a place about one-eighth of a mile from the first discovery. This was on Darley's road, the byway I have already mentioned. The road crosses the Baltimore and Ohio railroad track, a few degrees west of north, and leads toward what is known as "the red cut" from the fact that Darley's road at this point was excavated through a red gravel deposit which gave origin to its name. The point where the palæolith was found is a short distance above Joel Cloud's spring-house. The geological formation in which the implement was found seems to be a reddish gravel mixed with schist. Professor Wright who visited the spot with me has reserved his opinion upon the spot (with all due precaution), for the formation in this locality is a most difficult one to determine.

REMARKS UPON A CHIPPED IMPLEMENT, FOUND IN MODIFIED DRIFT, ON THE EAST FORK OF THE WHITE RIVER, JACKSON CO., INDIANA.

BY HILBORNE T. CRESSON.

The profile sketch[1], fig. 1, shows the position of gravel in which the large palæolith was found, on the east bank of White River, near the village of Medora, Jackson Co., Indiana.

The implement is thus shown to have been found in undisturbed gravel six inches distant from the boulder *R*, at *P*, the position indicated in the diagram. Its discovery was wholly a matter of ac-

[1]For figures of these implements see pages 160, 161, following.

[2] Especial attention is called to the fact that the plan on page 151 was made after a very hasty examination of the locality. It cannot, therefore, be depended upon as an exact section of the supposed aqueous deposits referred to.

cident. In company with Mr. W. R. Thompson of Philadelphia, in the month of May, 1886, I was making a casual examination of the gravel deposit along White river, when I noticed the boulder, and it was while digging with a hunting-knife about the boulder, in order to ascertain whether there were any glacial scratches upon it, that I found the palæolith. Careful study of gravel deposits in the valley of the Somme, where I had found implements of the river drift men in place, led me to recognize the importance of this discovery and take particular note of the fact that the palæolith lay in an undisturbed aqueous deposit.

The implement is chipped from a mass of gray flint. It is tri-

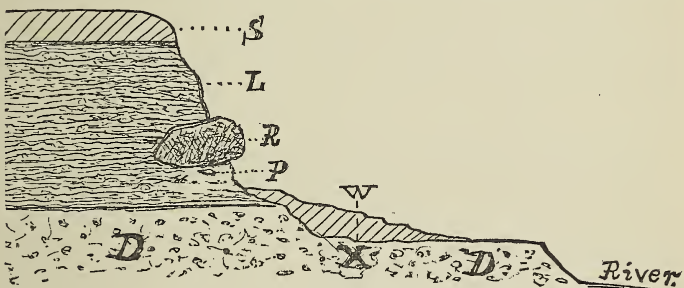


FIG. 1. Section of bluff at White River, Jackson Co., Ind. *S*, soil; *L*, gravel; *R* boulder; *P*, position of the implement; *W–X*, talus; *D*, *D*, older gravel.

angular and measures 6½ inches in length, 3¾ inches in greatest width and is 1⅝ inches in thickness. It is now in the Peabody Museum at Cambridge, and bears the catalogue number 46145. See pages 162, 163 for figures.

In relation to this gravel deposit on the White River, the following extract from a letter of my friend, Prof. G. F. Wright is of interest.

"From my notes it seems to me most likely that the situation is nearly identical with that at Trenton. The east fork of the White River occupies a very interesting relation to the ice movement, as a glance at the glacial boundary will show. The Illinois lobe of ice which crosses the outlet of White River extends considerably farther south than the lobe extending to the vicinity of Louisville and occupied by the head waters of the stream. This would have prevented much of a secondary glacial accumulation from taking place through Davies, Martin and Lawrence Counties.

And so I found it in fact. There is no evidence of much glacial drainage through those counties. But the glacial drainage was east of the knobs towards Louisville, Kentucky. This the Indiana geologists early perceived and called the glacial stream Collet's River. Medora lies a few miles west of where I located the boundary of direct glaciation, but in a valley where water deposits from the ice front would have been likely to have accumulated to a considerable extent. It is quite possible that the deposit marked *D* is a direct glacial deposit. If not it is what accumulated in the temporary lake which existed there for a while when the mouth of the river was dammed up by the Illinois loess. The triangular glaciated space in southern Indiana must have been a favorable place for preglacial man, and its borders present just the conditions for the preservation of his remains."

THE AGE OF THE PHILADELPHIA RED GRAVEL.

BY G. F. WRIGHT.

The discovery of palæolithic implements, as described by Mr. Cresson near Claymont, Del., unfolds a new chapter in the history of man in America. It was my privilege in November last to visit the spot with him, and to spend a day examining the various features of the locality, and the views presented on the screen have brought the situation vividly before your eyes.

Notwithstanding the danger of a little repetition, I will state that the cut in the Baltimore and Ohio railroad in which this implement was found is about one mile and a half west of the Delaware river, and about one hundred and fifty feet above it. The river is here quite broad. Indeed, it has ceased to be a river, and is already merging into Delaware bay; the New Jersey shore being about three miles distant from the Delaware side. The ascent from the bay at Claymont to the locality under consideration is by three or four well-marked benches. These probably are not terraces in the strict sense of the word, but shelves marking different periods of erosion when the land stood at these several levels, but now thinly covered with old river deposits. Upon reaching the locality of Mr. Cresson's recent discovery, we find a well-marked superficial water deposit containing pebbles and small boulders up to two or three feet in diameter, and resting unconformably upon other deposits different in character; and in some places directly upon the decomposed schists which characterize the locality. This is without question the Philadelphia Red Gravel and Brick Clay of Lewis[1]. The implement submitted to us was found near the bottom of this upper deposit, and eight feet below the surface. Not more than a mile from the same locality was a shelter-cave carefully explored by Mr. Cresson many years ago in which also palæolithic implements were found in the bottom beneath large accumulations of debris. The same railroad has cut through this also, and the continuity of the superficial deposit is manifest from one place to the other. As Mr. Cresson was on the ground when the implement was uncovered, and took it out with his own hands, there would seem to be no reasonable doubt that it was originally a part of the deposit, for Mr. Cresson is no novice in these matters, but has had unusual opportunities, both in this country and in the old world, to study the localities, where similar discoveries have heretofore been made. The absorbing question concerning the age of this deposit is therefore forced upon our attention as archæologists, and to this we will direct our discussion.

The determination of the age of these particular deposits at Claymont involves a discussion of the whole question of the Ice Age in North America, and especially that of the duality of the glacial epoch. At the meeting of this Society on Jan. 19, 1881, I discussed the age of the Trenton Gravel, in which Dr. Abbott has found so many palæoliths and was led also incidentally at the same time to discuss the relative age of what Professor Lewis called the Philadelphia Red Gravel.[2] I had at that time recently made repeated trips to Trenton, and with Professor Lewis had been over considerable portions of the Delaware valley for the express purpose of determining these questions. The conclusions to which we, that is, Professor Lewis and myself, came were those expressed in the paper above referred to; namely, that the Philadelphia Brick Clay and Red Gravel (which are essentially one formation) marked the period when the ice had its greatest extension, and when there was a considerable depression of the land in that vicinity; perhaps, however, less than a hundred feet in the neighborhood of the moraine, though increasing towards the northwest. During this period of greatest ice-extension and depression, the Philadelphia Red

[1]For Lewis's Views see Abbott's Primitive Industry, pp. 324, 335; "The Surface Geology of Philadelphia and Vicinity," Proc. Acad. Nat. Sci. of Phil., Nov. 25, 1888; "Geology of Philadelphia," Journal of Franklin Institute, June, 1883.

[2]See "Proceedings," Vol. XXI, Jan. 19, 1881, pp. 137-145.

Gravel and Brick Clay were deposited by the ice-laden floods which annually poured down the valley in the summer seasons.

As the ice retreated towards the headwaters of the valley, the period was marked also by a reëlevation of the land to about its present height, when the later deposits of gravel at Trenton took place. Dr. Abbott's discoveries at Trenton prove the presence of man on the continent at that stage of the glacial epoch. Mr. Cresson's discoveries prove the presence of man at a far earlier stage. How much earlier will depend upon our interpretation of the general facts bearing on the question of the duality of the glacial epoch.

Mr. McGee of the United States Geological Survey has recently published the results of extensive investigations carried on by him respecting the superficial deposits of the Atlantic coast.[1] He finds that on all the rivers south of the Delaware there are deposits corresponding in character to what Professor Lewis had denominated Philadelphia Red Gravel and Brick Clay. These deposits are rather coarse at the bottom and fine at the top, though boulders two or three feet through frequently occur in the clay, showing that the currents of water were ice-laden at the height of the period. But according to Mr. McGee these deposits diminish both in extent and elevation as we proceed southward along the coast. But still the marked evidence of floating ice is seen in the occasional boulders enclosed in the finer material. From the extent to which this deposit is developed at Washington in the District of Columbia, Mr. McGee prefers to designate it as the Columbia formation. But the period is regarded by him as identical with that of the Philadelphia Red Gravel and Brick Clay which Professor Lewis had attributed to the period of maximum glacial development on the Atlantic coast.

It is observable that the boulders in this Columbia formation belong, so far as we know, in every case, to the valleys in which they are now found. The boulders in the Philadelphia Brick Clay are all from the Delaware valley, and so, about Baltimore, the corresponding deposits can be traced to the local valleys converging at that point. At Washington the boulders and pebbles are all from the Potomac valley. It is observable also that it is not necessary in any case to suppose that these deposits were the direct results of glacial ice. Mr. McGee does not suppose that glaciers extended down these valleys to any great distance. In

[1]See Am. Jour. Sci., Vol. XXXV, Feb., April, May and June, 1888.

deed, so far as we are aware, there is no evidence of even local glaciers in the Allegheny Mountains south of Harrisburg. But, it is easy to see, that an incidental result of the glacial period was a great increase of snow and ice in the headwaters of all these streams, so as to add greatly to the extent of the deposits in which floating ice is concerned. And this Columbia formation is, as we understand it, supposed by Mr. McGee to be the result of this incidental effect of the glacial period in increasing the accumulations of snow and ice along the headwaters of all the streams that rise in the Alleghenies. In this we are probably agreed. But Mr. McGee differs from the interpretation of the facts given by Professor Lewis and myself in that he postulates, largely, however, on the basis of facts outside of this region, two distinct glacial epochs, and attributes the Columbia formation to the first epoch, which he believes to be from three to ten times as remote as the period in which the Trenton gravels were deposited. If, therefore, Dr. Abbott's implements are, as from the lowest estimate would seem to be the case,[1] from 10,000 to 15.000 years old, the implements discovered by Mr. Cresson in the Baltimore and Ohio cut at Claymont, which is certainly in Mr. McGee's Columbia formation, would be from 30,000 to 150,000 years old.

But as I review the evidence which has come to my knowledge since writing the paper in 1881 I do not yet see the necessity of making so complete a separation between the glacial epochs as Mr. McGee and others feel compelled to do. But, on the other hand, the unity of the epoch (with, however, a marked period of amelioration in climate accompanied by extensive recession of the ice, and followed by a subsequent readvance over a portion of the territory) seems more and more evident. All the facts which Mr. McGee adduces from the eastern side of the Alleghenies, comport, apparently, as readily with the idea of one glacial period as with that of two. I must add also, that the subsidence which Mr. McGee assumes in the valley of the Susquehanna above Harrisburg is much greater than Professor Lewis and myself had supposed necessary when we went over the field. Professor Lewis never, I believe, placed the limit of the Philadelphia Brick Clay as more than two hundred feet above the streams either in the Delaware or the Susquehanna valley. But Mr. McGee speaks of deposits above

[1] See my paper on the "Age of the Ohio Gravel-beds," Proc. of Boston Soc. Nat. Hist., Vol. XXIII, p. 436, Dec. 21, 1887.

Bloomsburg in the Catawissa Hills, Luzerne county, which he attributes to the Columbia floods, as reaching to the height of five hundred feet above the Susquehanna. It will be observed, however, that this is very near the margin of the terminal moraine as laid down by Professor Lewis and myself across the Susquehanna valley. But both of us became convinced that we did not, when examining that region, give sufficient attention to what we afterwards denominated the "fringe," — that is, to the scattered indications of direct glacial action found over a belt more or less wide in advance of the heavier deposits, which could more properly be called "terminal moraine."[1] In our report on this locality we refer to occasional transported boulders found upon hilltops in front of the moraine in the vicinity of the Susquehanna and Delaware rivers, and which, Professor Lewis remarks, it is difficult to explain, upon any theory of a flood, and that they may be of like origin with the fringe farther west. In view of these facts, therefore, I suspect at present that the highest boulders, to which Mr. McGee refers on the Catawissa hills in the vicinity of the Susquehanna, are the direct results of glacial action; the ice itself having extended that far below the terminal moraine. I am confirmed in this belief from the fact, that below this point on the way to Harrisburg, Mr. McGee does not find the deposits much above the two hundred foot line at which Professor Lewis had limited it. Until further examination of the district with these suggestions in view, or until a more specific statement of facts than we find in Mr. McGee's papers, it would therefore seem unnecessary to postulate a distinct glacial period to account for the Columbia formation.

Time would fail us, however, to enter into the whole discussion relating to the various stages of glaciation brought to light by recent investigations in North America. But no matter which view prevails, whether that of two distinct glacial epochs or of one prolonged epoch with a mild period intervening, the Columbia deposits at Claymont, in which these discoveries of Mr. Cresson have been made, are older (perhaps by many thousand years) than the deposits at Trenton, N. J., at Loveland and Madisonville, Ohio, at Little Falls, Minn. (of which more particular account was given this society a year ago), and at Medora, Ind., of which Mr. Cresson has given us an account to-night. Those all belong to the later portion of the glacial period, while these at Claymont belong to the earlier portion

[1] See "Pennsylvania Report," Z, p. 201.

of that period, if they are not to be classed according to Mr. McGee as belonging to an entirely distinct epoch.

Dr. C. C. Abbott exhibited a water-worn pebble, showing unmistakable evidence of artificial chipping, which he had taken from the bed of the Delaware river, near Trenton, N. J., where the stream flows over the most extensive deposit of the "Trenton gravel;" and called attention to the identical character of its surface with that of the associated pebbles. The specimen was found so far from the banks of the stream, that it was apparent it could not have been recently washed from them during a flooded condition of the river, nor even dropped by Indians into the water, as unquestionable relics of that class found in the river show but a slight water-worn condition. The archæological interest of the specimen centred in the fact that like objects (palæolithic implements) when found in the undisturbed gravel always exhibit an unworn and dull surface, due to atmospheric and chemical conditions operating upon them. Thus all objects from the gravel, where oxide of manganese or of iron occurred, have been found to be coated alike; thus showing that they had been exposed to the action of these salts for the same length of time. This uniformity of the condition of the surface of both the natural pebbles and chipped objects was held to be important evidence that the latter were of the same age.

Dr. Abbott also exhibited a quartz implement found in place in the Trenton gravel, at a depth of eleven feet, which was of identical pattern with some of those found by Miss Babbitt, at Little Falls, Minn. But four quartz implements have been collected from the Trenton gravel, and three of them are of this same pattern, which is one that does not occur, apparently, among the objects, of like age, made of argillite.

The President said that the importance of Mr. Cresson's discoveries, in the gravel and in the rock-shelter, could not be overestimated. The two implements (figs. 1 and 2) which he had found in the gravel, as shown by Professor Wright in the views which he has exhibited to us this evening, were from gravel beds much older than the Trenton, and corresponding to the Columbia gravel of McGee. Should the great antiquity now given to these lower gravels remain unchallenged, it would place man in the Delaware valley at a time long before the deposition of the Trenton gravels.

Bearing upon this question, it must be remembered that we have one palæolithic implement found, four feet from the surface, in the older gravel upon which the Trenton rests, at Trenton, New Jersey. This specimen was sent to the Peabody Museum by Dr. Abbott's son Richard, and I have brought it here for your examination.

The results of Dr. Abbott's investigation of the river-bed in the vicinity of Morris Island, below Trenton, which he has given us to-night, are of special interest, as they show that the stone implements, once buried by the Trenton gravel, have since been washed out of the gravel by the action of the river, and are now found upon its bed associated with other water-worn stones. Two of these water-worn implements are before you for examination and comparison with others taken from the gravel.

Mr. Cresson's discovery of a chipped-flint implement of large size (fig. 3), in place in the gravel of White river, Indiana, is another important fact in relation to the distribution of early man in America. Professor Wright has shown to us this evening, by a series of instructive lantern pictures, the continuity of this gravel deposit in Indiana with that of New Jersey, from which about four hundred implements have been taken by Dr. Abbott, and that of Ohio, from which we have two implements found by Dr. Metz.

Referring to Mr. Cresson's examination of the rock-shelter in Delaware, we have before us a series of objects taken from the several layers of the shelter, which give us a chronology of the utmost importance, as each period of occupation of the shelter was followed by a natural deposition, separating the different periods of occupation. The stone implements upon this tablet were taken from the lowest layer, indicating the earliest period of occupation of the rock-shelter; and, as you will see, they correspond in shape and rudeness of execution with those taken from the gravel-bed at Trenton, and like most of the latter, they are all of argillite. These specimens from the second period are of argillite, and while many are chipped into slender points, they are still of very rude forms; and these in turn correspond with the argillite points found by Dr. Abbott deep down in the black soil, or resting upon the gravel, at Trenton. In the upper layers of the shelter, we observe, as on this tablet, the gradual introduction of implements chipped from jasper and quartz, and corresponding in form with those found upon the surface throughout the valley. And as a further indication of this later development, it was only in the upper layers that pottery, bone implements, and ornaments of shell, bone and stone were found. The three distinct periods of occupation of the Delaware valley are thus distinctly shown; and this rock-shelter is a perfect exemplification of the results which Dr. Abbott obtained from a study of the specimens which he has collected upon the surface, deep in the black soil, and in the gravel, at Trenton.

The President then alluded to a recent paper by Mr. McGee, as a clear presentation of the geological condition under which early man existed in North America, but it is to be regretted that Mr. McGee had not examined the collection of palæolithic implements in the Peabody Museum, before writing his paper; for, had he done so, he would not have fallen into several errors in relation to some of the objects. Particularly in intimating that the specimens obtained by Miss Babbitt in the drift at Little Falls, Minn., were simply chips of quartz and of doubtful artificial character. To show that this was an error, the President exhibited a number of specimens, sent to the Peabody Museum by Miss Babbitt, all of which were found associated and in place in the river drift, a description of which has been given by Mr. Upham in a carefully prepared paper at one of our meetings last winter. These specimens found by Miss Babbitt are all of white quartz, and while some are simply chips, others of these before you are identical in shape as well as material with the specimens obtained by Dr. Abbott in the Trenton gravel, and certainly their artificial character will not be questioned. Fig. 4 is of one of these quartz implements from the Trenton gravel placed here for comparison with fig. 5, which is one of the quartz implements from Little Falls. Figs. 6 and 7 are two other chipped implements of quartz from Little Falls. Certainly these are something more than chips and are unquestionably artificial.

The President then alluded to the importance of the collection of palæolithic implements in the Peabody Museum at Cambridge, where nearly all the specimens obtained from the Trenton gravel, the two from the Delaware, one from the Indiana, and the two from the Ohio gravels, with a large proportion of those collected by Miss Babbitt at Little Falls, are exhibited side by side.

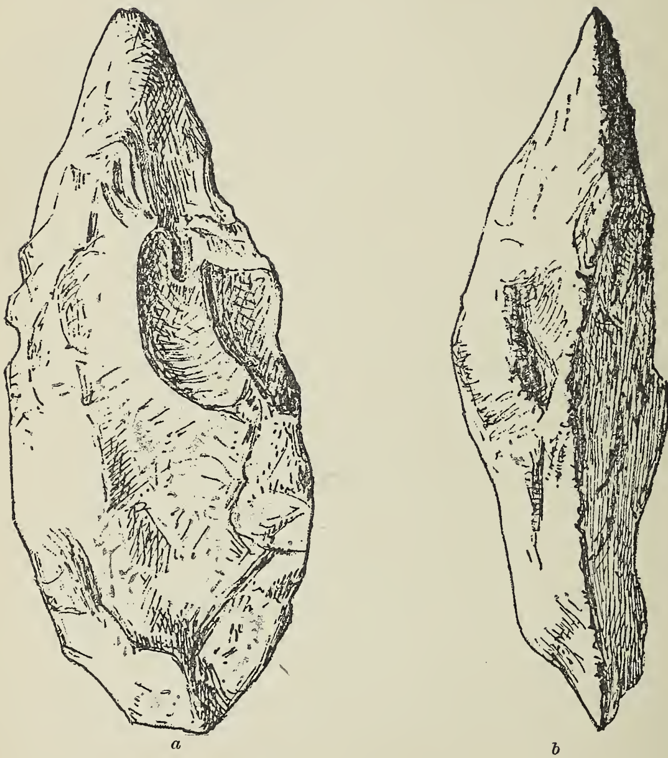
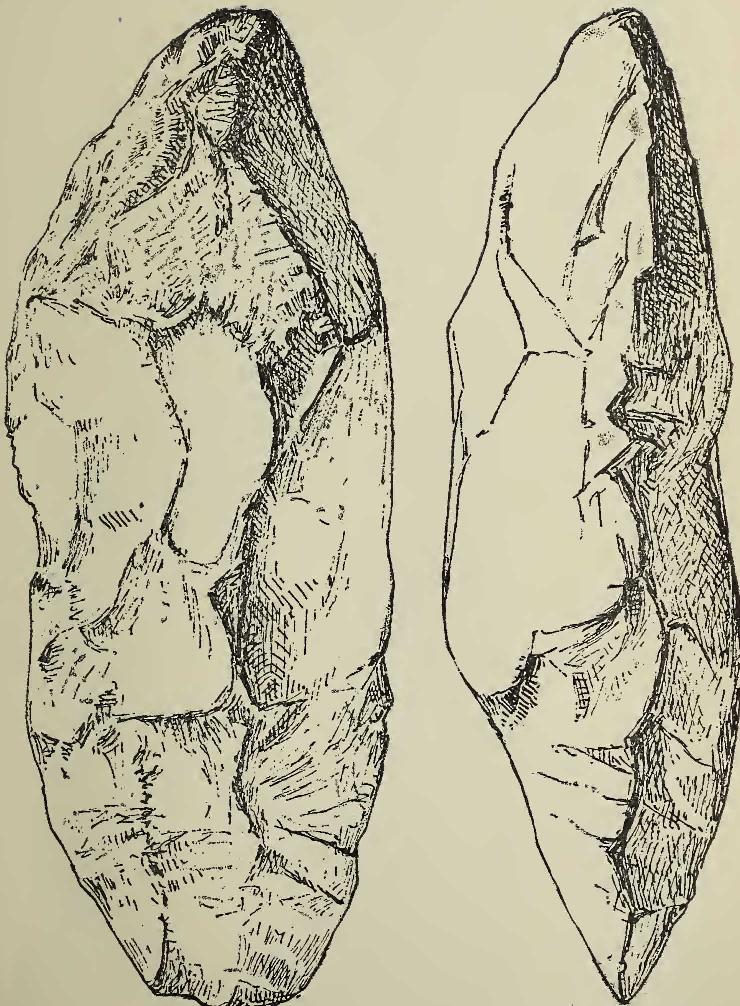


FIG. 1. *a*, face; *b*, side view, actual size. Implement of argillite from gravel, 8 to 9 ft. below overlying bed of clay. B. & O. R. R. cut near Carpenter's Station, Newcastle Co., Delaware. Peabody Museum, No. 45726. From Mr. Cresson.

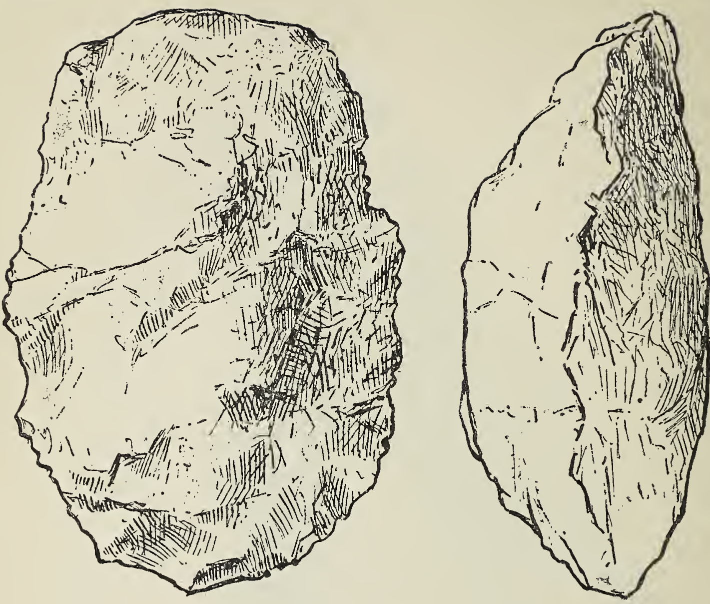


a b

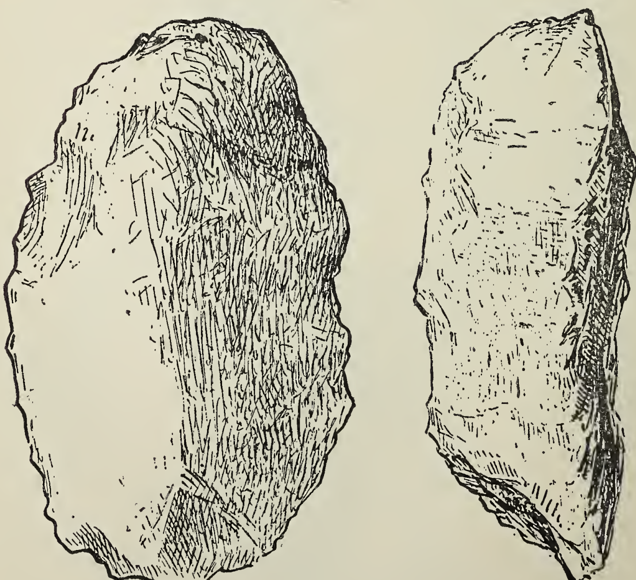
Fig. 2. *a*, face; *b*, side view, actual size. Implement of argillite. From gravel at Red Cut on B. & O. R. R., Carpenter's Station, Newcastle Co., Delaware. Peabody Museum, No. 46144. From Mr. Cresson.

FIG. 3, *a*. Actual size. Implement of gray flint in gravel 11 ft. from surface. Bluff East Fork of White River, Jackson Co., Indiana. Peabody Museum, No. 46145. From Mr. Cresson.

FIG. 3, *b*. Side view of Fig. 3.



4, *a*. 4, *b*.



5, *a*. 5, *b*.

FIG. 4. *a*, face; *b*, side view, actual size. Implement of quartz from gravel, Penn. R. R. cut, Trenton, New Jersey. Peabody Museum, No. 33164. From Dr. Abbott.

FIG. 5. *a*, face; b, side view, actual size. Implement of quartz from modified drift at Little Falls, Minn. Peabody Museum, No. 31331. From Miss Babbitt.

6, *a*.

6, *b*.

7, *a*

7, *b*

FIGS. 6, 7. *a*, face; *b*, side view, actual size. Implements of quartz, from modified drift at Little Falls, Minnesota. Peabody Museum, Nos. 31316, 34088. From Miss Babbitt.

General Meeting, January 2, 1889.

The President, Prof. F. W. Putnam, in the chair.

The following is an abstract of the first paper of the evening:—

LESSONS IN THE THEORY OF DIVERGENT EVOLUTION DRAWN FROM THE DISTRIBUTION OF THE LAND SHELLS OF THE SANDWICH ISLANDS.

BY REV. JOHN T. GULICK.

I will first exhibit the typical forms of *Achatinella Budii* and *fulgens*, described by Dr. Newcomb, from the valley of Palolo, island of Oahu. Though these species are found in the same valley and sometimes inhabit the same trees, they are distinguished from each other in a degree that is usually regarded as specific, as long as intergrades are not discovered. We find, however, that a complete series of the varieties and species collected in that valley, present a network of intergrading forms. Passing over the mountain ridge to the sheltered groves of the next valley on the northwest, less than a mile distant, we are astonished to find that neither of the two species with which we commenced is present, and that the species most fully developed here are only sparsely represented by divergent varieties in the first valley. Passing over another ridge into the third valley, we find nearly all the arboreal species different from those of the first valley, though the vegetation and the habits of feeding are quite the same.

Continuing our investigations in valleys ten and twenty miles distant, we find that the degree of divergence, for species of any one closely related group, is roughly measured by the distance by which the forms are separated, which is also the measure of the time and degree of the influences that have interfered with their free crossing.

We also find that the species found in valleys twenty miles apart completely intergrade with each other through lines of species and varieties, found, for the most part, in valleys occupying the intermediate portions of the mountain range. From this fact, we learn that species are nothing more than strongly pronounced varieties. If freedom from intergrading is received as the necessary and sufficient test of good species, then a multitude of forms that are now only varieties may be turned into good species by burning the forests in alternate valleys on the sides of this mountain range.

We further learn that the divergence of these forms is not necessarily dependent on exposure to different environments; for the climate, rainfall, and other physical conditions of the valleys on one side of the mountain range are the same, and the vegetation, with the birds, insects, reptiles and mammals, in some of these valleys is identical, though the molluscan species are quite distinct.

In some of these cases where the environment is the same, the habits of feeding have changed, which shows that diversity of suetude[1] of natural selection, and of stimulation, does not necessarily depend on exposure to different environments.

That divergent evolution, through the influence of diversity of suetude, natural selection, or any other principle, cannot take place without the independent generation of the diverging forms, is indicated by the fact that, in forms that are closely allied and liable to cross, divergence is measured by the degree of geographical segregation; while between contrasted groups, that are presumably held apart by mutual sterility, aided perhaps by dissimilar habits of feeding and by sexual instincts, the widest divergence is often presented by forms inhabiting the same valley.

This paper was discussed by Professors Hyatt and Putnam, Mr. S. H. Scudder and the Secretary.

Dr. D. F. Lincoln then spoke of the surface geology of the Middlesex Fells.

General Meeting, January 16, 1889.

Prof. Alpheus Hyatt, in the chair.

The following papers were read:—

A LARGE CARP AND ITS HISTORY.

BY SAMUEL GARMAN.

The first of the letters copied below was placed in my hands by Mr. William Hapgood, to whom it had been sent with a box containing fins, bones and scales of the fish. The letter was written to

[1] Under "suetude" I include use, disuse, and effort.

John H. Whitcomb, Esq., by Mr. Edwin L. White of Ayer. The pieces were handed to me for identification. They proved beyond question to have been taken from a carp, *Cyprinus carpio* L., probably var. *rex cyprinorum*. This notice is given to the matter because the occurrence and the size of the fish make it worthy the attention of those interested in our fisheries and in the success of the efforts of the Fish Commissioners in stocking our waters ; and, besides, making the case public may call out other notices, contributing to a knowledge of the condition and abundance of the introduced fishes. The letter is as follows :—

Ayer, Mass., Nov. 8, 1888.

Dear Sir :—

I enclose in the box which accompanies this note, the remains of the monster fish which was shot in Kilburn's pond, in the eastern part of Shirley, on the Mulpus brook, by Calvin L. Farnsworth, about September third of this year. The fish measured thirty-one inches from the end of the nose to the end of the tail, measuring over the back; and it was twenty-five and a half inches long on a board as it lay flat. Its body was ten inches wide and five inches thick; when the fins on back and belly were spread out it was sixteen inches from the top of one to bottom of the other. It weighed sixteen and a half pounds when taken from the water. I did not see it weighed, but lifted it afterward. So many saw it on the scales there is no doubt the weight given is correct. It was truly a monster. I supposed it to be a small-mouth Black Bass, but an enormous one for these waters. The tail, which I enclose, would spread eleven inches ; in drying it has shrunk some. The scales, some of which are in the box, were fully two inches broad by one and a quarter inches long. The ribs in the section I had for dinner were five and a half inches long or even longer. It seems too bad others did not see this fish. I never have heard of one of the kind nearly as large. I marked out by the piece that I had, the shape and size, as you will see, on the paper. The little jagged bone rolled up in white paper was in front of the back fin. I do not think of anything else of interest regarding this fish. When I found so many were interested I tried to get more of it, but was too late. This specimen had lots of spawn in it. The pond is a small one, and has not been drawn off for thirty years. But for one low dam the fish could have gone up stream about three miles. Gates at that dam have been open months at a time.

Yours truly,

Edwin L. White.

A dam below the pond is said to prevent access from that direction. Recognizing the fish at once, I wrote Mr. White for permission to use the contents of his letter, and also for any further information he might be able to add that would be at all likely to throw light on the history of the specimen. In response he has kindly made inquiries; among the answers to which, as it seems to me, we find a reasonable clew to the origin of this carp. The following is his reply to my questions:—

Ayer, Mass., Dec. 31, 1888.

Dear Sir:—

I received your letter of the nineteenth instant in due time and have since been trying to find something reliable or, at least, plausible to say to you regarding the origin of what we called the "monster fish." There were several stories which when followed out did not give much satisfaction. Mr. George Kilburn, whose father used to own the pond where the fish was shot, says that about fifteen years ago, a Mr. Pierce came to the mills with a few little fish that he called black bass and put them in the pond. I do not know that there has been a black bass caught or seen there since. The man who owns the pond and shot the fish says that about eight years ago he put what he had left of some live bait, shiners, suckers, and other little fish, into the pond. He thinks it might have been one of them. I do not see much to depend on in that. There have been no ponds stocked with any fish in Shirley that I know of. This particular pond is on the Mulpus brook which has its origin in a spring in the northeast part of Lunenburg. There were two of the large ponds in that town stocked with black bass some fifteen years ago, but I see no way they could have got into the Mulpus. I have to-day heard a more plausible story direct from the man who planted the fishes. Mr. Herbert Mead who lives in the northern part of Lunenburg has a small pond where he cuts ice in winter. It discharges into the Mulpus, when it overflows, but gets pretty dry in summer. About eight years ago he put into it twenty German carp that were nearly four inches in length. In about six months the pond was almost dry, and in bailing it out only four of the carp were found. These had grown to be a foot in length, which is growing pretty fast. Mr. Mead thinks the fish was one that escaped from his pond during a freshet, and, if it was a carp, it may be so. I never have seen a carp, or any fish like this. It is fully five miles from his pond to where the fish was found, and she would have to come through several small mill ponds. That, however, would be easy enough in high water. Altogether this seems as likely to indicate the source as anything I have heard. The fish had been seen several times in the pond where it was found, during the past two years. This pond is not large, perhaps five or six acres in all, but there is a deep pocket in it near the dam, which has not been drawn off in thirty years I am sure. I judged it to be an old fish from its size, and think it was hardly one-third covered with scales; there were some along the back bone, and a strip on the sides, none on the belly, which was a dark yellowish green, not very handsome. It had been seen apparently feeding from the bottom as near shore as it could get. I have written all I could get hold of that was likely to interest you or help to establish the identity of the fish.

Respectfully yours,

Edwin L. White.

The portions submitted for identification comprise ribs, vertebræ, scales, the dorsal spine, the caudal fin, and the pharyngeal bones with their teeth. They confirm Mr. White's statements in regard to the size of the specimen. According to data gathered from various sources a length of twenty-five and a half inches, with a weight of sixteen and a half pounds might be attained in about six years, varying with the amount of food and warmth of water. Mr. Poppe, who began carp farming in California in 1872, had specimens that reached a weight of fifteen pounds in five years. In the first year they acquired a length of twelve inches. Other specimens have grown to about six pounds in three years. Hessel states that in two summers the weight of some had become as much as three pounds. He mentions two specimens that at fifteen years of age weighed forty-two and fifty-five pounds respectively. He also comments on others up to ninety pounds. It is well known that the carp lives to more than a hundred years.

The statement of Mr. Mead furnishes a probable explanation of the presence of the fish in Kilburn's pond, yet it is quite possible that it may have been helped up around the dam, with live bait or otherwise, from waters connecting, through the Nashua, with the Merrimac river and its tributaries. The government distributed carp to the Fish Commissioners of Massachusetts and of New Hampshire and to others in these states in 1880, following the lots then distributed by others in the following years. These were distributed in the states mentioned in such a manner that a considerable number of the localities supplied were drained by the Merrimac. Wherever it might have been planted at first it would be possible for a fish to reach any of the small brooks or ponds of the system, if not prevented by insurmountable obstacles, as falls or dams.

From what we have gathered it is not at all likely this specimen from Kilburn's pond was more than eight, or less than five years of age.

ON THE EVOLUTION OF THE RATTLESNAKE.

BY SAMUEL GARMAN.

Primarily the object of the study that has led to the writing of this paper was to determine the structure and development of the rattle. A secondary purpose was that of tracing, if possible, the manner of its acquisition by the various species characterized by it. The work was based on material provided by the Museum of Comparative Zoölogy, at Cambridge, Mass., and the greater portion of the results was published in the Bulletin of the Museum, Vol. VIII, No. 10, p. 259. It was only by means of a stage from one species, a later from another, a still later from another, and so on, that the growth could be followed from the very early stages to the latest; yet, the course of development being the same in all, it is evident that a series formed thus would answer the purposes of the inquiry quite as well as if made up from any one of the species represented. In connection with the work, observations have been made on a large number of individuals, belonging to many species, venomous or non-venomous, in alcohol or living, captive or in the field.

The snakes, without exception, so far as we know, have the habit of sloughing one or more times each year; that is, they throw off the outer layer of the skin, the epiderm, from time to time. The number of times the slough is shed varies in different specimens, and, possibly, in the same specimen at different ages. A large "king snake" in my possession went through the process in April, July and December; its mate did the same in March, May, August and October. These snakes were kept in a warm room throughout the year, and the number of sloughs is probably more in each case than it would have been under normal circumstances, out of doors, where the animals had been allowed the customary winter sleep. Ordinarily it appears as if not more than two sloughs are cast in a season: one on coming out of winter quarters in the spring, another about mid-summer or later.

What appear like scales on the snake are really folds in the skin; from these the slough comes off entire, extending over, around and under them, so that from head to tail it forms but a single piece of very thin horny material. As this is stripped off it is generally turned inside out, excepting the little hollow cone covering the tip of the tail. This cone, or *cap*, as we shall call it, usually slips off without being turned; its outlines are those of the extremity, behind the regularly arranged folds. On some of the serpents, kept under notice, the new epiderm was plainly visible, about three weeks before casting the old. It was indicated by a milky appearance, just beneath the slough that was to be removed. As this whitish growth covered the whole body, eyeballs included, it interfered greatly with the vision. While ability to detect large shadows no doubt remained throughout, there was a period of a couple of weeks during which partial blindness, in consequence of the new growth, prevented readiness in distinguishing smaller objects. A week before sloughing the whiteness had disappeared, the eyes were bright as before, and, if it had not been for a dullness in the colors of the skin, one would have thought the slough had been lost. A few days later, restlessness and a disposition to rub the sides of the head against rocks, or the boards of the cage, showed that the creature was ready to free himself from the slough. By dint of pushing and rubbing, it was loosened around the lips and crowded back over the head and the neck. Thus far the work was done by pushing against one object or another.

As soon as the liberated portion was far enough back to permit it, the snake rested the lower side of his neck and body on the floor, in such a way as to bring their weight upon the epiderm that had been set free; then reaching forward some of the broad ventral scales as if gliding, he caught their edges in it and pulled it backward. Though the pulling was all done on the lower surface, it stripped the coat from sides and back as well. In this manner the whole anterior part of the body was freed. Afterward the tactics were changed and by winding about among the sticks and stones the loose skin was soon entangled and held, while the snake going ahead crept out of the balance in less time than it has taken to describe it. The slough was somewhat like damp paper; it seemed to have been wet on the inner side with a mucilaginous secretion which in drying held firmly to the object in contact. The snake after sloughing was in his most brilliant, most active and most hungry condition. The manner of removing the useless skin varies among different serpents, and, undoubtedly, would be varied to some extent by the individual under different circumstances.

The description has been taken from a non-venomous serpent of the most common type of tail, that is, a tail that tapers gradually to a conical point from which the slough is shed as a hollow cone, the *cap*. In the longitudinal section of such a tail the vessels, muscles and vertebræ diminish in size toward the extremity until the portion within the cap is reached, where the identity of one or more of the vertebræ is lost in a conical mass of bone, forming the end of the column, the lateral outlines of which are similar to those of the cap. The number of caudal vertebræ varies from half a dozen or less in some of the short, thick-tailed forms, to more than two hundred in some of the excessively elongate types. On the copperheads and moccasins (*Ancistrodon*) the number may be estimated at from forty-five to fifty-five, and on the rattlesnakes (*Crotalus* and *Sistrurus*) from twenty-five to thirty-five.

The epiderm of the rattlesnake is shed in much the same way as that of other snakes. It comes off the whole body, and is all thrown away excepting what covers the end of the tail. The cap is set free from the skin in a measure, but it cannot get entirely away because of its shape. Though loosened and dislodged from its place of growth, by its form it is mechanically retained to become a part of a rattle. The tip of the tail in one of these serpents is called a "button;" each of the sloughs (caps) from the button forms a "ring" of the rattle. With modification and thickening of the skin in the button the epiderm has become thicker and firmer than over the balance of the body; the structure and mode of growth are apparently the same. The character of the organ is such that it is necessarily a post-natal acquisition, yet its existence at the later period is assured by the condition of the button at birth. In fact, specialization has already proceeded so far when the creature is born that the inquiry must be taken up in much earlier embryonic stages.

In an embryo showing the body and tail well formed, previous to the appearance of the scale folds on the skin, the vertebral column in the tail is similar to that of other ophidians at the same stage: each vertebra is distinct, movable, and supplied with the usual muscles. The folds are seen first anteriorly, on the body, and later they appear on the tail; so that by the time the cap is formed on the button, the scales are completed over the whole skin. This stage is illustrated in figs. 1 and 2. Externally they show a short, broad, rounded cap, without shoulders or constrictions, of a shape intermediate between that of the pointed-tailed species and that of young rattlesnakes just before the first slough, and distinctly and regularly separated from the folds in front of it, or, in other words, without sign of having been enlarged by fusion of scales. The condition within the button is shown in fig. 2. The vertebral column is flexible; the vertebræ are distinct and surrounded by muscles. At this time the embryo appears to have attained the condition in which the majority of the serpents are hatched; but it still makes a considerable advance before birth. It is as if there had been a later addition to the embryonic development, resulting in important changes of structure. An advance is made beyond the point reached by the embryo of the ordinary species producing living young, as the latter may be said to have gone farther than that of the egg-laying species. If the cap were complete in this stage (figs. 1 and 2) it would be lost with the slough from the body, and a rattle would not be possible.

Figs. 3 and 4 are taken from a specimen shortly after birth. The changes, as compared with the preceding, are very marked. In addition to the part of the cap that was present in the earlier stage, we find an anterior, wider portion, a shoulder or swelling, separated from the posterior section by a slight constriction, as if subsequent growth in this part of the tail had demanded the interpolation of a wider band to contain a greater bulk, and as if increase in length of the button had crowded the cap back from the scales, compelling expansion at its anterior margin. That the increase in size of the cap is not entirely, or even mainly, due to a backward growth from its anterior margin will be seen from what follows. In a section of this stage, fig. 4, the hinder seven or eight of the vertebræ are seen to have coalesced into a single mass, showing a disposition to expand so as to obliterate the processes and lines of demarcation of the bones of which it is composed, but which are still plainly indicated. This composite bone may be called the *shaker*. Through its own expansion, and the thickening of the skin around it the muscles between the bone and the skin are on the way to disappear. The muscles controlling the shaker lie in front of it and are strongly developed. This stage has the completed button. As yet the snake has no rattle. After the first sloughing he finds himself in possession of one made up of a single ring and the button. The ring is the cap with which he was born; it has been freed from the button and pushed backward, far enough to make room for the anterior swelling of a new cap between itself and the scales, and there it clings loosely but securely to its successor. The process is the same for each succeeding ring.

Figs. 5 and 6, from a specimen which had displaced the first cap and was in the act of displacing the second, illustrate the manner in which the ring is moved back as the new cap is formed. At the time of the new growth, the tail immediately in front of the button has the appearance of being swollen, and its owner is more than ordinarily sensitive in this portion of his body. The milky appearance in the skin seems to mark a period of rapid growth. In consequence of the latter, the swelling, and the limited space within the cap, a fold, the anterior shoulder or chamber of the new cap, forms between the scaly skin and the anterior edge of the cap about to be set back as a ring. This part of the new cap does not grow within the old one, but under the epiderm in front of it. The slough of the button is connected with that farther forward until the latter is torn away. Externally the growing fold is so covered by the slough that it can not be seen ; in a section, fig. 6, it is shown in position, the old epiderm still covering it and connected with the old cap, the new ring. The operation of casting the old coat bears some resemblance to what occurs in crustaceans when the old shell is too small : the owner creeps out of it and at once forms a new one. There is this difference, however, the snake creeps only so far out of the cap as is made necessary by the new growth, and the swelling in the skin, at the time of the rapid production of dermal tissue. The increase in size itself pushes back the cap ; at the same time the first and second chambers of the latter are so closely filled by the tissues that it goes no farther back than it is crowded. The enlarged button is too bulky to be contained in the old cap, and the fold in front of the latter rises on the overplus. After the tumid condition is passed, the new cap shrinks a little more in proportion than the new ring ; this gives the freedom of movement needed for the rattling. The changes in the vertebræ of the button have gone on until a very substantial shaker has been formed, fig. 6. Indications of the different vertebræ included are less distinct than in the preceding stages, but they are still apparent in the forward portion. The extent to which the transformation is carried is seen in fig. 8. In the specimen from which this sketch was taken the shaker is a very clumsy bone with scarcely any indication of the original constitution. It is surrounded by the thickened skin, except in front, where the muscles by which it is held and vibrated are attached. On its surface the shaker has a smooth and solid appearance, but if cut through longitudinally it is found to be lightly constructed, to be full of cavities, and to contain the vessels of the column in their original positions, as before the consolidation.

The large specimen from which figs. 7 and 8 were drawn has an entire series of eleven rings and a button. Each ring grasps two of the shoulders of that next succeeding it in time, and each, excepting the first, is grasped in the same manner by its predecessor. Not having been formed within a ring, the shape of the first, the hindmost of the series when present, differs from that of the others ;

it may always be recognized by its simple rounded outlines and lack of some of the constrictions and shoulders. Even when the rings are all present they cannot be said to give a certain indication of the age of the individual. Apparently each slough adds one ring; the number of sloughs may vary from one to several in a season. From the first ring to about the seventh, in the larger species, and to about the sixth in the smaller ones, the increase in the size of the body is usually very rapid; this is traced in the comparative sizes of the rings. Each succeeding being larger than the predecessor, the series is of the acuminate or tapering pattern. After the seventh or eighth the sizes are more nearly the same, and thenceforth the rattle is of the type formerly described as parallelogrammic. Rings being acquired in the spring as also in the fall, the age of a specimen in possession of a complete series may better be estimated by counting two rings to the year. The shape of the hindmost ring will decide any question as to presence of all the rings. On large individuals an entire series is rarely found.

On the uses of the rattle there is not a great deal to be said. Very thick-tailed species and, possibly, those with prehensile tails being excepted, snakes pretty generally are addicted to making a rattling noise, when excited, by striking the tail from side to side. Primarily these motions may have indicated only nervous excitement; meaning no more than the movements of the tail of the cat; or they may have originated in efforts to prevent attacks upon the sensitive organ by various enemies, from insects to carnivores, the dangers besetting serpents being similar to those met with by so many of the lizards. Whether the movement and rattling as developed in later times have come to signify more is still a subject of inquiry. Possibly the motions and sounds of the tail may in attempts to capture prey serve to distract the attention of the victim from the head, that the spring and seizure may be more successful. At any rate, when a rattlesnake is excited, he springs his rattle. When anxious to escape observation he makes no sound. On such occasions he will pass very near a person, going on his way in silence. Should accident betray him, and should he realize the fact, from a quick motion or even a passing shadow, he at once throws himself on the defensive and sounds a warning against any offender. By preventing cattle, horses and other animals from treading upon him the rattling certainly would prove beneficial. It is likely that, beyond this, the greater benefits are derived in the prevention of useless expenditure of venom upon objects unfit for prey. As I take it, the snake does not have a great number of chances to feed in the course of the summer, and if one or more of these were lost, through lack of the venom recklessly thrown away on anything that came along, the consequence might be a long period of fasting before another opportunity of getting food presented itself. After having thrown himself into coil, on the defensive, if the snake is not molested for a time he will start to escape. As he goes he often looks back over his shoulder, to be sure of not being pursued, sounding the rattle at the same time. Satisfied that attack is not intended he moves off more rapidly and quietly. The sound made by a rattle of half a dozen rings can be heard a distance of eight rods. Dampness modifies the sound. It has been suggested that the rattling serves as a call for the sexes. I have not found the snakes to be quick of hearing. There is much resemblance between the sound and the shrilling of certain insects, and it is possible, as has been remarked by Professor N. S. Shaler, that it may serve to bring animals that prey on the insects within reach of the rattler. Some specimens met with have never had rattles, through deformity, and through accident some have lost all except the button, yet those so deprived were in as good condition as others provided with long series. Thinness and brittleness in the rings cause such frequent losses that a perfect series of more than nine is something of a rarity.

The rattle of the rattlesnake is a series of the sloughs of the end of the tail, mechanically and loosely held together by reason of their shapes. This being the character of the organ, of course it cannot exist before the sloughing processes begin. The animal is not born with it, but acquires it some time after birth. Consequently, though we may not say exactly that the creature inherited the rattle, we can say that he has inherited the form of cap that induces it, that makes it both possible and unavoidable. It follows that in order to answer the inquiry as to how the snake got its rattle we shall have to trace the history of the cap.

The testimony of the embryo is to the effect that the cap on the tip of the tail of the progenitor of the rattlesnake was essentially similar to that of the snakes which have no rattle, but it tells nothing of the causes of the later modification. For these we shall have to interrogate forms, in the various groups of serpents more or less remotely allied, that bear evidences of effects which are probably due to the action of similar causes.

If we accept the nearly perfect cone on the end of the tail of some of the colubrine snakes as the typical button, and compare a number of specimens in the same species, we shall find that there is a large amount of individual variation. Some caps will be regular, others flattened, blunted, or otherwise imperfect in shape. The variations are much greater in some species than in others. They are especially noticeable in certain genera of venomous serpents belonging to the same family as the rattlesnakes. On the species of Bothrops, a South American genus allied to that containing the moccasins (*Ancistrodon*), there are caps that are compressed, others that are boat-shaped, others awl-shaped, others club-shaped, and some that bear slight transverse grooves suggestive of likeness in habit to the copperhead. *Rhinocerophis ammodytoides* of the same family illustrates the extreme form of the boat-shaped cap, fig. 9; and the structure of the interior, fig. 10, indicates that the button is applied to and rubbed against the earth. The "mute rattlesnake," *Lachesis mutus*, a close ally of the large South American rattler, *Crotalus durissus*, has most often the blade-like button shown in fig. 11; its variations include the awl-shaped, and among others the very irregular form from which fig. 12 is taken. The latter is a shape that must have presented some difficulty in sloughing. From the squamation of the tail, and the shape and inclination of the button, it is likely this species has a habit of rattling in which the hinder portion of the tail is raised from the ground.

It is not to variations that may affect individuals diversely that we must turn for aid in solving the problem of the rattle, but rather to a modification that similarly affects all, or at least a considerable number of the members of a species. Fortunately, one that is directly in line with this study occurs in the North American genus *Ancistrodon* containing the copperhead and the moccasin, and ranking next to *Sistrurus* and *Crotalus*, which include the rattlers. As it parallels the development of the cap in the latter to a point little short of the attainment of the rattle, we shall devote attention exclusively to it.

The moccasin, *Ancistrodon piscivorus*, is one of the "Water Snakes." It feeds mainly upon fishes, frogs and the like, that frequent the streams, ponds, marshes and other wet localities. Its tail is a little stouter, less flexible, and a little more compressed than that of the copperhead. The cap and button are horizontal, figs. 13, 14, that is, they lie in the axis of the vertebral column. They resemble those of the common water snakes, *Nerodia*, the habits of which are similar. A pair of scales usually overlie the cap and are fused with it; another pair is often present on the lower side, but at times the traces are almost obliterated. Occasionally, on the cap just below the edges of the upper pair of scales and parallel with them, longitudinal on the button, there is a shallow fold, fig. 14, in character like the transverse folds on the cap of the following species. It is evident, from shape folds and axis, that when the moccasin is excited the button strikes on the lower side and not on the apex.

The copperhead, *Ancistrodon contortrix*, is closely allied to the preceding. Its habits, however, are very different, and their effects have impressed themselves on the structure. This snake inhabits rocky or dry places, more or less free from vegetation. The tail is rather more round, slender and flexible than that of the moccasin, and the button, instead of being directed backward in the axis of the column, is inclined obliquely back and downward; so that in striking to produce a warning rattle the extreme end is struck upon the ground. The stroke itself is peculiar, in that the terminal inch or more of the tail is swung over in the arc of a circle and brought down from side to side. Such a method is suited to localities destitute of leaves or grasses. The cap on the young, fig. 15, is bluntly rounded, somewhat compressed, and with or without a shallow fold near the edge of the scales. Afterward the button becomes longer, more pointed, and the cap acquires one or more constrictions or shoulders similar to but shallower than those of the rattlesnake, figs. 16–18. This modification with age in the caps of these snakes is in direct comparison. On the other hand to compare with the moccasin is sufficient to establish the fact that the differences in the cap are due to the different methods of striking with the tail; in the one, the concussion affects the lower side of the button, in the other the apex. Each manner is best suited to its own locality. Fig. 15 is taken from a small one, fig. 16 from a larger one, fig. 17 from an average specimen and fig. 18 from the largest of the copperheads at hand. On very young individuals the declination of the axis of the button is comparatively little, not more than may have been handed down from progenitors that were expert climbers and used the tail for grasping the branches. If the young snake were born with all the corrugations on the cap, to trace them to their cause would be more difficult. As it is, it seems to have inherited the peculiarity in the habit of striking, and the possible results, the inclination and the blunted apex of the cap, while the folds are induced by the exercise of the habit. From direct observation of captives the habit of striking is well known; it is known also that the result of intermittent pressure, of percussion, on the skin of other animals is to produce thickening and hardening, callosities, corns and bunions in cases; and no reason is known why a similar cause should not produce a similar effect on these snakes. The pressure is applied at the apex of the button. The result is a harder, less yielding dermal covering at that point, and the folds are confined to the portion least affected by the pounding. With age the shoulders and constrictions increase in scope. This also is what happens on the young rattlesnake. In the latter the change is brought about entirely by inheritance; in the former it is due to the continuous modifying influence of surroundings exerted during the existence of the individual.

Unless we are prepared to disprove the fact of transmission of the effects of such modification from parents to offspring in instances like those of the blind fishes and crustacea, we shall agree that it obtains here. It will be conceded, also, that these effects are handed down little by little, and not all at once, until after the accumulation has been made. What the young rattlesnake inherits represents a completed sum of the results of influences such as are now making themselves felt on the copperhead. On the cap and button of the young of the latter, the effects of a habit modified by locality are already apparent; they become more so as the animal grows older. In other phrase, the tendency toward deeper constrictions and higher shoulders is continuous and progressive. Having reached a certain degree of development in these respects, more and more being transmitted to the progeny in the meanwhile, it is evident that on further advance in the same line the shape will become such as to prevent the loss of the cap in sloughing. Of itself this would not provide a rattle; but the ordinary increase in size of the tail, from growth and tumescence, and, possibly, a small amount of backward growth of the cap, induced by percussion, serves to displace the old cap enough to prevent growing the new one entirely within it. The similarity in the essential features of a series constructed in this manner to the rattle of the rattlesnake is apparent.

The result is so directly in the way of the actual development seen in the copperhead that one should not be at all surprised to find an occasional specimen of this serpent on which the cap still clung to the button.

While this might furnish the creature with a rattle, the approach to which is so very near already, it would do so without traversing the entire distance between it and its nearest allies, the "Massasaugas" and the "Ground Rattlers" of the genus *Sistrurus*. Yet to bridge over the gap between them it will be necessary to call in the assistance of nothing but what is naturally induced by change of habit.

Immediately upon the establishment of the rattle, the influence of its presence would begin to assert itself. The acquisition of the organ would be as likely to involve changes in structure, as a removal from a damp to a dry and rocky locality to induce those of habits and consequently of anatomy. The tail of the copperhead is slender and very flexible towards the end ; a condition favoring the present method of making sound. A cap clinging to the button would interfere, and, further, in the more soft and tender condition of the ever sensitive skin of the extremity, at the time of casting the slough, would in all probability inflict punishment if struck against objects offering resistance. Inconvenience and distress from attempts to practise the old method and, afterward, discovery of ability to accomplish the same result in a new one, would be powerful inducements to change. The motions when rattling in the air without percussion are much like those made by the snake when the tail is pinched or hurt, a possible effect of an outgrown cap. Rigidity rather than flexibility is demanded in the tail when vibrated in short, quick strokes without contact with anything. Loss of flexibility would follow such usage and the slenderness would gradually disappear, because of the development of muscles formerly neglected, but newly called into use, and with it of enlargement of the vertebræ to which the muscles are attached. The forward muscular strain, simultaneously applied, above, below, and at the sides of the column, during exercise of the muscles in crepitation, would tend to shorten the tail, and, with increase in size of the cap, to consolidation of the posterior vertebræ.

In short, the course outlined here would result in transferring a species from one genus to another : starting as a copperhead, *Ancistrodon*, the animal would finally appear as a ground rattler, *Sis-*

trurus. A great portion of the route is really gone over by a living species, and this fact, in connection with what is known of the effects of use and disuse from whatever causes, points in a very direct manner to the likelihood that the rattlesnakes have travelled one somewhat similar.

EXPLANATION OF PLATES.

PLATE I.

Figs.	1, 2.	*Sistrurus catenatus* Raf.; Garm. $\times 4$.
"	3, 4.	*Sistrurus catenatus*. $\times 3\frac{1}{2}$.
"	5, 6.	*Crotalus confluentus* Say. $\times 2$.
	Fig. 7.	*Crotalus horridus* Linné. Nat. size.

PLATE II.

	Fig. 8.	*Crotalus horridus*. Nat. size.
Figs.	9, 10.	*Rhinocerophis ammodytoides* Leyb.; Garm. $\times 2\frac{1}{2}$.
"	11, 12.	*Lachesis mutus* L.; Daud. $\times 3$.
"	13, 14.	*Ancistrodon piscivorus* LaC.; Cope. $\times 2$.
	Fig. 15.	*Ancistrodon contortrix* L.; B. & G. $\times 3\frac{1}{2}$.
Figs.	16, 17, 18.	*Ancistrodon contortrix*. $\times 2\frac{1}{2}$.

General Meeting, Feb. 6, 1889.

Mr. J. H. Emerton in the chair.

Mr. Geo. H. Barton read a paper on "The Great Precipice of Oahu, Sandwich Islands." He pointed out the physical features of this elevation by means of a map and a plaster model, and discussed the theories of Dana and Dutton as to the method of its formation.

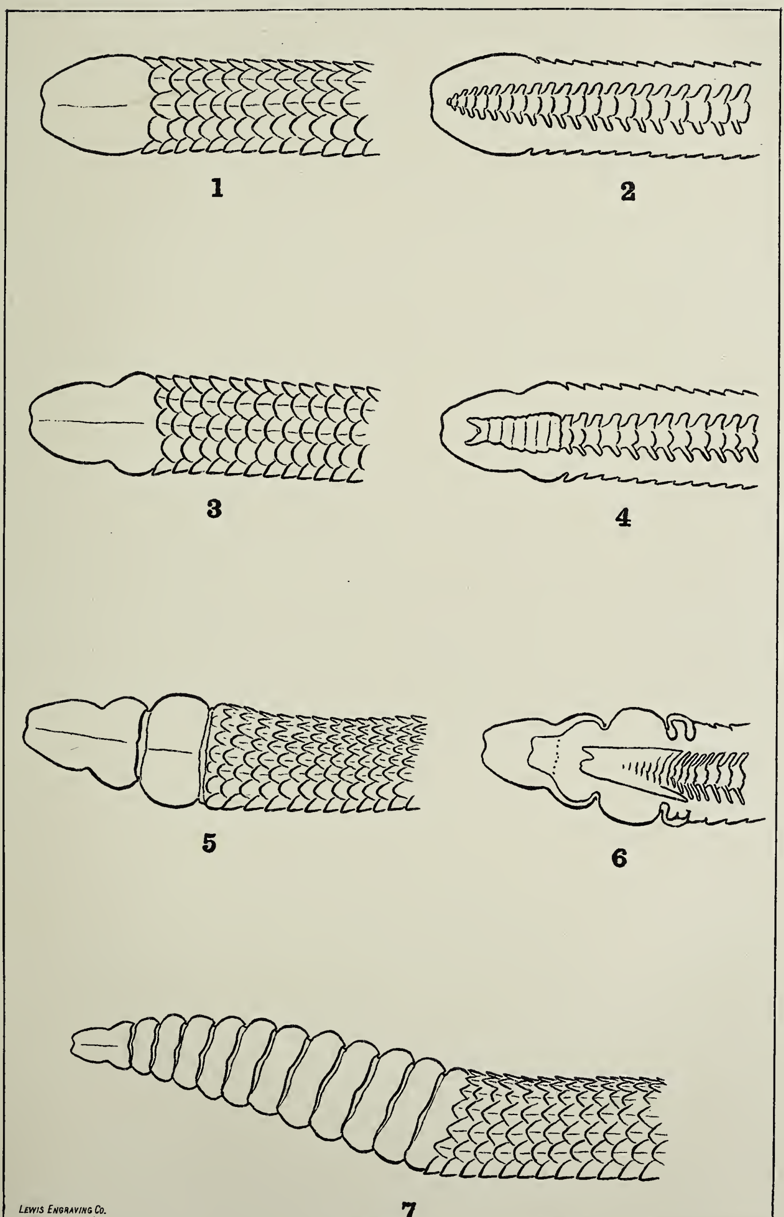
The Secretary spoke of the resemblance of coral rocks from Oahu and the Bermuda Islands and discussed the evidences of elevation and submergence of coral islands.

The following paper was then read:

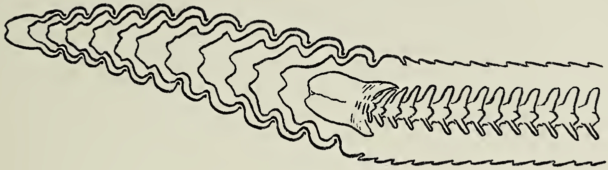
LIST OF FUNGI, COLLECTED IN 1884 ALONG THE NORTHERN PACIFIC RAILROAD.

BY A. B. SEYMOUR.

The fungi enumerated in this list were collected by the author in August and September, 1884, along the line of the Northern



EVOLUTION OF THE RATTLESNAKE.



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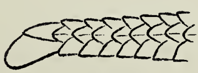

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LEWIS ENGRAVING CO.

EVOLUTION OF THE RATTLESNAKE.

Pacific Railroad. Beginning at St. Paul, Aug. 21, short stops and hurried collections were made at various points until Sept. 23rd. The dates and localities of collecting are as follows :

August 21, St. Paul, Minnesota,
" 22, Brainerd and Detroit, Minnesota,
" 23, Fargo, Dakota,
" 25, Valley City, Dakota,
" 26, Jamestown, "
" 28, 29 and 30, Bismarck, Dakota.
September 2, Medora, Dakota,
" 3, Miles City, Montana,
" 4, Billings, "
" 6, Livingston, "
" 8, Bozeman, "
" 11 and 12, Helena, Montana,
" 15, Sand Point, Idaho,
" 17, Wallula, Washington,
" 19, Thompson Falls, Montana,
" 23, Minneapolis and Lake Minnetonka, Minnesota.

A few other localities are mentioned in the list, represented by specimens picked up at points where the train stopped. Species distributed in *exsiccati* from this collection are so noted.

For aid in the determinations, I am indebted to Drs. W. G. Farlow and P. Magnus and especially to the lamented Dr. Winter.

CHYTRIDIACEÆ.

Synchytrium decipiens, Farl., on *Amphicarpœa monoica*, plentiful ; Bismarck, Dakota.

PERONOSPOREÆ.

Peronospora Halstedii, Farl., on *Rudbeckia laciniata;* Fargo and Valley City, Dak.

Peronospora ribicola, Schrt., Jahresbericht d. Schles. Gesellsch. 1883, p. 179 ; *Plasmopara ribicola*, Schrt. Krypt. Fl. Schles. Vol. III, p. 238, where it is described as follows : "Rasen fleckenweise, sehr locker, weiss. Conidienträger straff aufrecht, 2-4 mm. hoch, mit 3-5 aufrecht abstehenden graden Aesten, meist in eine Endspitze auslaufend ; Aeste grade, die untern mit 3-5 graden Seitenästen ; Endästchen grade, verschmälert, abgestutzt. Conidien kurz elliptisch, 15-20μ lang, 11-13μ breit, mit flacher Papille. Keimung nicht beobachtet. Oosporen unbekannt. Auf Blätten von *Ribes rubrum*."

The Minnesota specimens show conidia 11.7–17μ by 13–21μ; oospores smooth or obscurely roughened, nearly filling the oogonium and closely invested by its thin, fuliginous wall, 25.5 to 35.7μ. The papilla of the conidium is seen with difficulty and appears more like an inward thickening of the wall than as an external prominence. On leaves of *Ribes hirtellum*. Detroit, Minn.

Peronospora parasitica, (P.) Tul., on *Lepidium;* Jamestown, Dak.

Peronospora Arthuri, Farl., on *Oenothera biennis;* Sand Point, Idaho. Oospores 15.6 to 39μ.

Since this species was first published as occurring in Iowa and Minnesota, it has been reported from Illinois, Wisconsin, Missouri, Kansas and New York. To these localities may be added Nantasket Beach, Mass., where it was found by the author, June 23, 1885 and Grand Manan, Aug. 13, 1888, K. Miyabe.

Peronospora Trifoliorum, D By. On *Astragalus;* Bismarck, Dak., Livingston, Mont.

Exs.: Fungi Europæi 3576.

Cystopus Bliti, (Biv.) Lev. On *Amarantus retroflexus;* St. Paul and Brainerd, Minn., Jamestown, Dak.

ERYSIPHEÆ.

DETERMINED BY F. S. EARLE.

Sphærotheca Humili, (DC.) Burrill., on *Viola;* Valley City, Dak.

Sphærotheca pannosa, (Wallr.) Lev., on *Rosa;* Valley City, Dak.

Sphærotheca Mors-uvæ, (S.) B. & C., on *Ribes floridum;* Fargo, Dak.

Sphærotheca Castagnei, Lev., on *Erechtites hieracifolia* and *Nabalus* sp. Lake Minnetonka, Minn. *Hydrophyllum Virginicum;* Valley City, Dak.

Erysiphe communis, (Wallr.) Schl., on *Ranunculus Cymbalaria;* Livingston, Mont. *Lathyrus?;* Lake Minnetonka, Minn. *Oenothera biennis;* Kootenai, Idaho. *Oenothera* sp.; Bismarck, Dak.

Erysiphe Cichoracearum, DC., on *Aster*, Valley City, Dak. *Solidago* and *Cnicus;* Bozeman, Mont. *Helianthus;* Fargo, Dak.

Erysiphe Linkii, Lev., on *Artemisia dracunculoides;* Bozeman, Mont. *Artemisia* sp.; Valley City, Dak. Also on *A. Ludoviciana;* Helena, Mont., Sept., Rev. F. D. Kelsey.

Erysiphe Galeopsidis, DC., on *Stachys palustris;* Detroit, Minn.

Uncinula parvula, B. & C., on *Celtis;* Wallula, Washington.

Uncinula Salicis, (DC.) Wint., on *Salix;* Lake Minnetonka, Minn., Jamestown and Bismarck, Dak., Bozeman, Mont.

Phyllactinia suffulta, (Reb.) Sacc., on *Betula?;* Lake Minnetonka, Minn. Also on *Cornus stolonifera;* Helena, Mont., Sept. 1888, Rev. F. D. Kelsey. Remarkable for occurring on both sides of the leaf.

Podosphæra Oxyacanthæ, (DC.) D By., on *Prunus* (cult.?) ; Livingston, Mont. *Spiræa* sp., Sand Point, Idaho. Also on *Prunus Virginiana;* Helena, Mont., Sept., 1888, Rev. F. D. Kelsey.

Microsphæra Alni, (DC.) Wint., on *Ceanothus Americanus;* Brainerd, Minn. *Syringa vulgaris* and *Betula;* Lake Minnetonka, Minn.

Microsphæra diffusa, C. & P., on *Lespedeza capitata;* Brainerd, Minn.

Microsphæra Ravenelii, B. on *Lathyrus?;* Detroit, Minn.

Microsphæra Symphoricarpi, Howe, on *Symphoricarpus;* Valley City, Dak., Bozeman, Mont., Sand Point, Idaho, Cheney, Washington.

UREDINEÆ.

Uromyces Terebinthi, (DC.) Wint., on *Rhus Toxicodendron;* Valley City, Dak.

Uromyces Lupini, B. & C., on *Lupinus argenteus;* Bozeman, Mont.

Uromyces Genistæ-tinctoriæ, (P.), on *Trifolium;* Thompson Falls, Mont. *Lupinus argenteus;* Livingston, Mont.

This is the same as *U. Lupini*, Sacc., and is characterized by warty apiculate spores with fragile pedicels. *U. Lupini*, B. & C. has smooth spores and is very different. It is erroneously referred here by Dr. Winter in "Die Pilze," I, 146, on the authority of Thuemen, Myc. Univ. 842. The form on Trifolium has somewhat smaller spores but is not specifically distinct.

Uromyces Psoraleæ, Pk., on *Psoralea lanceolata;* Medora, Dak.

Uromyces argophyllæ, Seymour, in Ell. and Ev. N. Am. Fung. 1862.

Spots none; sori amphigenous, small, scattered, inconspicuous, obscured by the hairs of the leaf; teleutospores subglobose to oblong, broadest at, above or below the middle, 17–25 $\times$ 22–45 μ; epispore thin, of uniform thickness or slightly thickened and papillate at the apex; pedicel fragile. Differs from *U. Psoraleæ*, Pk. chiefly in longer and narrower spores and more deciduous pedicels.

On *Psoralea argophylla;* Valley City and Bismarck, Dak.

Uromyces sp. on *Glycyrrhiza lepidota;* Jamestown and Bismarck, Dak., Miles City and Livingston, Mont. This was called *U. Trifolii* by Dr. Winter (in litt.) and distributed under that name in Ell. & Ev. N. Am. Fung. 1876, but I have been unable to satisfy myself with the determination.

Uromyces Viciæ, (P.) D By., on *Lathyrus;* Brainerd, Minn.; Valley City, Jamestown and Bismarck, Dak.

Uromyces Rudbeckiæ, Arth. and Holw., on *Rudbeckia laciniata;* Fargo and Valley City, Dak., Livingston, Mont.

Exs., Fungi Europæi 3412.

Uromyces Euphorbiæ, C. & P., on *Euphorbia marginata;* Miles City, Mont. *Euphorbia* sp.; Medora, Dak.

Uromyces Polygoni, (P.) Fckl., on *Polygonum aviculare;* Medora, Dak.

Uromyces Eriogoni, Ell. Hark., on *Eriogonum* sp.: II, Helena, Mont.; III, Medora, Dak.; II, III, Livingston, Mont.

Exs.: Ell. Ev. N. Am. Fung. 1871.

Uromyces Junci, (S.) Tul., on *Juncus;* Bozeman, Mont.

Uromyces Scirpi, Burrill, on *Eleocharis;* Jamestown, Dak.

Uromyces acuminatus, Arth., on *Spartina cynosuroides;* Valley City and Bismarck, Dak. *Spartina gracilis;* Medora, Dak.

Uromyces Alopecuri, n. sp.

II. Sori epiphyllous, small, scattered, inconspicuous, mostly covered by the epidermis; spores subglobose to elliptical; epispore rather thick, warty; size, 12–20 × 15–24μ.

III. Sori epiphyllous, small, blackish, covered by the epidermis; spores obovate to elliptical, broadly rounded or truncate at the apex, 17–23 × 23–32μ; epispore of nearly equal thickness throughout; pedicel persistent, as long as the spore or shorter.

On *Alopecurus geniculatus*, var. *aristatus;* Brainerd, Minn.

Puccinia Anemones-Virginianæ, S., on *Anemone patens*, var. *Nuttalliana;* Livingston, Mont. *Anemone cylindrica;* Valley City, Dak.

Puccinia mirabilissima, Pk., on *Berberis repens:* II, Helena, Mont.; II, III, Thompson Falls, Mont.

Puccinia Violæ, DC., on *Viola;* Valley City and Jamestown, Dak.

Puccinia Arenariæ, (Schum.) Wint., on *Cerastium arvense;* Livingston, Mont.

Puccinia Malvastri, Pk., on *Malvastrum coccineum:* II, III, Almont, Dak.; III, Jamestown and Bismarck, Dak.; Billings and Helena, Mont.

Exs.: Ell. and Ev. N. Am. Fung. 1850; Fungi Europæi 3515.

Puccinia Petalostemonis, Farl., on *Petalostemon violacens:* II, III, Jamestown, Dak.; III, Valley City and Bismarck, Dak.

Exs.: Ell. and Ev. N. Am. Fung. 1844.

Puccinia Amorphæ, M. A. Curtis, on *Amorpha canescens;* Brainerd and Lake Minnetonka, Minn., Bismarck, Dak. *Amorpha fruticosa;* Valley City, Dak.

Puccinia Pruni-spinosæ, P., on *Prunus* (*Americana?*)*;* Valley City, Dak.

Puccinia Epilobii, DC., on *Epilobium paniculatum;* Bozeman, Helena and Thompson Falls, Mont.

Exs.: Ell. and N. Am. Fung. 1846.

Puccinia Pimpinellæ, Lk., on *Osmorrhiza brevistylis;* Bozeman, Mont.

Puccinia Jonesii, Pk., on *Cymopterus bipinnatus;* Livingston, Mont.

Puccinia Galiorum, Lk., on *Galium boreale;* Valley City and Jamestown, Dak.; Helena, Mont.

This is apparently the form called *P. rubefaciens*, Johanson; see Lagerheim in Hedw. 1889, p. 106, fig. 5.

The sori are elliptical or oblong, large, dark, convex. Those commonly seen on *Galium concinnum* are punctiform; on *G. Aparine*, squarish and usually remaining covered by the epidermis. The uredospores have have been rarely if ever found in the United States and the æcidia are rarely if ever seen except on *G. Aparine*. The host name *G. triflorum* in ILLINOIS UREDINEÆ, p. 181, is an error for *G. Aparine*.

Puccinia Kuhniæ, S., on *Kuhnia eupatorioides;* Valley City and Bismarck, Dak.

Puccinia Asteris, Duby, on *Aster conspicuus;* Helena, Mont. *Aster* sp.; Fargo, Dak.

Puccinia Grindeliæ, Pk., on *Grindelia squarrosa;* Livingston and Helena, Mont. Exs.: Fungi Europæi 3513.

Puccinia Helianthi, S., on *Helianthus annuus;* Miles City, Mont. *Helianthus*, sp.; Lake Minnetonka, Minn. Fargo, Valley City, Jamestown, Bismarck, and Medora, Dak., Billings and Miles City, Mont.

Puccinia Tanaceti, DC., *Artemisia dracunculoides:* II, III, Medora, Dak.; III, Bismarck, Dak., Livingston and Bozeman, Mont. *Artemisia Ludoviciana*, Jamestown, Dak.

Exs.: Ell. and Ev. N. Am. Fung. 1848.

Puccinia Xanthii, S., on *Xanthium Canadense;* St. Paul, Minn., Bismarck and Medora, Dak., Miles City, Mont. *Ambrosia psilostachya;* Valley City and Medora, Dak., Billings, Mont.

Exs.: Ell. and Ev. N. Am. Fung. 1853.

Puccinia variolans, Hark., on *Actinella acaulis;* Livingston, Mont.

Puccinia Balsamorrhizæ, Pk., on *Balsamorrhiza sagittata;* Thompson Falls, Mont.

Puccinia cladophila, Pk., on *Stephanomeria minor;* Livingston, Mont. Differs slightly from the original specimen.

Also collected in Washington Terr., Sept., 1883, by Suksdorf; Spokane Falls, Sept. 24, 1880, Watson; on *Stephanomeria runcinata;* foot hills of Santa Rita Mountains, Ariz., June 1, 1884, Pringle. Exs.: Ell. and Ev. N. Am. Fung. 1839.

Puccinia flosculosorum, (A. & S.) Roehl., on *Cnicus;* Fargo, Dak., Billings, Mont. *Hieracium;* Fargo and Bismarck, Dak., Billings and Thompson Falls, Mont. *Taraxacum;* II, Fargo, Dak.

Puccinia Menthæ, P., on *Mentha* sp.; II, III, Brainerd and Lake Minnetonka, Minn. *Monarda fistulosa*, Jamestown, Dak., Livingston, Bozeman and Helena, Mont.

Puccinia plumbaria, Pk., on *Gilia* sp.; Bozeman, Mont.

Puccinia Convolvuli, Cast., on *Calystegia sepium:* II, III, Fargo; III, Valley City, Dak.

Puccinia Gentianæ, (Strauss) Lk., on *Gentiana Oregana;* Helena, Mont. *Gentiana* sp.; Jamestown, Dak.

Puccinia Polygoni-amphibii, P., on *Polygonum amphibium* or allied form; II, III, Brainerd and Lake Minnetonka, Minn., Bozeman, Mont.

Puccinia angustata, Pk., on *Scirpus Eriophorum;* Brainerd and Lake Minnetonka, Minn.

Puccinia Caricis, (Schum.) Reb., on *Carex;* Bismarck, Dak., Helena, Mont.

Puccinia Phragmitis, (Schum.) Körn., on *Spartina cynosuroides;* Valley City and Bismarck, Dak. In the specimens gathered at Valley City the spores are often acuminate.

Puccinia Stipæ, Arth., on *Stipa viridis;* Southeart, Dak. *Stipa viridis (?);* Jamestown, Dak., Helena, Mont.

Puccinia vexans, Farl., on *Bouteloua racemosa;* Valley City and Jamestown, Dak.

Puccinia graminis, P., on *Bouteloua oligostachya* (?); Jamestown, Dak. *Ammophila longifolia;* Jamestown, Bismarck and Sweet Briar, Dak. Wheat; Fargo, Dak., scarce. Oats: II, Billings, Mont.; III, Jamestown, Dak. *Hordeum jubatum;* Lake Minnetonka, Minn.

Puccinia Rubigo-vera, (DC.), on Wheat; Fargo, Valley City and Jamestown, Dak. *Agropyrum;* Bismarck, Dak., Thompson Falls, Mont. *Hordeum jubatum*; Fargo and Valley City, Dak. *Elymus Canadensis;* Bismarck, Dak. In some cases these specimens have the ordinary paraphyses with the teleutospores and different capitate paraphyses with the uredospores. *Elymus;* Fargo and Jamestown, Dak., Livingston, Mont. In the Livingston specimens, the teleutospores have apical points, suggesting *P. coronata*, Cda.; Specimens on an unknown grass from Thompson Falls, Mont., resemble *P. coronata*, but have paraphyses like *P. Rubigo-vera*.

P. coronata, Cda., on Oats; Fargo, Jamestown, Bismarck, Dak.

Puccinia tomipara, Trelease, on *Bromus ciliatus;* Detroit, Minn. Exs.: Ell. and Ev. N. Am. Fung. 1842.

Puccinia emaculata, S., on *Panicum capillare;* Lake Minnetonka, Minn.

Puccinia Andropogi, S., on *Andropogon furcatus;* Brainerd, Minn., Jamestown and Bismarck, Dak. *Andropogon scoparius;* Jamestown and Bismarck, Dak.

Phragmidium Fragariæ, (DC.), on *Potentilla Norvegica;* III, Helena, Mont. *Potentilla gracilis*, var. *rigida;* III, Bozeman, Mont. *Potentilla* (near *P. gracilis*); III, Helena, Mont.

Phragmidium Potentillæ, (P.), on *Potentilla Pennsylvanica;* III, Helena, Mont. This species is characterized by dark colored firm spores and firm pedicels.

Phragmidium mucronatum, (P.) Lk., on *Rosa* sp.: II, III, Brainerd, Minn., Fargo, Dak., Miles City, Livingston and Bozeman, Mont.; III, Detroit, Minn., Jamestown, Dak., Helena and Thompson Falls, Mont.

Phragmidium Rubi-idaei, (P.) Wint., on *Rubus strigosus;* Helena, Mont. *Rubus Nutkanus;* Helena and Thompson Falls, Mont.

Coleosporium Sonchi-arvensis, (P.) Lev., on *Aster macrophyllus;* II, III, Brainerd, Minn. *Aster conspicuus;* III, Helena, Mont. *Aster* sps.; II, Brainerd, Minn., Fargo and Valley City, Dak., Bozeman

Mont.; II, III, Thompson Falls, Mont. *Solidago:* II, Medora, Dak., Miles City and Helena, Mont.; II, III, Detroit, Minn.

Melampsora Lini, Tul., on *Linum* sp.; II, III, Livingston, Mont.

Melampsora Epilobii, (P.) Fckl., on *Epilobium angustifolium;* II, III, Brainerd, Minn., Helena and Thompson Falls, Mont., Kootenai and Sand Point, Idaho. *Epilobium coloratum:* II, Bozeman, Mont., II, III; Livingston and Helena, Mont.

Melampsora populina, Lev., on *Populus monilifera;* II, III, Jamestown and Bismarck, Dak. *Populus balsamifera;* II, III, Helena, Mont. *Populus tremuloides;* II, III, Livingston, Mont. Very injurious to young cottonwood trees planted on tree claims.

Melampsora salicina, Lev., on *Salix* sps.: II, Detroit, Minn., Fargo and Bismarck, Dak., Billings, Livingston and Helena, Mont.; II, III, Bozeman, Mont.

Cronartium asclepiadeum, (Willd.) Fr., var. *Thesii*, B., on *Comandra umbellata;* II, III, Livingston, Mont.

Cronartium asclepiadeum, (Willd.) Fr., var. *Quercuum*, B & C., on *Quercus coccinea;* Brainerd, Minn. Exs.: Ell. & Ev. N. Am. Fung. 1881; Fungi Europæi 3418.

Æcidium Euphorbiæ, P., on *Euphorbia* sp.; Miles City, Mont.

Roestelia lacerata, (Sow.) Fr., on *Cratægus* sp.; Bozeman, Mont. *Amelanchier alnifolia;* Livingston and Bozeman, Mont.

USTILAGINEÆ.

Ustilago subinclusa, Körn., on *Carex trichocarpa*, var. *Deweyi;* Bismarck, Dak. Exs.: Ell. & Ev. N. Am. Fung. 1889.

Ustilago segetum, (Bull.) Ditm., on Oats; Sand Point, Idaho; Billings, Mont.

Ustilago Rabenhorstiana, Kühn, on *Panicum glabrum;* Minneapolis.

Ustilago Syntherismæ, S., on *Cenchrus tribuloides;* St. Paul.

Sorosporium Ellisii, Wint., var. *occidentalis*, Seymour, on *Andropogon furcatus;* Bismarck, Dak.

In the original specimens described by Dr. Winter the undeveloped flowers are infested before the expansion of the inflorescence. In these specimens, individual flowers of the fully expanded inflorescence are affected. The spores measure 9–10 μ. This has been referred to *Ustilago Andropogonis*, Kell. and Swingle (Journ. Myc. Vol. v, p. 12, pl. I, figs. 12–26) but the measurements of the spores are less than those of the Kansas specimens as there stated, also somewhat less than those given by Dr. Winter (Torr. Bull. x, 7). The spores certainly fall apart very easily, but the glomerules may be seen by careful examination. This was positively stated by Dr. Winter (in litt. July 9, 1885) to be his *U. Ellisii*. I alone am responsible for the varietal name.

Entyloma Menispermi, Farl. and Trelease, on *Menispermum Canadense;* Fargo and Valley City, Dak.

Entyloma Compositarum, Farl., *Erigeron Philadelphicum*; Valley City, Dak.

Entyloma Physalidis, (Kalch. & Cke.) Wint., on *Solanum triflorum;* Bismarck, Dak.

Exs.: Ell. & Ev. N. Am. Fung. 1491*b* after 1900.

The Secretary called attention to peculiar calcareous formations from the Bermudas known as "Fossil Palms."

SKETCH OF THE LIFE AND WORK OF DR. ASA GRAY.

BY G. L. GOODALE.

[Read at the meeting of the Society on Feb. 15, 1888.]

Mr. President and fellow-members of the Boston Society of Natural History:—

The time has not yet come for an exhaustive analysis of the life, the character, and the work of Professor Gray. Later, there must be given to the world by those who have the memorials of his life in their keeping, a full account of the life and character of a naturalist whose ceaseless activity, conjoined with great charm of manner, made him one of the most engaging personalities of modern times. Later, there must come from the hands of his lifelong foreign correspondents an adequate presentation of the results achieved by him in his chosen field of work. Recognizing the fact that one of the sciences cultivated by this Society owes more to Asa Gray than to any other American botanist, you have hastened to express your sense of loss in his death.

Your President, whose absence to-night is sincerely to be regretted, called attention, at the last meeting, to the propriety of setting apart an evening for the adoption of formal resolutions expressive of our irreparable loss. On that occasion he further said that one of Professor Gray's colleagues would present some account of the leading events in the life which has so lately closed. To another of Professor Gray's colleagues was assigned the preparation of the resolutions. These duties are of such a character that neither Professor Farlow nor I can enter upon their performance except with a diffidence which is no wise feigned.

In framing phrases to express our sense of loss we are restrained by the vivid remembrance of the exceeding modesty of him whom we commemorate. But if even this early and brief examination of a few salient points in his career may serve to stimulate us to renewed endeavor to carry out his cherished plans, we may hope to escape the charge of being rash or premature.

Asa Gray's life-work was the elucidation of the North American Flora; his fondest hopes centred in its completion. Knowing that his days would not suffice to bring order out of all the vast amount of material accumulated, he desired above everything else that his herbarium, the treasury of his collections, should be placed upon a safe financial basis. In this way only could be retained the services of its distinguished curator, Dr. Sereno Watson, who has been for more than twenty years Dr. Gray's coadjutor in herbarium labors, and who with other systematists, may continue to its end its great work which may indeed be termed monumental. To aid in this task of placing the Gray Herbarium beyond the reach of present or of future want is to carry out the will of him whose loss we have met this evening to deplore.

With the leading facts in the life of the great botanist you have been made familiar through the public press. Therefore it is not necessary that these should be much dwelt upon at this time, but rather that we should see in some manner, although imperfectly, the unity of purpose which guided his whole life.

Even the briefest account of Asa Gray's life and work must recognize three periods. The first ends when his acquaintance with Dr. Torrey began; the second closes with his removal to Cambridge; the third, by far the longest, was his life in the university.

Of the first two we have an interesting but too brief account in an unfinished autobiographical sketch which speaks of his parentage, his home life, his fondness for reading, his school triumphs, his early training in science and the many changes in his plans. The few excerpts which I have been permitted to take, can give but an imperfect impression of the truthfulness, the playfulness, and the modesty which characterize the sketch. Asa Gray was born in a settlement called Saquoit, in the town of Paris, New York, Nov.

18, 1810. His parents were New Englanders, his father from Vermont, his mother from Longmeadow in this State. He traced his descent from Scotch-Irish stock. The school advantages appear to have been good for the time and region, and every opportunity for reading was eagerly seized by the lad. After a little training in a private school, he passed two years in the Clinton Grammar School, and was then transferred to Fairfield Academy in Herkimer County. At the close of the school year, it was decided that he should begin the study of medicine. In the autumn of that year, at the age of sixteen, he attended lectures in the Medical College of the Western District, at Fairfield. From his sketch, it appears, that he had already listened to the courses in chemistry given by Professor Hadley, whom he calls his earliest scientific teacher and most excellent friend. At this time he was very fond of mineralogy and chemistry. The first hint we have of any interest in botany is a little later. In 1827, he read the article Botany in Brewster's Cyclopædia, and became so much interested in the subject that he purchased a copy of Eaton's Manual of Botany, and, as he says, "waited impatiently for spring. I was out of reach either of greenhouse or potted plants, but on an April day, in 1823, I sallied forth into the bare woods, found an early specimen of a plant in flower, peeping from dry leaves, brought it home, and with Eaton's Manual, without much difficulty, ran it down to its name, *Claytonia Virginica*. I was pleased at my success and went to collecting and examining all the plants on which I could lay my hands, and the rides over the country with my preceptor in visiting patients gave me good opportunities. I began an herbarium of shockingly bad specimens. In autumn, going back to Fairfield for the annual course of medical lectures, I took specimens of those that puzzled me to Professor Hadley who had learned some botany of Dr. Ives of New Haven, and had made a neat herbarium of the common N. E. and N. Y. plants which I studied carefully that winter."

He took the degree of M.D. at the close of the session of 1830—31. In his sketch he gives a charming account of a journey which he made at this time to New York by way of Albany. At the latter place he saw, as he says, "a grave looking man who I was told was Professor Henry who had just been making a wonderful electro-magnet." This was the first meeting of two men who were afterwards to sustain such pleasant relations with each other in connection with the Smithsonian Institution, and who were to give such an impetus to physical and natural science in America.

A serious disappointment attended this first visit to New York city. The youth had brought a package of botanical puzzles for the celebrated Dr. Torrey to unravel, but the botanist was absent, and the package was left as a basis for subsequent correspondence. In the succeeding year or two, he taught chemistry, geology, mineralogy, and botany, in a boy's school in Utica, making journeys in the vacations. On one of these he met Dr. Torrey and began that personal acquaintance which fixed his determination to be a botanist.

He became the assistant in botany to Dr. Torrey who was then Professor in a prominent medical school, and devoted much of his time to the herbarium. In that year he issued a set of North American sedges and grasses, and this may be spoken of as his first botanical publication; indeed, Sir William Hooker says of it, "Dr. Asa Gray has already deserved well of science by the publication of his specimens illustrative of the grasses and Cyperaceæ of N. A. of which the first volume has appeared, and it may be fairly classed among the most beautiful and useful works of the kind that we are acquainted with."

Now began his botanical career. His training for it had been of a broad kind. He had been a student in medicine, in itself a good training in observation; he had taught botany and certain collateral sciences in a manner so satisfactory, that at the age of twenty-two his name was proposed as a candidate for a professorship in Hamilton College. It was not an insufficient discipline with which he went to his work with Torrey.

This second period, extending from his acceptance of Dr. Torrey's offer to his removal to Cambridge, was marked by four important events: First, his forced interruption of systematic work by the failure of the means at Torrey's disposal, which led young Gray to prepare an educational work. At this time he became curator of the Lyceum of Natural History in New York, an occupation which made no serious demands upon his energies, and he was able to give his best work to the book. This treatise, published in 1836, under the title Elements of Botany, possesses the characteristics of style with which you are familiar in his later works, breadth of scope, nicety of distinction, felicity of expression. The second event was his acceptance of the position of botanist to the Wilkes' expedition. Of this he says, "In the summer of 1836, I was appointed botanist to the great South Pacific exploring expedition, which met with all manner of delays in fitting out and changes in commanders till finally in the spring Lieutenant Wilkes was appointed to command. The number of vessels was cut down and the scientific corps more or less diminished. The assistant botanist, William Rich, an appointment of the secretary of the navy was left out and I resigned in his favor."

The third event in this period was his provisional acceptance of the Professorship of Natural History in the newly chartered University of Michigan. He stipulated that he should have more time for preparation, part of which time he designed to spend abroad. He says that he had done fully half the work on the flora of N. A. which Torrey had in hand, "and he invited me to be the joint author." He now went to Europe to fit himself for higher botanical work by the examination of the older herbaria, and he carried also a commission from the University of Michigan to procure its library.

Although he never entered on active service at Ann Arbor, he was always interested in the institution, and his temporary connection with it led to very pleasant relation with the authorities in later times. No message more fully freighted with good wishes came from any source at the celebration of Dr. Gray's seventy-fifth birthday, than the greetings from the officials of the University of Michigan. At its last Commencement, being the semi-centennial, the University of Michigan gave Dr. Gray its Doctorate of Laws.

The journey to Europe was fruitful in many ways. He made himself familiar with the earlier collections from America, and became personally acquainted with all the leading botanists of Europe, to whom by that time he was known by his thorough work. It must ever be a source of regret that Dr. Gray did not carry out his purpose of recording fuller reminiscences of those men. This journey to Europe may be regarded as the most important of the four events.

With the third period of his life, that which began and ended at Cambridge, the older members of this society, now alas ! so few, are familiar. They remember that on his assumption of the duties of the chair in Harvard University, he gave no small portion of his time to the meetings here, and the records show that he presented not only memoirs of a systematic character, but also more familiar communications.

Dr. Gray must have entered on the duties of the office of professor with some misgivings; not that he was unprepared in any way for the place, but that the place was unprepared for him. Dr. Joshua Fisher's bequest was to be devoted to the support of a professor of Natural History comprehending "the mineral, vegetable and animal kingdoms, or any part of them." But the professorship had no appliances for investigation or instruction except an impoverished botanic garden. At the time of Dr. Gray's arrival, the garden was in a wretched condition, and his account of its low estate would excite a smile if it were not so pathetic.

His first task was to begin an herbarium, and to this he devoted no small share of a slender income. To the acquisition, the care and the study of the plants which constitute the great herbarium, he gave the next forty-five years.

His college duties were not wholly free from anxiety. He was scrupulous in the care with which he prepared himself to speak; but in those days botany was, for a while at least, a prescribed study, and his words fell sometimes on unheeding ears. In the pleasant spring mornings it is said that, after the roll had been called, the class would be diminished by the surreptitious withdrawal of some who thought they were escaping without attracting the attention of the absorbed professor, but it is surmised that he was not wholly averse to this anticipation of the elective system, preferring to have a few willing listeners instead of those to whom the science was unattractive. This view is confirmed by the well-known hearty welcome accorded to his work-room to the very few who wished to make a practical acquaintance with plants. It may well be questioned whether he found class teaching other than irksome: the quiet direction of studies in his private work-room was always to him a pleasant task.

The acquisition of an herbarium involves an enormous correspondence. Questions came in from every hand, and demanded a prompt response. Dr. Gray conducted this for more than forty years with his own hand, answering even the most trivial questions with a patience seldom seen. His published works are roughly grouped under the four heads, educational, systematic, philosophical, critical. The enumeration of these works is startling: in the Royal

Society's catalogue, the abbreviated titles occupy about seven columns, and this list comes down only to 1873, at which period he was relieved of administrative and tutorial work at his own request. Since that time the titles are more numerous, and if we add to the roll of papers and books, the minor articles, often of a playful character with which he was fond of lightening his cares, the catalogue would assume enormous proportions.

Of course this is not an occasion on which these works can be examined. We must pass over without notice the long list of educational publications reaching from the first elements in 1836, to his last volume, also termed Elements of Botany, bearing the date of 1887. We cannot even refer to his expositions of Darwinism, nor to his reviews. Nor is this the place to speak at any length of the Flora to which he gave all his work. We can only say that it is well on its way towards completion.

The question will not be kept back, How did he find time for such an incredible amount of scientific work? How with all this work, enough for three men, could he give time to the duties of the secretaryships and presidencies to which he was called?

This will be found no easy question to answer. But it can be partly met by remembering that he worked very rapidly and at the same time carefully, seldom having to do the same work twice. Then, too, he had an amazing command of written words, so that alike in scientific composition, in philosophical disquisition, and in critical reviews, he lost no time in searching for expressions. And lastly he made every minute count for some work or for some recreation. So that, with his nearly perfect health and buoyant spirits, he made his days encroach far upon the night.

Upon all with whom he came in contact he gave the impression of alertness and of reserve strength. But this strength was united with simplicity itself.

His six journeys to Europe, his three visits to the Pacific coast, and his four rambles along the Alleghanies, were no interruptions to his work. He made them tributary to his health and to the ever-present Flora.

We must now glance for a moment at the material results of his work in Cambridge, so far as they are apparent in the department which was his own. The instruction and its appliances have so far developed that what he was able for many years to carry on single-handed is now delegated to a curator of the herbarium and to three professors. Few things were more pleasant to Dr. Gray, in the last years after he had relinquished the work of teaching and certain administrative cares to others than to watch the progress of the garden, the arboretum, the cryptogamic collections, and the botanical laboratories. His counsel was always at the service of his young associates; but his chief interest was, as it well might be, in the herbarium. He felt its importance to American botany, but he regarded it as a means only, not an end. Hence he gave his time and money to this indispensable means. He made everything in his Cambridge life contribute to the advancement of a knowledge of the Flora of North America. His text-books were designed to introduce the youth of this country to the subject in which they might afterwards help on this great work. His studies of Darwinism were to enable himself to gain a better comprehension of the origin of our vegetation, and having found upon trial that it was of service to himself in this work proclaimed the fact boldly to others. All of his systematic work, even his extraordinary study of the Japanese flora, is made to throw light on our own plants. Even up to the very last days in November when the shadow fell, his thoughts were given to the future of his herbarium, as a means of working out all the relations of the vegetation of North America. Hence his associates believe that there has been intrusted to them a definite charge to carry out his plans. On some of his associates will fall the burden of teaching; to others must come administrative duties; while to others still must be given the task of completing the unfinished volumes of the synoptical Flora of North America. In short, the work which Asa Gray carried on so long, single-handed, must now be intrusted to many hands.

It is surely a reason for profound congratulation that three great naturalists like Agassiz, Wyman and Asa Gray, have interested themselves in our Society. It should stimulate us to high endeavor to carry out the plans for the advancement of the sciences which they loved so well.

General Meeting, Feb. 20, 1889.

The President, Prof. F. W. Putnam, in the chair.

Professor Putnam gave an account of an "Indian Burial Place at Winthrop," which was illustrated by the stereopticon.

Mr. H. G. Woodward read a paper on the "Geology of Brighton," which will appear in later pages of the Proceedings.

General Meeting, March 6, 1889.

The President, Prof. F. W. Putnam, in the chair.

The President made the following remarks:—

Members of the Society:—

Since our last meeting we have lost from our number one who for thirty-four years has been connected with the Society and taken an active part in its work. Charles L. Flint died on February 25th, in Hillman, Ga., where he was passing the winter. On Monday last the funeral services were held at his late residence in this city, and his body was conveyed to Grafton for burial in the family lot. Mr. Flint was born in Middleton, May 8, 1824, where his boyhood was passed on a farm. In 1841, he entered the Phillips Andover Academy, and afterwards worked his way through Harvard College, graduating in 1849. After teaching for two years he returned to Cambridge, where, for two years more, he studied in the Law School. On the organization of the State Board of Agriculture in 1852, the many qualifications of Mr. Flint for the office led to his appointment as Secretary of the Board, and in this position he did much to encourage and direct the agricultural interests of the State. During this time he published several practical treatises, among the best known of which are his "Grasses and Forage Plants," "Milch Cows and Dairy Farming," and his "Manual of Agriculture." To us he is best known from the interest which he took in the formation of the State Cabinet of Natural History, which for some time was displayed in his office at the State House, and was afterwards removed to the Agricultural College at Amherst. During the formation of this cabinet, Mr. Flint took much interest in natural history, and it was largely through his influence that the State ordered the publication of a new illustrated edition of Harris's "Insects Injurious to Vegetation," thus securing, in 1861, the wide circulation of this valuable treatise which its importance demanded. Mr. Flint, while thus identified with natural history and agricultural matters, was also thoroughly in earnest in the part he took in the educational matters of this city, where he served for several years on the School Committee. After resigning his position as Secretary of the State Board, he became an active member of several agricultural societies and clubs; and his broad mind led him also into historical and genealogical studies. In 1857 he was married to Ellen E. Leland of Grafton who died in 1875, leaving three children who are still living. Since 1875 Mr. Flint has been a member of the Council of our Society, and we all know of his constant attendance at the business meetings, where his advice and influence always received the attention due to one who was so much in earnest in his efforts to advance the interests we all have at heart. For several years past, as known to you all, he has been a constant attendant at our general meetings, where we shall all miss his kindly face as well as the benefit of his counsel.

Prof. W. O. Crosby then read a paper on the "Relations of the Pinite to the Felsite and Conglomerate of the Boston Basin."

The following paper was then presented:

ON A METHOD OF DEFENSE AMONG CERTAIN MEDUSÆ.

BY J. WALTER FEWKES.

THE Siphonophora in common with other Medusæ, as is well known, possess a very powerful organ of defense, in the stinging-cells, also called lasso-cells and nematocysts. There is reason to believe that there may be, at least, one other method of protection adopted by these animals. I propose this evening, to lay before you the evidence of the existence of this second method of defense made use of by these animals and to open the discussion of the homologies of the structures, in which this new means of protection is lodged.

It may be well to anticipate what follows, by the statement that the new method of defense is that of discoloring the water by the emission of colored pigment from certain chromatic cells on the bracts, and that these cells bear relationships and perhaps are homologous with the nematocysts in other genera of the groups in which they exist. The new method of defense is found, as far as known, only among the Siphonophores, and is limited to one or two genera.

Let us, on the threshold of our study, consider the history of the discovery of the structures in which this peculiar power is thought to be lodged.

In the year 1880, while engaged in the study of an Agalma, found at Villa Franca, South France, the author noticed on the covering-scales, certain colored bodies, which resemble in distribution in longitudinal rows, that of the nematocysts which are ordinarily found on these structures. In the same year (1880), I described and figured these bodies, and called attention to the fact that when the covering-scale is broken from its connection with the axis, a colored fluid is emitted from these organs. A covering-scale, ruptured from its connection, was seen to pour out a considerable quantity of yellow fluid, and to discolor the water in the immediate vicinity. When irritated, even while the bract is attached, the animal was supposed to discharge the coloring matter in the same way, although not in the same quantity. A similar phenomenon, connected with other organs, had already been described, for a discharge of coloring matter from the tasters of Forskalia had been observed and mentioned by Kölliker, but as far as known, no one had spoken of a like power of the chromatic "cells" or glands of the covering-scales of any Siphonophore.

My observations were not verified, or at least were not mentioned, by those who studied the Mediterranean Physophores, up to the close of last year, when Dr. M. Bedot[1] again took up the subject, and from a study of what he regards a new species of Agalma (*A. Clausi*), possibly the same as mine, or at least found in the same locality, describes and figures these glands again, generously quoting my description of eight years ago. His additions to our knowledge of the subject is so important that I have taken the liberty of quoting from his account somewhat at length.

Bedot says (p. 79), "Ce qui donne un aspect particulier au bouclier, c'est la présence, à sa surface, d'un grand nombre de petites taches d'un rouge-carmin foncé(fig. 13 *gl*). Lorsqu'une de ces Agalmes est capturée, elle rejette une quantité très considérable de matière colorante d'un rouge jaune très intense. Pour l'observer facilement, on est obligé de changer plusieurs fois l'eau du bocal où elle se trouve. Au premier abord, j'ai cru que cette matière color-

[1]Tirage a part du Recueil Zoologique, T. 5me., 1er fascicule. Sur l'Agalma Clausi.

ante provenait des tentacles comme on le voit souvent chez les *Forskalia*. Mais j'ai pu me convaincre plus tard que ce n'était par le cas. Cette couleur est produite par les boucliers ; les taches rouges qui ce trouvent à leur surface sont des espèces de petites glandes, qui éclatent et laissent échapper la matière colorante.

Lorsqu'on observe ces glandes au microscope, on voit (fig. 2 *gl*) qu'elles sont formées par une agglomération de cellules contenant un noyau et un protoplasme rempli de grosses granulations. Elles ont une forme sphérique ou allongée et sont implantés dans la substance gélatineuse, de telle sorte que la moitié de la glande, à peu près, dépasse la surface du bouclier. Elles sont recouvertes par l'epithelium. Lorsque le contenu de la glande s'est déversé au dehors, toute trace de cellule glandulaire a disparu et il ne reste plus, sur le bouclier, qu'une petite excavation entourée d'un léger nuage jaune.

On remarque encore une quantité de petits corps sphériques qui forment une bordure autour de la gland et d'étendent ensuite en traînée jusqu'au bord du bouclier, parallèlement à son grand axe. Ces corps sphériques (fig. 14, 27 et fig. 2 *ct*) ne disparaissent pas après l'explosion de la glande (fig. 37). Ils sont formés d'une enveloppe creuse à paroi épaise (fig. 14 *e*) et l'intérieur se trouve un corpuscule également sphérique (*s*) accoli à la paroi. Sa structure est difficile à observer ; néanmois on peut distinguer à l'intérieur une figure qui rappelle le fil d'un nematocyste ces corps se rencontrent sur les boucliers d'autre espèces de Siphonophores. Ils sont été déjâ mentionnés comme étant des nematocystes, mais, je crois, sans qu'on en ait fourni la preuve, sans qu'on ait pu observer le fil déroule. Il est très possible que cette opinion soit fondée, ou, tout au moins, que l'on ait affaire ici à une forme spéciale de cellule urticante. On les trouve souvent accumulés au bord du bouclier de l'*Agalma Clausi*, parfois aussi, ils y forment seulement de petits amas placés de distance en distance."

There is little doubt that while the bodies mentioned above have sometimes been mistaken for nematocysts, and while there is nothing to show that they have not in their interior the "fil d'un nematocyste," that a distinction ought to be made between them and true nematocysts. We find similar rows of bodies not only among the Siphonophores, but also on the bell of many Hydromedusæ. It is doubtful, for example, whether the meridional lines on the external bell walls of Ectopleura are rows of nematocysts as they are generally considered, and the same is possibly true of the peculiar nematocyst-like bodies on the outer surface of the bell of genera like Gemmaria and Willia. In Athorybia also, the rows of so-called nematocysts on the outer walls of the covering-scales do not in many cases show the "fil d'un nematocyste," and therefore we may well question whether they are functionally nematocysts, lacking as they do this characteristic internal organization of these organs. Still the homology of these structures to nematocysts is an open question and it remains yet to be seen whether they might not be regarded as lasso-cells in which certain parts have suffered a change in form.

There seems nothing to prevent our accepting the theory that the "corps sphériques" of the above description are homologues of nematocysts, and Bedot's figure as far as it goes does not disprove that they are these organs even if the central "thread" is absent.

Between these spherical bodies, however, and the pigment pouches or glands, Bedot thinks it necessary to recognize a distinction and certainly their form is very different, and justifies his views in this regard. Moreover the pigment glands discharge their contents, whereas the spherical bodies do not have this power. Is there, however, anything to show that the pigment glands are not more completely developed clusters of the so-called spherical bodies, and may not the pigment gland be formed by an aggregation and maturation of the spherical bodies? Such an interpretation was given the colored bodies, when I studied them, and there is no new evidence to lead me to abandon my former opinion. The "pigment spots" were at that time regarded as remotely represented in *Apolemia* "by elevations composed of *clusters* of cells on the surface of the tract." My use of the word cell with two meanings, one as a lasso-cell, and the other as a histological cell, has led to a confusion, and a just criticism by Bedot. I consider the pigment glands to be formed of an aggregation of nucleated cells, and each pigment spot to be comparable with a nematocyst (lasso-cell).

In some genera, irritation of the animal leads to a change in color of the covering-scale which may be akin to the discharge of pigment from these bodies. This phenomenon seems also to be connected with pigment cells in the organs, although the character of these structures has not been fully described.

Dr. Carl Chun mentions a change of color of the covering-scales in *Ceratocymba spectabilis* from the Canaries. He speaks of this phenomenon in the following manner:

"Sehr eigenthümlich verhält sich das Deckstück bei stärkerer Berührung, insofern auf einen Reiz hinzuerst in der Umgebung der beiden hornförmigen Canäle des Olebehälters und späterhin auch von den Ecken beginnend in der gesammten Gallerte eine weissliche Trüburg auftritt. Dieselbe beruht auf dem Erscheinen ausserordentlich feiner Körnchen, die wieder (nach etwa einer halben Stunde) verschwinden, wenn die Eudoxie der Ruhe überlassen wird. Die eigenthümliche Trübung erinnert an eine analoger Erscheinung bei Hippopodius.

Nurdass hier auf einer Reizerfolgende und später verschwindende milchige Färburg an die Ektodermzellen der Schwimmglocken gebunden ist. In gewissem Sinne muss selbst die structurlose Gallerte des Deckstückes einem Reize zugänglich sein, wie das allmähliche Auftauchen und ebenso langsame Verschwinden einer ziemlich intensiven Trübung beweist."

We might possibly compare this phenomenon with the cutaneous circulation and change of color in pelagic fish embryos and in Cephalopoda, but as we know so little of the organs by which it is produced that one can as yet hardly venture an explanation.

The excretion and discharge of a colored fluid from those organs which are known as "cystons" or tasters with a terminal opening, has been noticed by several authors. Both Kölliker and Leuckart speak of it, although they seem to regard the discharge as due to a rupture of the wall rather than through a normal terminal opening. Kölliker says, "Ohne Zweifel ist diese Substanz ein Excretionstoff, doch wird ohne genauer Kenntniss ihrer chemischen Beschaffenheit nichts Näheres überihre Bedeutung beizubringen sein."

Haeckel describes the structure of these Cystons or "anal vesicles" showing that they are excretory organs, with a terminal anus and glandular walls often highly colored. They are according to him confined to the Physophores, mainly to the Apolemidæ, Agalmidæ and Forskalidæ.

The "cystons" or hydrocysts, with "mouths" in the Agalmidæ are often, according to Haeckel (*op. cit.* p. 219), colored red or brown, and "the fluid secretion, or the pigmented granular or crystalline masses secreted by it, are ejected by the distal mouth, or rather the anal opening, which is closed by a muscular sphincter." In the genus Forskalia the same author says, "When a quietly floating Forskalia is touched, it suddenly discharges the contents of the chromadenia [pigment glands] and makes the surrounding water dark and intransparent."

Haeckel offers the following explanation of the phenomenon in Forskalia: "The excretion of the pigment-masses and the darkening of the water by it have probably the same physiological function as in the Cephalopoda—to protect the attacked animal from its persecutors, and facilitate the capture of food animals."

The character of the "cystons" in a genus of Apolemidæ called Dicymbia is described by Haeckel. Each "cormidium" or cluster of the stem is said to have in this genus a single deep red cyston and the secreted pigment is accumulated in a "head-like terminal expansion of the distal proboscis, and thrown out by a small terminal opening, the anus."

In *Apolemia uvaria*[1] which often reaches a great size I have repeatedly observed the so called "cystons" in specimens from Villa Franca. Haeckel simply mentions the fact that each cormidium of this genus has several cystons but gives no special description of them.

The cystons of Apolemia are brick red in color and easily distinguished from the remaining appendages of the cormidium. Their general relationship to the covering scales may be seen in my figure of the axis of well known *A. uvaria* from the Mediterranean. I have not seen them discharge their excretions,[2] but the intensity of their color varies in different individuals and in different cormidia on the axis. Although I have repeatedly watched the well known "lana di mare," Apolemia, I have never been fortunate enough to discover one which ejected coloring matter from these reddish bodies, and have not been able to produce it by an irritation of the animals.

There is a peculiarity in the tasters of the genus Nanomia, which would seem to have a bearing on the discussion of the pigmented bodies of the cystons.

A. Agassiz, in his description of Nanomia, called attention to the pigment at the base of the taster of this genus, which he designated as an "oil-globule." He supposed that this body formed the float of the young Nanomia which budded from the parent.

[1] The existence of what I have called "Nectotasters" or tentacular appendages to nectostem in Apolemia is not mentioned by Haeckel (*op. cit.*) although it is an exceptional feature in Apolemia. These appendages and the stem which bears the nectocalyces of Apolemia are easily seen and have been figured and described. Kölliker speaks of them as the "Fuhler zwischen den Schwimmglocken."

[2] Bull. Mus. Comp. Zool., Vol. VIII, No. 7.

From a comparison of this oil-globule with the float of the adult, I have shown that a derivation of the young from the adult by budding is improbable. Still oil-globules are very conspicuous structures on the stem of the Nanomia and have not been observed by me in other genera. Consequently, although the tentacular knobs and most of the other structures of Nanomia are identical with those of *Agalmopsis pictum*, a genus to which I formerly referred Nanomia, the exceptional character of the cystons seems to me to separate it from Sars' genus.

This "oil-globule" forms a swelling at the proximal end of the "cyston" and was not observed to be ruptured. There seems in point of fact no opening through which it can be discharged. Its regular form, its constancy, its position, all stamp it as an organ of some kind. If we regard it as a float of a new individual it differs very greatly from the adult float of Nanomia. If we consider it a pigmented accumulation of excretory matter we disregard completely its character as far as the examination which has been made goes. It seems as if it should be regarded as connected in some way or another with the function of the cystons, but how I am unable at present to say.

Reviewing the data which have been brought forward, we have the following facts bearing on the discharges of a colored fluid from organs of the body or the modification in color due to irritation in Siphonophores.

1. Certain Agalmidæ, Forskalidæ and Apolemidæ discharge a colored fluid from their cystons. This fluid is regarded as an excretion and is supposed by Haeckel in one case to be the means of protection, as the sepia of the Cephalopoda.

2. A typical genus of Agalmidæ (Agalma) has pigment glands on the bracts which discharge their contents when the covering-scales are broken from the stem. This discharge probably takes place on simple irritation.

3. Certain Hippopodidæ and a single known monogastric Calycophore, change color somewhat on irritation. (See Chun's description above.)

4. Nanomia has a prominent pigmented "oil-globule" at the base of the cyston, which has never been seen to discharge its contents.

What conclusions may be drawn from the above statements?

Are we dealing here with phenomena of a similar character or have we organs with two or three different functions? Are these discharges when they occur simply the throwing off of excretions, or do they also serve for protection of the Medusa from its foes?

It seems not improbable that the physiological function of certain of the tasters, which are known as cystons in Forskalia is that of excretion. This power of throwing off excretions may also serve for protection. Yet it must be borne in mind that all the Calycophoridæ, the Pneumatophoridæ and Hippopodiæ have no cystons or similar excretory organs, nor has the function of excretion yet been referred in them to any special organs. Is it possible that the discharge of colored matter from the pigment cells of the bract of Agalma is also a method of excretion, and is it the same as that of the cystons of Forskalia? It seems to me improbable that we have to deal with excretions only, in this case, although we may have an instance of a novel means of protection, which is in part accomplished by the discharge of the excretion in Forskalia. Upon this theory, however, we need much more light which can best come from more observation.

It is legitimate to conclude that the discharge of a highly colored fluid by the scales of Agalma is in part a means of protection for the medusa, and it would seem natural to connect it with the function of excretion, but we know so little about the character of the excretions, and the manner in which they are produced in Medusæ, that at present we can hardly definitely ascribe the special function to these glands. Possibly similar glands are found in other Physophores, and the excretion has not been recognized from the fact that it is not so highly colored as in *Agalma clausi* and Forskalia. The discharge of this fluid from a living animal, if it take place without rupture of the wall of the scale, would imply special excretory openings somewhere on the bract, and one is tempted to search for such openings, if they exist, on the distal tip of the scale, when they would be homologous to the excretory openings known to exist on the bell margin of certain Hydromedusæ, as Metschnikoff and others have shown.

If we accept the theory that the discharge of a colored fluid is a method of defense, the question arises, How is that defense accomplished? Does the fluid darken the water in the immediate vicinity of the Medusa which possesses this power and in that way conceal it from its foes, as in the case of the Cephalopoda, or does it serve, as is possibly the case with the rattle of the rattlesnake, to warn away its enemies? May it not even bewilder its prey and thus be rather a means of capturing its food than of self-protection? Has it possibly a poisonous nature fatal to its prey or foes? Our knowledge of its nature is all too small to give us an answer to these questions. Its bright color would indicate that even if it is poisonous that this is not its only property, or that its sole function is that of killing its enemies or prey. The ability to change the color mentioned in Ceratocymba by Dr. Chun might come in the same category as a similar power in fishes and Cephalopoda. In that instance we might have a kind of cutaneous pigment circulation. The discharge of pigment, however, is something different and possibly capable of a very different interpretation.

Is the discharge normal or abnormal? Is it a result of extraordinary conditions under which the animal is placed in confinement in our aquaria, or is it an habitual mode of protection? It seems to me that the latter interpretation will best satisfy our limited knowledge, and although when the bracts are broken the discharge is more voluminous, since the glands are wholly emptied of their contents, the method of its discharge shows it to be a function which is perfectly normal.

It seems to me that we have in these "glands" the homologues of nematocysts, the thread of which is wanting and the cells of the interior of which have degenerated or rather specialized into pigment bodies, instead of functioning as an urticating thread. These modified nematocysts throw off a colored fluid which, while it serves in a similar way in protection or in killing its prey, bears little morphological likeness to the well known lasso-cell.

General Meeting, March 20, 1889.

The Vice President, Prof. Geo. L. Goodale, in the chair.

Dr. R. R. Andrews made a communication, illustrated by the stereopticon, on "The Germ Theory of Dental Decay."

Mr. R. T. Jackson gave the results of his recent "Studies of Ostrea, Pecten and certain other Pelecypoda."

Mrs. Sarah S. Fuller, Miss Harriet E. Richards and Mr. John C. Sharp, jr. were elected Associate Members.

General Meeting, April 3, 1889.

The President, Prof. F. W. Putnam, in the chair.

Dr. J. Walter Fewkes read a paper on "The French Marine Laboratory at Roscoff in Brittany." (See American Naturalist, February, 1889.)

The following papers were read by title:

PALEONTOLOGICAL NOTES.

BY ALPHEUS S. PACKARD.

I. ON A FOSSIL MACRURAN CRUSTACEAN FROM PERU.

PLATE III, FIG. 1.

The specimen here described was received from Professor J. S. Newberry, with the statement that it came from Peru.

The fossil occurs in a fine, homogeneous, hard, gritty limestone; but it scratches glass owing to the fine particles of silica scattered through it, while it is soluble with dilute acid; it has a decided conchoidal fracture, and is black when freshly broken, but weathers to a whitish gray.

The fossil itself, unfortunately, is not sufficiently well preserved to allow us to decide to which family of Macrurans it belongs, though enough so to enable one to recognize the species and genus, should other examples be discovered.

The antennæ and mouth appendages have not been preserved; and the carapace is much out of place, while the rostrum is obscurely indicated, if present at all. Yet the five pairs of thoracic appendages are tolerably perfect, though the terminal joints are not present; still the form of the legs and carapace is such as to prevent our referring the fossil to any of the families of known Macrurans, whether living or extinct. The abdomen is wanting.

Description.—Of the five pairs of legs, those of the first and second pairs are considerably larger than those behind, the three posterior pairs being of moderate dimensions, and nearly equal in size, the fifth pair being as large as those of the third and fourth pairs. Of the first pair of legs, the five basal joints are present; the basal or first joint is short, being only as long as the second joint is thick; the second to fifth joints are triquetral or triangular in outline. The second joint is long, with the inner angle armed with short stout spines, of which there are seven of equal size on the distal half of the joint. The third joint is also provided with similar spines, but the joint is only half as long as the second and somewhat slenderer. No spines are to be seen on the rest of the leg and the remaining joints are so fractured and ill preserved as not to present good characters, though the remainder of the limb is evidently as long as the three basal joints taken together; and though the joints are broken and their outline is indistinct, it is evident that the appendage did not end in a large chela, as in the Astacidæ or Carididæ, but probably in a not very long band, no thicker than the second joint of the limb.

The second pair of legs are nearly as large as the first, but only the three basal joints are preserved; they are like the first pair, triquetral and spined, and the second joint is of the same shape and size as the corresponding joint of the first pair of legs. The third, fourth and fifth legs are a little more than half as thick as the first pair, with the three basal joints preserved; they are flattened cylindical rather than triangular in transverse section. Unfortunately the terminal joints are not preserved, so that we are unable to say whether the four hinder pairs of feet ended in claws, or were simple.

The carapace is imperfectly preserved, being partly shattered, so as not to show the characteristic shape; but a large proportion is preserved, and it looks at first sight like the carapace of a crab, such as that of a species of Cancer, but without the regional marks characteristic of the shields of Brachyura. One side is partly preserved; the surface is slightly convex and coarsely but uniformly pitted.

Whole length of the specimen including the legs and carapace 48 mm. Length of the first pair of legs, 25 mm.; of second joint, 8 mm., thickness of second joint, 2.3 mm.; length of third joint, 3.2 mm.

The fossil does not apparently belong to the *Carididæ*, as the body of this crustacean was probably not laterally compressed while the carapace was quite solid, without a median ridge, neither prolonged into a long rostrum. It cannot be referred to the *Astacidæ* on account of the lack of large chelæ and of the well-marked regions of the carapace, the transverse and two median creases wanting. The form is excluded from the *Loricata*, or Palinuridæ, by the less dense and solid crust, and the apparent want of a large broad abdomen, so characteristic of Scyllarus. From the *Galatheidæ*, the fossil form differs in having the last pair of legs as large and stout as the third and fourth. It cannot be referred to the *Hippidæ*. To neither of the extinct mesozoic families *Eryonidæ* and *Glyphæidæ* can our fossil be referred, since the carapace lacks the median ridge and the lateral serrations of the former group, and the complicated sculpturing of the latter.

In the shape of the first pair of legs there is a resemblance to those of *Eryon propinquus* of the Solenhofen slates, but the fifth pair of feet are much stouter. It perhaps may, when better preserved specimens are brought to light, fall into the Eryonidæ or Palinuridæ. It appears to have no special relationship to the Carboniferous family *Anthracaridæ*. We may give it the provisional name of *Adelocaris*[1] *peruviensis*.

Casts kindly taken from the type by Mr. N. N. Mason of Providence, have been placed in the Museum of Comp. Zoölogy, Cambridge, Mass. Boston Society of Natural History and the British Museum, etc.

II. NOTES ON CARBONIFEROUS ARTHROPODS FROM ILLINOIS.

The following notes on fossils kindly sent me for examination by Mr. W. F. E. Gurley, may be regarded as supplementary to the descriptions contained in the author's memoirs entitled, "On the Syncarida, a hitherto undescribed synthetic group of extinct Malacostracous Crustacea," "On the Gampsonychidæ, etc."; "On the Anthracaridæ, etc.," and "On the Carboniferous Xiphosurous Fauna of North America," published in the memoirs of the National Academy of Sciences, III, 1886.

Belinurus lacoei Pack. A finely preserved specimen in a Mazon Creek nodule, is worthy of notice. It shows the inside of the ventral surface of the integument, the specimen probably being a cast skin. The very long genal spine is better preserved than usual; it is very long and slender, reaching as far back as a point in line with the eighth abdominal segment, *i. e.*, that next to the ninth segment, which forms the caudal spine. It agrees in this respect with my description, but not exactly with the restoration (Pl. v, fig. 5), in which the genal spines are represented rather too wide at the base,

[1] ἄδηλος uncertain; καρίς, a shrimp or prawn.

and a little too short. It is really in proportion nearly as long and quite as slender as that of *Prestwichia longispina* Pack. (Pl. v, fig. 4).

The following measurements of this specimen will give the proportions of the genal spine to the rest of the body.

Length of body, exclusive of caudal spine, 32 mm.

" " head, 16 mm.; breadth at base of genal spine, 35 mm.

" " abdomen, 16 mm. " " " lateral spine, 22–23mm.

" " genal spine, 20 mm.

Distance from middle of frontal edge of head to end of genal spine, 36 mm.

Rachura venosa Scudder. Two specimens of this Phyllocaridan were received from Mr. Gurley; one shows the carapace, and the other the end of the abdomen, with the caudal spine; they are preserved in the dark hard gritty limestone of the middle coal measures of Danville, Ill. The specimens appear to be referrible to the form described by Mr. S. H. Scudder under the above name in the "Proceedings of the Boston Society of Natural History, XIX, 296, Pl. 9, figs. 3, 3*a*.

In the specimens before me the ill-preserved portions of the carapace indicate that it was a little over three inches long, and of a general oval-triangular shape though the outlines of both anterior and posterior ends are, unfortunately, not clearly to be traced. It seems to have been perhaps laterally compressed, and a broad thickened margin on what seems to be the upper side is apparently the median or hinge-margin connecting the two valves or sides of the carapace.

The last two abdominal segments are as described by Mr. Scudder, but three caudal spines are preserved, where apparently only one is represented in Mr. Scudder's figure. What he represents as a second curved caudal appendage, the left one in his fig. 3, and drawn as bearing a single broad rather obtuse spine, is in the specimen before me detached from the rest of the body, and its nature is problematical to me. The appendage is considerably curved and bears two large sharp thorn-like spines of unequal size, and about a fifth of an inch apart. The length, as curved, is equal to that of either of the normal caudal spines. There are traces of another similar appendage, showing that there were a pair of them. I do not know of any such armature in others of the group. Two bayonet-like caudal spines are clearly indicated, and are in place, being attached to the terminal segment. They are 15 mm. in length.

We still need more specimens of this fossil, in order that we may determine whether it is a Caratiocaris, as we have formerly regarded it, or a Dythyrocaris, to which Prof. J. M. Clark has referred it, or whether Rachura is an independent genus. What is preserved of the carapace shows that it is, at least, quite different from that of Mesothyra. The abdominal segments are sculptured much as in Ceratiocaris; but the surface of the carapace itself when well preserved shows white, stellate enamel-like spots on a dark ground. Such a structure of the carapace has not, so far as we are aware, been noticed by previous observers, in this group.

Palæocaris typus Meek and Worthen. In one specimen from Mazon Creek, Morris, Ill., the antennæ of the first and second pair on one side are so well preserved as to show their relative proportions and the entire length of their flagella. The outer, or first pair (antennules), are somewhat longer than represented in the restoration (Pl. III, fig. 1), being between $\frac{1}{3}$ and $\frac{1}{2}$ as long as the whole body. Only one branch or division of the flagellum is preserved, and probably this is the lower or longer division, of which the basal joints only are shown in the restoration of this crustacean.

The second antennæ are well preserved throughout their entire length, the flagellum is very long and slender and extends to the end of the last segment of the abdomen, hence the second antennæ were probably as long as the body, exclusive of the terminal abdominal appendages (uropoda). The number and shape of the joints of the scapes of both pair of antennæ are as represented in the restoration.

Another specimen shows distinctly that the different joints of the scape of both pairs of antennæ were provided with numerous stiff dense setæ; these have not hitherto been revealed in any specimen previously examined and hence are not represented in the restoration.

There are also traces of large well developed second antennal scales, like those in the female of *Petalophthalmus armatus*, but larger and broader, well rounded at the end, and extending nearly to the end of the scape; these scales show no traces of setæ or spines in this specimen, but in another what appears to be an antennal scale is edged with fine very distinct setæ.

There are also traces of what may possibly be the outlines of stalked eyes, but they are very uncertain, and present no traces of facets.

III. RECENT DISCOVERY OF ANNELIDES AND THE SUPPOSED TRACK OF A GASTROPOD MOLLUSC, IN THE CARBONIFEROUS SHALES OF RHODE ISLAND.

During excavations for a sewer made in Division St., Pawtucket, R. I., in the spring of 1888, an apparently rather thin bed of black carboniferous shale was found by Rev. E. F. Clarke to be not only rich in ferns, but unexpectedly rich in animal remains. With the help of a friend whom he had interested in collecting fossils, Mr. Clark discovered the remains of a cockroach belonging according to Mr. Scudder to the genus Gerablattina; also a species of harvest man (Architarbus). It will be remembered that a year or two before this Mr. Clark discovered in the carboniferous beds of Bristol, R. I., the remains of *Mylacris packardii* Scudder.

From the Pawtucket beds on Division St., my young friends, Mr. Henry Scholfield and Mr. F. P. Gorham, have obtained several specimens of *Spirorbis carbonarius;* and Mr. Scholfield has found what is apparently the impression of a worm, most probably an annelid, and what appears to be the track of a gastropod mollusc, besides other cockroaches.

From this bed, then, have been taken the traces or remains of a mollusc, two worms, a species of the arthropod order Arthrogastra, and several insects, allied to the cockroach.

The age of this bed has been determined by M L. Lesquereux after the examination of a collection of plants collected and presented to the Museum of Brown University by Rev. E. F. Clark and Mr. C. Williams, both of Providence, R. I. M. Lesquereux writes: "These specimens taken altogether are interesting as indicating more than any other lot I have seen of fossil plants of Rhode Island, the stratigraphical relation of your coal strata to those of the upper part of the anthracite measures of Pennsylvania, where, even, I have not observed such a predominance of species of Odontopteris typically allied to those described by Fontaine and White from the Upper Carboniferous of Pennsylvania."

Spirorbis carbonarius. Three tolerably preserved specimens attached to the leaves of ferns were found by Messrs. Scholfield and Gorham in the Pawtucket plant bed. They agree with better preserved specimens from Cannelton, Pa., received from Mr. Lacoe, both in size, and the peculiar flattened shape of the outer whorl, but the Pawtucket specimens only show faintly the transverse ridges, which are well marked in the Pennsylvania examples. They also agree with Dawson's description (Proc. Geol. Soc. London, Dec. 20, 1865) of Nova Scotian specimens.

Impression of an Annelid? This impression found by Mr. Scholfield occurred in the black shale of the Pawtucket plant bed, and is 25mm. long. Its width is about 3mm., but it is not well defined, as the edges of the impression are chipped off irregularly. It is sinuous, there being three bends. The surface is nearly flat, and along the middle is a distinct furrow, which seem to prove that it is the impression of the under side of a worm. What seems to be the head-end is narrower than the rest of the body, which tapers somewhat to a point at the other or posterior end. There are no markings to suggest the lateral appendages of an annelid, such as a Nereid, and hence it is not possible to refer it with certainty to the order of annelides, and yet the *facies* of the impression does not suggest anything else.

Impressions of worms, including true Nereids, are not uncommon in the Middle Carboniferous nodules of Mazon Creek, Ill., as we have been enabled through the kindness of Mr. Lacoe to examine the impressions of five or six species. It would be premature to assign a name to the Pawtucket impression until additional specimens are discovered.

Track of a mollusc. Mr. Scholfield was also fortunate enough to discover in the same bed a well defined track, which appears to be that of a gastropod mollusc; though it may possibly be that of a nemertean worm. It is of uniform width and is sinuous, making three turns. It is about two inches in length, and uniformly about 4 mm. in width; at one end it terminates in an evenly rounded flat area, which is either the beginning or end of the track; the other end was broken off in collecting. The surface of the track is smooth and perfectly flat, uniformly so, except at one turn, where there is a short slight irregular median ridge, perhaps the result of a slight disturbance after the track was made.

The track was apparently made by a snail, with a perfectly flat creeping disk, and the probabilities that it is a molluscan track are greater than that it was made by some nemertean worm.

CANADIAN GEOLOGICAL CLASSIFICATION FOR THE PROVINCE OF QUEBEC, BY JULES MARCOU.

BY ALFRED R. C. SELWYN.

Director Geol. and Nat. History Survey of Canada.

It seems almost idle to attempt any discussion or explanation about the geology of Quebec with Mr. Marcou,[1] because when he has the boldness to assert that the Fall of the Montmorency is not over gneiss, in spite of the dictum of every other geologist who has visited and examined it, and when he persists in stating that the slates, shales, etc., of the Citadel Hill and of the Trèsplat are under the Trenton limestone, in spite of all evidence to the contrary, and that the Potsdam is above the Lévis, it becomes quite evident that his statements are simply expressions of his individual opinion and certainly have "no basis of fact" to support them.

There are, however, one or two pertinent questions to which I think Mr. Marcou might be asked for a reply:

1. Does he think Emmons, Logan and myself and many other geologists, who agree with us, do not know gneiss from quartzite? A simple yes or no to this would suffice.

2. What are the sandstones of the Strait of Belle Ile if not Potsdam?

3. If the Point Lévis beds are older than the Potsdam, why have they never yet been discovered underlying the latter?

4. Page 69 (*op. cit.*), we are told "we have there (Vicinity of Quebec) two distinct formations, one of very small extent [? thickness] belonging probably to the Trenton, and another extremely thick forming the hill of the city of Quebec, Point Lévis and La Chaudière Falls,[2] strongly upheaved and broken before the deposit of the Trenton limestone." Why, if this impression is correct, is the Trenton limestone nowhere, in its entire course of hundreds of miles, seen resting on anything resembling this supposed older formation?

5. If there is no fault, as indicated by me between Lévis and the Citadel, why do the Lévis beds not reappear with their characteristic fossils on the Quebec side directly towards which they are striking?

[1] Proc. Bost. Soc. Nat. Hist., Vol. XXIV, pp. 54–83.

[2] Here are three very distinct series lumped together.

6. Would Mr. Marcou state where I have ever called the break synclinal.

7. When did I say, or even imply that I could "almost point out what part of the northern coast of the St. Lawrence and Labrador they came from as boulders?"

I am in no way responsible for the work or the conclusions of my predecessors, which Mr. Marcou, however, very rashly and incorrectly criticises while mixing them with mine.

As regards his criticism of the maps I have published, Mr. Marcou ought to know that a preliminary map always differs more or less from one in which the details of distribution have been worked out, and that the amount of detail that can be shown on a map depends on the scale used, and on the closeness with which the ground has been examined.

I can only regret that Mr. Marcou does "not know with any degree of certainty what Mr. Selwyn intends by using the English names." (p. 67.) It only shows he has never looked at my scheme of coloring and nomenclature, published in the Report of the Canadian Survey 1880–81–82, where my meaning is fully explained, though certainly without reference to the name Taconic, which I am free to confess I never understood; its distribution never, so far as I know, having been mapped or defined in America or elsewhere. There appeared to me to be no need for the name, the more widely known terms I have used meeting all requirements apart from those of a purely personal nature.

That "Mr. Selwyn is the only one who continues to maintain that the primordial fossils, etc." (p. 68), is a statement entirely incorrect. It would perhaps be more nearly correct to say that Mr. Marcou is the only one who maintains otherwise.

The fossils, graptolites, etc., not in the pebbles are not primordial.

The statement that in the eastern townships the Cambrian does not contain fossils (p. 68) is another rash and unauthorized statement; that they have not been found is no proof that they are not there.

Indeed some forms not unlike Oldhamia have been found there and doubtless others will be found sooner or later in these lower Cambrian slates.

There are in Mr. Marcou's paper a great many more inaccuracies, misstatements and partial references to what I have written on the geology of Quebec, especially the omission of any reference to that "On the Quebec Group in Geology" read before the Royal Society of Canada in 1882, and published in the first volume of its Transactions.

I have, however, no time for further discussion, and in any case I would probably not be able to convince Mr. Marcou that I can distinguish gneiss from quartzite, or that I am able to discern the evidence of a fault, or the difference between it and a landslide, or that the Lévis beds are not older than the Potsdam.

The completed map and report on the district which embraces the city of Quebec and the Island of Orleans will soon be ready for publication. These will give the final conclusions reached by this survey.

They are based on the most recent and careful topographical measurements and stratigraphical field work and are supported by new, and in most cases abundant, palæontological evidence showing the relative age of the various groups; further that the Lauzon and Sillery divisions of Logan are below and not above the Lévis and represent some part of the Cambrian system, whether above or below the Potsdam cannot at present be determined. Had Mr. Marcou investigated the facts on the ground over the whole area as closely and carefully as I and my colleagues have done during the past twenty years, he would at least have some right to criticise our work; and such criticism is always acceptable, and often valuable, but to criticise as Mr. Marcou does after very partial observations, and consequently, in ignorance of many most important facts, and entirely regardless of others, is, I think, misplaced, and certainly affords no assistance in elucidating the geological structure of such a complicated region as we have to deal with in the Province of Quebec. Neither do questions of nomenclature and it is, therefore, useless to discuss these.

General Meeting, April 17, 1889.

The Vice President, Prof. Geo. L. Goodale, in the chair.

The following papers were presented:

INDIAN POT HOLES, OR GIANTS' KETTLES OF FOREIGN WRITERS.

BY T. T. BOUVÉ.

It is well known that wherever there exist waterfalls of any magnitude, pot holes, so called, are often found beneath the rushing waters, formed by the friction of stones which have been lodged in the hollows of the rock surface over which the torrent pours, and which having a somewhat circular motion imparted to them, gradually wear away the rock, with the result of producing these singular objects.

It is not surprising that when these have been found, as has often been the case where there was nothing to indicate there had ever been a river or running stream, they should have excited alike the wonder and interest of both scientific and unscientific beholders.

It should be borne in mind that the knowledge of a great continental ice sheet resting over our whole northern region is but a recent acquisition, and that phenomena having their origin under such a condition of things could not possibly be understood previously by the most learned of observers.

It is interesting to note in this connection the conflict in mind of that acute investigator, Dr. Chas. T. Jackson, when writing upon the pot holes of this character, mentioned by him in his Final report upon the geology of New Hampshire. In remarks upon some in Orange, near the summit of elevated land, he says:—

"No pot holes have been noticed as belonging to the drift epoch and the absence of them has induced geologists to deny that water was concerned in the drifting of soils and stones from the north. Hence this discovery will be regarded as one of great interest for it not only proves that waters rushed over these rocks in this elevated mountain gap but that a series of rapids and falls existed there."

After dwelling further upon the matter, he seems to have had an intuitive perception of what might be the truth, for he adds:—

"If we could only know that there was here a glacier such as in Switzerland, then all would be plain."

The great fact that he stood when viewing the holes where thousands of feet of ice rested for very many centuries did not and could not at that time dawn upon his vision.

The ideas of the unlearned respecting such pot holes are often ludicrous. With our own people they have been regarded as the work of the Indians and where found have been called Indian Pot Holes, from the thought that they had been wrought for and used as cooking vessels. Abroad they have been called Giants' Kettles, undoubtedly from the belief that they were made by giants for their culinary use.

The study of glacial phenomena within a few years has thrown a flood of light upon much that was before obscure, and we now can well understand how pot holes may have been formed in localities remote from any water courses of the present period by rushing torrents through crevasses in the great ice sheet. The best description of such that has been published may be found in the 30th volume of the Journal of the Geological Society of London, in which they are called Giants' Kettles. Along the shores of the Scandinavian peninsula these kettles are numerous and of some at Kongshaven a particular account is given, embracing a statement of the thorough examination of their contents, which were morainic and which had remained intact since the glacial waters had ceased to flow.

Of one of these kettles I will quote from the description, in order to give an idea of their general character and contents, omitting what is unimportant:—

"This kettle is scooped out in the form of a cylinder almost perpendicularly into the rock 16 feet deep and 5 broad. The horizontal plan is somewhat elliptical. From the bottom a distinct spiral line is worn into the walls to the height of 6 feet. Higher up are marks of a process-like turning with indications of spirals. In consequence of this movement the kettle inside was a little wider below than above. The walls consisted entirely of Egeberg gneiss. The filling up was as follows:—uppermost under the water of high tide, were found mud and rubbish from outside, then the contents of the kettle began at 4½ feet from the opening to show, first, common moraine matter with only a few large stones; at from 8 to 10 feet a portion came where at least fifty stones were found of a more rounded and regular shape than those of moraine matter generally; here lay also four large stones like a floor. Under these began moraine gravel; and nearer the bottom came many more of the rounded stones among which were nine stones, two of them a foot long and the rest smaller, unusually regular and elliptical in form. These with those of the 8–10 foot level may all be distinctly recognized as different from those found in the moraines."

Other interesting kettles are described, but the description given of one will be sufficient to indicate the character of the contents that would probably have been found in those I am to speak of as occurring at Cohasset, if time had not destroyed the integrity of the vessels, and what they once contained had been preserved for our examination.

Two years since and possibly earlier, I heard of there being what were called pot holes in the rocks of the coast at Cohasset; but being especially engaged, during all the hours I could spare from business cares, in preparing a report for the forthcoming History of Hingham upon the Botany and Geology of that town, I postponed visiting the locality where they were said to be, until near the close of the last season, when by the courtesy of Mr. Charles S. Bates, the owner of the land, I visited it in his company. What I saw there was particularly interesting and I may add quite astonishing when I called to mind the fact that Dr. Charles T. Jackson had lived several seasons within about a mile of the spot, and that if the pot holes had ever come under his observation he would not have failed to give a full account of them before this Society. To make sure that he had not done this, I carefully looked through all the volumes of its Proceedings; but finding nothing concerning the matter in his communications, I thought it my duty to present here what I now do.

The pot holes are to be found in Little Harbor, Cohasset, on Cooper's Island, so called, which however is not an island in the sense of being a body of land surrounded with water, but from its being a somewhat elevated land surrounded partly by water and partly by low marshy ground. There is a border of rocky cliffs on the northern portion of the east coast of this island which end at a beach that separates them from other cliffs farther south; and it is near the termination of those first mentioned and quite close to the beach that the pot holes are found. Just before this termination there is a partial separation of the rocky mass by an opening on the water side, which however rapidly narrows inland but a few feet from the water. It is on the northern side of this opening, that is, on the rock that slopes towards the south, and very near the water at low tide, that two of the holes, or what remains of them, may be readily seen when the tide is out.

Of the lowest of these and the best preserved of them and which I designate as No. 1, there yet remains a pot hole in the rock which will hold water to the depth of 1 foot 9 inches, having a well defined rim just at the surface of the water. The diameter of it at rim is $25\frac{1}{2}$ inches; below the rim 30 inches. Above this rim the whole southern side of what once formed a portion of the kettle is gone; but on the northern side there remains, as a concavity in the rock, what formed a part of it, having well-worn marks upon the surface and these are plainly discernible for a height of 4 feet. From the rock sloping away rapidly above, it is very probable that even these traces, which prove a depth of 6 feet, do not give the whole of that of the original vessel when it was intact. Exterior to this pot hole, the tide sinks below the level of its bottom, but at high tide all is covered.

The second kettle has its bottom three feet above that of the lowest one, and a perpendicular line from the centre of each shows the two to be three feet apart. The wall dividing them must have become, while yet action went on within them, very thin and probably one broke into the other before it ceased altogether. The whole southern side of this second hole, which I call No. 2, is gone and water can only now stand in its bottom to the depth of about two inches.

The concavity above this which formed the northern portion of the hole, exhibiting as it does a well-worn surface of 3 feet in width, shows it must have been as large or larger than the first. This concavity can be discerned to the height of 5 feet, where further traces are lost; but, as is the case with No. 1, the whole depth of the pot hole may have been much greater that what is indicated. The slope of what remains of the walls of these holes shows that the flow of water over the rock surfaces was from the northwest. That of No. 2 approximates to 30° from that direction towards the southeast.

Of No. 3, so designated by me, there is but little to be said, except that it is small and shallow. It is 4 feet 9 inches above No. 2 in a northwest direction, and there may be traced from it westerly a narrow water channel about 6 feet in length.

The fourth of the kettle holes which I will mention is or was the largest of all and hence has been called by the people near by the "Well."

Passing over the rocky elevation in a northerly direction, it may be found about a hundred feet distant from the others in front of a cliff which faces an opening in the rocks more immediately near the water. This pot hole, unlike those previously mentioned, is not found on a sloping portion of rock, but is on a flat surface directly at the base of the cliff. Horizontally, the form of it is oval and its largest diameter, which is northeast and southwest in direction, is 4 feet, the narrowest 2 feet 10 inches. The depth at which water is now retained is about 1 foot.

The cliff rises 9 feet high from the margin of the "Well" and

10 feet from its bottom. The "Well" itself was probably as deep at least as 10 feet, the curvature and wearing of the rock of the cliff above the present hole clearly showing this.

The rocky ridge in which all these pot holes or kettles are found, has a height of from 20 to 25 feet and is of granite. Besides the pot holes, of which an account has been given, there are other depressions showing distinctly a commencement of action towards their formation. Two of such may be found 20 feet in a northerly direction from those numbered 1, 2 and 3; that is, between these and the one called the "Well," No. 4. One is shallow, appearing like the bowl of a spoon, about a foot across, showing, extending from it, a water-worn channel sloping easterly to the edge of the rock surface about 10 feet; and on a lower surface of the same rock, another and larger depression just where water from the first might descend. Moreover, a large portion of the rock surface shows not only glaciation but continued water action.

Having learned that on a high, rocky elevation, perhaps half a mile from Cooper's Island, there might be seen a singular hollow in the granite, which from its form has been called the Devil's Seat, I visited it. Examination satisfied me that this, though not well defined, was a small pot hole; and in this instance, as in others, an apparent water-worn channel extended on the rather abrupt slope of the rock for several feet, ending in another yet smaller hole, the diameter of the first being about 1 foot across in one direction and 7 inches in another, both having a depth of about 9 inches. The direction from the larger one to the smaller was found to be east-southeast.

It is very certain that no river has ever existed in the region of the pot holes at Cohasset to account for their existence. We are forced, therefore, to ascribe their origin to the flowing of water from the great continental glacier.

Considering the shallowness of the portions of the pot holes described on Cooper's Island, remaining for our observation, and the probable likelihood of their visitation by generations of people, both of the Indian and the white man, it is not surprising that nothing is left of their contents in or about them. There is, however, one rounded stone in the possession of Mr. Charles S. Bates which tradition states to have been taken from the deepest one mentioned. It is elliptical, nearly spherical, in form; its longest diameter being about $4\frac{1}{2}$ inches, its shortest 4 inches. Transversely, it is quite circular. It is of granite, not unlike that of the surrounding country. There is no reason to question the truth of the tradition.

To account for the phenomena presented by the pot holes described, it is necessary to recognize that when the great glacier lay over the land, many hundreds of feet in depth, during the summer, particularly towards the close of the period, rivers flowed over its surface, as they now do over the glaciers of the Alps. As there, crevasses were formed in the ice, into which the water poured and worked passages to the bottom of the great sheet, discharging itself in torrents, often conveying stones and other moraine matter to the rock surfaces below. Such passages in modern glaciers become somewhat circular in form and are hence called wells. They are also called moulins, the latter name from the noise made by the rushing waters in the ice, being not unlike that of a mill. The water, and the material conveyed by it through such wells of the great glacier of our continent, must have smoothed and worn rapidly away the rock surface on which they impinged, often causing, by the same kind of action as is witnessed under falls of water in some of our rivers, holes in the rocks of like character as those now under consideration. Of course the action of the water and material conveyed by it would be immensely more rapid in forming such holes, falling, as they undoubtedly did, from a great height and striking upon the rocks below with intense force. This would lead to the abrasion of the rock, by any rotating stones lodged in the hollows, so much more powerful than any action we know under falling waters of the present day, as to render estimation of the result incalculable.

It is doubtful, however, to the mind of the writer, if circumstances often favored the formation of pot holes directly beneath such a fall and where its full force would be felt. He is impressed with the view that if this were the case they would not be found having the form they horizontally present.

It has, indeed, been thought strange that, as the ice moved continuously on, the holes were not found generally elongated in the direction of the movement of the glacier rather than circular. Such thought, however, is only consistent with the presumption that the holes were made just where the water first fell upon the rock surface below. Far more reasonable is it to suppose that the holes were formed somewhat distant from this place, where the masses of

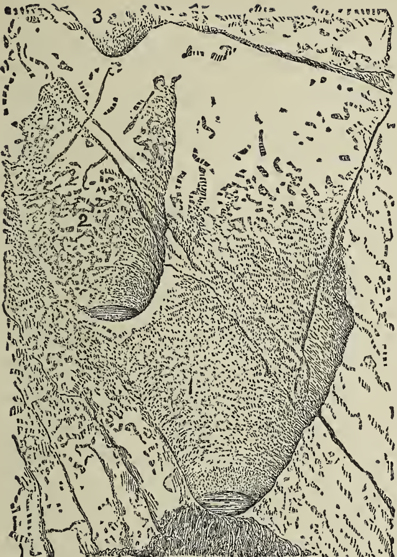


FIG. 2.

FIG. 1.

FIG. 3.

FIG. 1. Packard. Fossil crustacean (see p. 209).
FIGS. 2, 3. Bouvé. Pot holes from Hingham.

rocks borne by the waters found a lodging in some depression and there by rotation worked out the pot holes. The ice might move on and the waters descend through the moulin far from where they first fell, yet continue their flow in the same direction as at first and go on with the work of rotating the contents of the hole through a whole season. In such case there could be, of course, no reason to expect elongation.

The fact that pot holes have been found in near proximity and in such positions relative to each other, showing them apparently to be the result of independent falls of water, as in the case of the "Well" so-called, of the holes described at the distance mentioned from the others, leads to a consideration of what has been noticed in the Alps. Observation upon the glaciers there shows that as a crevasse is carried forward by the general movement of the ice from where it received the flow of waters in the summer, and winter cuts off the supply, it closes, leaving only upon the surface of the glacier a mark showing where it had once been. Subsequently, a new one is formed just where in relation to the land at the margin of the glacier, the former one existed; and the waters of the succeeding summer again descend upon the rock surface near where they before fell, but not often, probably, in exactly the same place; and thus other pot holes are formed contiguous to those of a preceding season, and yet far enough distant to make it evident that they were not produced by the same flow of water.

Respecting the formation of the crevasses in about the same places on the ice sheet, there can be no question but that this is due to the irregularities of the subglacial surface; and as high ridges transverse to the direction of the glacial flow must favor their formation, it is no wonder that pot holes are often found in the slopes of such ridges and at their bases, as in the case of those described at Cohasset.

In the discussion of this paper, Mr. Warren Upham stated that he had examined the locality in company with Mr. Bouvé and Professor Crosby, and that the contour of the vicinity convinced them of the impossibility that any stream could have flowed there, excepting when the country was partly or wholly enveloped by the ice-sheet. But the glacial origin of these and other "Giant's Kettles," by waterfalls plunging through *moulins* of the ice-sheet, seems difficult to be understood, because the observations of Agassiz and others show that the *moulins* of the glaciers of the Alps, where they are known to reach down sometimes 500 feet or more to the underlying rock, are not stationary but move forward at the same rate as the ice itself.

Mr. Upham, therefore, suggested that the time of the excavation of these glacial pot-holes was probably the early part of the epoch of glaciation, when the ice-sheet was being formed upon the land by snow-fall. He thought that upon any hilly country the ice must have attained an average depth somewhat exceeding the altitude of the hills above the adjoining lowlands before any general motion of the ice-sheet could begin. During this process of slow accumulation of the ice-sheet, the summer melting upon its surface would produce multitudes of rills, rivulets and brooks, which might unite into a large stream, and this, pouring through a crevasse and melting out a cylindric *moulin*, might fall a considerable depth to the bed-rock, perhaps one or two hundred feet or more upon an area so moderately uneven as the vicinity of Cohasset, while yet the ice-motion, though sufficient to permit the formation of the crevasse, might not have gained a definite current to carry the crevasse, *moulin*, and water-fall away from the spot where they were first formed. We may thus explain the continuation of a glacial water-fall in one place while it was excavating one of these "Giant's Kettles" or pot-holes. After the ice-sheet acquired a current because of the greater thickness and pressure of its mass, such deep cylindric excavations in the bed-rock could not be made; and during the recession and final dissolution of the ice-sheet it seems probable that its receding border had steeper gradients and consequently even more rapid motion than in the culmination of the glacial epoch. It is also to be observed that the streams formed on the surface of the ice-sheet by the summer melting before it was so thick as to have motion would be free from drift, so that they could readily find their way through crevasses, wearing pot-holes in the rock beneath, and thence flowing in subglacial courses; but that the glacial streams during the departure of the ice were heavily freighted with the gravel, sand, and clay of the modified drift, which must have soon choked up the passages wherever these drift-laden streams found crevasses, causing them to flow in superficial channels walled and underlaid by ice.

In support of this view, Mr. Upham referred to the fact that the glacial pot-holes are commonly found full of drift, which indicates that they were eroded near the beginning rather than the end of a glacial epoch. This was true of the "Giant's Kettles" near Christiania, Norway, the largest of which, cleared from its drift under the direction of Professor Kjerulf, has a depth of about forty feet and diameter of eight to twelve feet; also of the two much larger potholes near Archbald, Pa., described in the Annual Report of the Geological Survey of Pennsylvania for 1885. The Archbald potholes are one thousand feet apart and were both discovered in coal mining, their bottoms being in the coal bed. When the drift filling them was cleared out, one was found to be thirty-eight feet deep, with a diameter of about fifteen feet at the bottom, increasing to a maximum of forty-two feet and a minimum of twenty-four feet across its top; and the second, the diameter of which is not definitely noted, was about fifty feet deep in rock, with a covering of fifteen feet of drift above.

Further evidence relating to the time of formation of the "Giant's Kettles" is supplied in Norway by their occurrence near the present sea level, where it is known, by fossiliferous marine beds overlying the glacial drift, that the land was submerged to a depth of several hundred feet beneath the sea when the ice-sheet was being finally melted. During the departure of the ice, therefore, no water-fall through a *moulin* could wear these caldrons, because they were then below the sea level; but, on the other hand, they were probably formed in this way when the ice-sheet was beginning to be accumulated. They may be accepted as proof that the land in preglacial or interglacial time had at least as great elevation as now, while the fiords indeed indicate that it was much higher.

THE STRUCTURE OF DRUMLINS.

BY WARREN UPHAM.

The purpose of this paper is to record notes of several interesting sections of drumlins, and therefrom to gain whatever they may teach concerning the manner and time of the deposition of these remarkable hills of glacial drift. In this study, the literature of the subject has been collated, so far as it is known to me, including the following authors. One of these, Prof. William M. Davis, to whom we already owe much, has undertaken the mapping and discussion of the drumlins of this country for the United States Geological Survey.

Sir James Hall, Trans. of the Edinburgh Royal Society, vol. vii, 1815, pp. 169–183, first pointing out the parallelism of the trends of these drift hills with the striæ on the bed-rocks.

M. H. Close, "Notes on the General Glaciation of Ireland," Journal of the Royal Geological Society of Ireland, vol. i, 1866, pp. 207–236. In this paper the name *drumlin* was first specifically applied to these accumulations of till.

G. H. Kinahan and M. H. Close, "The General Glaciation of Iar-Connaught and its neighbourhood, in the counties of Galway and Mayo," Dublin, 1872, pp. 20, with map.

James Geikie, Great Ice Age, second ed., 1877, pp. 13–21, 76, 394.

J. R. Dakyns, "Lenticular Hills of Glacial Drift," Geol. Magazine, II, vol. vi, 1879, p. 382.

J. G. Percival, Report on the Geology of Connecticut, 1842, pp. 256, 461, 479, 485.

James Hall, Geology of New York, Survey of the Fourth District, 1843, pp. 319, 414, etc.

N. S. Shaler, "On the Parallel Ridges of Glacial Drift in eastern Massachusetts," Proceedings of this Society, vol. xiii, 1870, pp. 196–204; Illustrations of the Earth's Surface: Glaciers, 1881, pp. 60–63; Seventh Annual Report of the U. S. Geol. Survey, 1888, pp. 321, 2.

W. M. Davis, Illustrations of the Earth's Surface: Glaciers, text describing Plate xxiv; in paper on "Glacial Erosion," Proc. of this Society, vol. xxii, 1882, pp. 34, 40–42; "Drumlins," Science, vol. iv, pp. 418–420, with illustrations, Oct. 31, 1884; "The Distribution and Origin of Drumlins," Am. Jour. Sci., III, vol. xxviii, pp. 407–416, Dec., 1884.

C. H. Hitchcock, "Lenticular Hills of Glacial Drift," Proc. of this Society, vol. xix, 1876, pp. 63–67; Geology of New Hampshire, vol. ii, p. 446; vol. iii, pp. 233, 254, 282, 309.

Warren Upham, "The Distribution of the Till," Geol. of N. H., vol. iii, 1878, pp. 285–309, with heliotype, and with maps in Atlas; "Glacial Drift in Boston and its vicinity," Proc. of this Society, vol xx, 1879, pp. 220–234; "The Till in New England," Geol. Mag., II, vol. vi, 1879, pp. 283, 4; "Marine Shells and

Fragments of Shells in the Till near Boston," Proc. of this Society, vol. xxiv, 1888, pp. 127–141.

G. F. Matthew, in "Report on the Superficial Geology of New Brunswick," Geol Survey of Canada, Report of Progress for 1877–78, p. 12 EE.

G. H. Stone, in Proc. of this Society, vol. xx, 1880, p. 434; Proc. of the Portland Society of Natural History, Nov. 21, 1881.

L. Johnson, "The Parallel Drift Hills of western New York," Trans. N. Y. Acad. of Sci., vol. I, 1882, pp. 78–80; Annals do., vol. II, 1882, pp. 249–266, with map.

J. D. Dana, in Am. Jour. Sci., III, xxvi, 1883, pp. 357–361, relating to Round Hill, in Orange, Conn., near New Haven.

T. C. Chamberlin, Geology of Wisconsin, vol. I, 1883, p. 283; Third Annual Report of the U. S. Geol. Survey, 1883, p. 306; Proc. Am. Assoc. for Adv. of Sci., vol. xxxv, 1886, p. 204.

Nearly all of the many sections of drumlins observed by me in New Hampshire and Massachusetts consist, as these hills are described by others in various parts of our own glaciated area and in the British Isles, simply of the unstratified glacial drift, called till or boulder-clay, deposited directly by the ice-sheet, with no intercalated thick beds or even thin seams or veins of modified drift, as gravel, sand, or clay, assorted and deposited in a stratified condition by water. Last autumn, however, I found on the east shore of Scituate, Mass., about twenty-five miles southeast from Boston, two extraordinary drumlins, known as the Third and Fourth Cliffs, which consist of till upon their whole surface and to a depth that varies from 15 to 25 feet and more, but below include beds of modified drift that attain in Third Cliff a thickness of at least 30 to 40 feet, reaching to the boulder-strewn shore, and in Fourth Cliff a thickness 10 to 20 feet, being seen there to be underlain by till and to be also in part interbedded with it.

Proceeding southward from the entrance of Scituate Harbor, the First and Second Cliffs are passed in less than a mile (fig. 1). These are gently sloping drumlins, with gracefully rounded, nearly flat tops, which are elevated respectively about 30 and 45 feet above the sea. The eastern third of each has been eroded by the Atlantic, and the resulting steep sections appear to be till throughout, from the natural surface to the shore formed of the boulders which have been left in this process of erosion and are piled in a moderate slope to a height about ten feet above mean tide, the difference between low and high tide being here about six feet. Peggotty beach, a third of a mile long, on which many fish-houses and moss-houses are built, the latter being used for storage of Irish moss or carrageen, connects the Second aud Third Cliffs; and between the Third and Fourth Cliffs an excellently developed shingle beach extends nearly one mile, with its crest about fifteen feet above mean tide. The drumlins of Third and Fourth Cliffs rise respectively about 70 and 60 feet above the sea, by whose waves the eastern half of each of these hills has been worn away, forming steep and in large part almost vertical sections of the till and modified drift, with their base at the top of the shore of boulders. Third Cliff is about two-thirds of a mile long, and Fourth Cliff one-third of a mile; and the crest of each maintains a nearly uniform height along the central half of these distances, coinciding approximately with the extent of their included beds of modified drift. These four hills are doubtless to be classed as drumlins, although they have not so steep slopes nor so distinct trends as commonly mark the contour of the drumlins of Nantasket, Hingham, Boston Harbor, and all the vicinity of this city, instead of which they rise, so far as their original outlines remain, in nearly round, smooth, low domes, surrounded on all sides by low land, marsh, or sea.

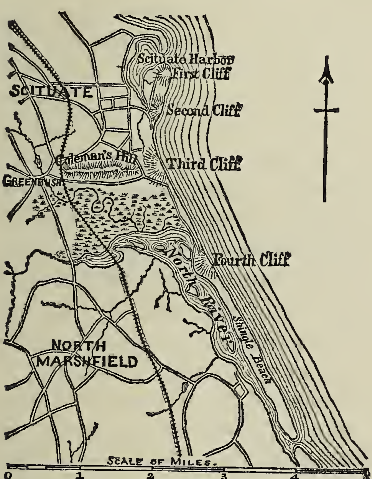


FIG. 1. Map of portions of Scituate and Marshfield, Mass.

If only the surface of these drumlins was known, they would be supposed to have the usual structure, consisting only of till, for this forms their entire surface, with plentiful boulders up to five feet in diameter and occasional larger boulders up to the size of eight or ten feet. But the sections of Third and Fourth Cliffs, worn away by the Atlantic which beats heavily upon them during every storm, show very distinctly a complex structure of associated deposits of till and modified drift.

Both the north and south ends of Third Cliff (fig. 2) for a dis-

FIG. 2. Section of Third Cliff; length, about 3,000 feet; height, 70 feet above the sea. (The base of the section is at the top of the shore of boulders, 10 feet above the sea.)

tance of about fifty rods at each end, where the hill-slope rises from near the sea level to the height of 50 or 60 feet or more, that is, nearly to the full height of this drumlin, are composed wholly of till, the usual very compact and hard gravelly and stony clay, with frequent large boulders; but in the central portion of the section only its upper half or third is till, and this lies upon beds of gravel, sand, and clay, which in the middle and greater part of their extent are very nearly horizontal in stratification, but dip down in slopes of 3° to 6° toward each end, the slopes terminating the nucleal mass of modified drift being somewhat steeper than those of the surface of the drumlin. A feature especially noteworthy is the conformability of the stratification of the modified drift with the line of junction which separates it from the overlying till; but no seams of gravel, sand or clay were observed within the till above, nor were any layers or masses of till, nor any boulders, seen enclosed in the modified drift. The section shows the two deposits divided by a definite and regular line, which curves down at each end. Throughout its whole extent, the bedding of the modified drift and the obscure lamination, which is commonly a characteristic of the till and is distinctly seen here, are parallel with each other and conformable with the line of division. The upper part of the modified drift is mainly sand and gravel to the thickness of 10 or 15 feet, enclosing fragments of stone up to six or eight inches in diameter, but no boulders. Beneath are beds of laminated dark gray clay or very fine sandy silt, which form the greater part of the deposit of modified drift toward the north, while its corresponding lower portion at the south consists mainly of coarse sand, much of it stained yellow or brown with limonite. The modified drift of Third Cliff extends below the slope of boulders that forms the shore, and its base is not exposed to view.

In Fourth Cliff (fig. 3) a section similar with the preceding, but only about half so long, and having some ten feet less height, presents the same relationship of till and an underlying anticlinal de-

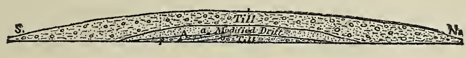


FIG. 3. Section of Fourth Cliff; length, about 2,000 feet; height, 60 feet above the sea.

posit of sand and gravel, the laminated structure of the till and the stratification of the modified drift being conformable with their line of division, but without interbedding there. Under the sand and gravel in this section a thickness of 5 to 10 feet of till is seen, extending also below the shore of boulders, along a distance of forty rods or more, and in one place these deposits exhibit very instructive interbedding (fig. 4). The extent of the modified drift is nearly sixty rods, and its thickness ranges from 10 to 20 or 25 feet. It consists wholly of sand and gravel, with no clay or fine silt, and with only the usual slight tinting of limonite. Its central part lies between 20 and 40 feet above the sea, and is overlain by about 20 feet of till. A little south of the middle of the cliff, the stratum of modified drift is divided by a tapering, wedge-like accumulation of till (A in fig. 4), which thickens from three to six feet or more in a distance of a hundred feet from north to south, sinking meanwhile about seven feet, so that the underlying sand layer, four to five feet thick, which branches from the main stratum of modified drift and is intercalated between two accumulations of till, dips in that distance beneath the upper line of the boulder-strewn shore.

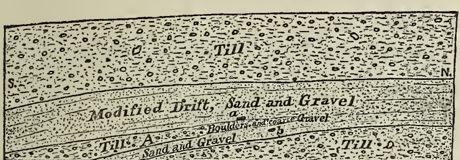


FIG. 4. Part of the section of Fourth Cliff, on enlarged scale; length, about 400 feet; height, 55 to 60 feet above the sea.

The north extremity of the tapering mass of till changes to a bed of boulders, cobbles and coarse gravel, which is three or four feet thick and extends about seventy-five feet into the finer modified drift, to which it gradually changes northward. Lying on the top of this coarse bed, a boulder (a) three to four feet long, and nearly as wide, projects with its whole thickness of one and a half feet into the overlying sand deposit. A short distance farther north I noted a second boulder (*b*), of nearly the same size, wholly enclosed within the underlying sand layer; but I saw no other boulders enclosed within the modified drift of this whole section, excepting in the very coarse bed already described, which continues northward from the intercalated southern mass of the underlying till, and with which these two boulders are closely associated. The one first mentioned was evidently deposited slightly later, and the other slightly earlier than the principal bed of boulders and gravel; and this bed seems clearly to have been formed contemporaneously with the till into which it merges. Indeed, my study of the two strata of modified drift at the south, the tongue-like deposit of till between them, and its prolongation in the layer of coarse gravel with boulders, convinces me that they were rapidly accumulated in the order and place where they now lie, with no considerable interval between the deposition of the lower sand stratum and the till above it, nor between that till and the upper stratum of the modified drift, the three together representing only the time that was occupied in the formation of the single stratum of modified drift into which these three deposits unite toward the north.

From this conclusion others are immediately suggested, namely, that the whole drumlin of Fourth Cliff was probably deposited somewhat rapidly; that the conditions leading to the accumulation of the basal till were followed by such as caused the modified drift to be spread over it, the latter perhaps requiring no longer time than a single summer or the portion of the year attended by abundant ice-melting; and that conditions again ensued favoring the accumulation of till, which was thenceforward uninterrupted until the formation of the hill was completed and the overlying ice was melted away. Excepting the one place described, no other evidence of interbedding or gradual transition was seen, but the till beneath, like that above, is separated from the modified drift by a well defined line with which the obscure lamination of the till and the bedding of the sand and gravel are parallel. No evidence of erosion, nor of tumultuous pushing forward, was anywhere seen; but instead the whole section appears to represent continuous deposition. The very hard and compact condition of the till, and its characteristic flakiness, which I have spoken of as lamination, both below and above the modified drift, indicate that it was deposited as a ground moraine beneath the pressure of the ice-sheet, instead of as englacial till falling loosely from the ice when it melted. It is, in short, the typical subglacial till, such as forms the drumlins everywhere; but here and in Third Cliff very unusual subglacial deposits of modified drift are associated with it.

The only organic remains observed in these sections are small fragments of lignite, resembling charcoal, which Prof. W. O. Crosby and Mr. Bouvé found in Third Cliff (at *c* of fig. 2) scattered through a thickness of about six inches of the sand where it rests upon stratified clay 10 or 12 feet below the overlying till. The object of our visit together to this section, on the occasion when we discovered its remarkable structure, was to search for glacially transported fragments of marine shells like those of the till forming drumlins in Hull, Quincy, the islands of Boston Harbor, East Boston and Winthrop,[1] but no trace of them was found. It seems probable that the lignite fragments were wood from preglacial or interglacial forests that were overwhelmed by the arctic climate, snowfall, and ice-sheet of the last glacial epoch, these fragments being enclosed like boulders, gravel, sand and clay in the ice and forming part of its englacial drift, until they were washed away by streams on its dissolving surface and finally were carried beneath the ice to form part of the nucleus of modified drift in this drumlin. A similar derivation was suggested ten years ago for such scanty deposits of lignite noticed in the modified drift of Cape Cod;[2] but there the deposition evidently took place in an embayment of the border of the waning ice-sheet, where the sediments were spread in a flood-plain open to the sky and bounded on each side by higher areas of ice.

Peculiar dark bands (*d*), evidently representing successive stages of deposition, were noted in the till of Third Cliff above the north end of the modified drift and along an extent of about 200 feet to the north. Their number is seven or eight, each six to twelve inches thick, varying from one to three or four feet apart, continuing separate throughout, with no branching nor inosculation. The portion of the till thus banded has a vertical width of 15 to 20 feet and dips about five degrees northward, being included between 20 and 45 feet above the sea. Like the dips at each end of the modified drift, it is more inclined than the overlying surface of the drumlin, which is there about 60 to 55 feet above the sea, or than even its steepest slope farther down. No stratified layers or seams of

[1]Proceedings of this Society, vol. xxiv, pp. 127–141, Dec. 19, 1888.
[2]American Naturalist, vol. xiii, pp. 560, 561, Sept., 1879.

modified drift occur in the banded part of the till, which is nearly like the remainder of the extensive deposits of till in this section, excepting that it has somewhat more sandy and porous layers alternating with somewhat more clayey and therefore impervious layers, the latter being noticeable because they retain the moisture more persistently and have a slightly darker color. But no definite line of demarcation separates these layers, there being instead a gradual change which occupies a thickness of several inches. Nor is the contrast so distinctly seen in examining the section near its base, or in climbing up for closer inspection, as at a distance of several rods where the small difference in color is better displayed in the wider view. Boulders and gravel are indiscriminately mingled through the whole deposit, which is the ordinary boulder-clay or till; and these alternations in the proportions of clay seem probably to be attributable to the slightly varying conditions of alternating summer and winter, affecting the rate of motion of the ice-sheet, its power to erode drift elsewhere, and its tendency to deposit its ground moraine on the surface of this drumlin. If this is the true explanation, the yearly addition of till to that part of the section averaged two or two and a half feet, and the accumulation of the entire drumlin of Third Cliff required probably not more than twenty-five or thirty years.[1] Again, in the till overlying the south end of the modified drift of this section such banding is faintly developed in two or three layers (*e*) for a length of fifty feet or more at an elevation about 40 feet above the sea and 15 feet below the surface. But no trace of this structure was seen in the other sections on the east shore of Scituate.

Though descriptions of this structure in deposits of till have not previously been published, so far as I am able to learn, and though apparently it is not found in the drumlins of New Hampshire and of northeastern Massachusetts, nor even of the vicinity of Boston, excepting within close proximity to the sea, it is yet frequently observable in the drumlins of the islands of Boston Harbor. For example, it is finely developed in the cliff of till forming the northeast end of Peddock's Island, where five or six such bands are separated

[1] Similar indications of the rate of annual increase in deposits of modified drift are found by the writer in the valley of the Minnesota river at Jordan, Carver and Chaska, Minn. (Proc. Am. Assoc. for the Adv. of Science, vol. xxxii, 1883, p. 225; Am. Jour. Sci., III, vol. xxvii, p. 106, Feb., 1884; and Geology of Minnesota, vol. ii, 1888, pp. 131, 144), and by Prof. B. K. Emerson in the Connecticut valley at Northampton, Massachusetts (Am. Jour. Sci., III, vol. xxxiv, pp. 404–5, Nov., 1887).

by intervals that vary from three to six feet; at the southwest end of Long Island, where a single dark band about half-way up the cliff, or 30 to 40 feet above the sea, extends fully 400 feet; and at the south end of Spectacle Island, where two dark bands six or eight feet apart are distinctly seen along a distance of at least 150 feet, at a similar elevation above the sea and below the top of the cliff as on Long Island. In all these sections, as in Third Cliff, Scituate, the dark bands have anticlinal dips, which are somewhat more inclined than the overlying arched surface. On the islands of the harbor this structure is best seen in sailing by within a short distance; and my attention was first directed to it by Prof. W. O. Crosby in a yachting excursion. Its significance as evidence that the deposition of till was in progress contemporaneously upon a former surface of the growing drumlin is nearly the same that is occasionally otherwise indicated by lines of more plentiful boulders than the average in other parts of the till deposit. Such a line of exceptionally abundant boulders and small rock-fragments, of sizes from a few inches to two or three feet in diameter, I noted in the cliff at the east end of the drumlin close south of Point Allerton, extending 50 or 75 feet in its northern slope about six feet below the surface; and another, of similar situation and extent, is seen in the till of Walnut or College Hill, Medford, where it is cut by Curtis street.[1]

Thick beds of modified drift enclosed in the lower part of drumlins and overlain by their accumulations of till are certainly very rare. My only observations of them in eastern Massachusetts are the two sections in Scituate already described; and the only other notes of their occurrence in this district that have come to my knowledge are those of Mr. W. W. Dodge, who saw in the base of Great Head, Winthrop, exposed by excavation for a railroad, an anticlinal deposit of fine gravel overlain by till, as in Third and Fourth Cliffs,[2] and who further informs me that when Fort Hill in Boston,

[1]Compare Prof. H. Y. Hind's notes of the arrangement of boulders in the till at Toronto, Ontario (Report of the Assiniboine and Saskatchewan Exploring Expedition, Toronto, 1859, p. 120); my observations of a buried moraine in Big Stone, Swift and Chippewa counties, Minnesota (Geology of Minn., Eighth annual report, for 1879, p. 116; do., Final Report, vol. ii, 1888, p. 214, noting in one locality a striated pavement of boulders); and Mr. Hugh Miller's suggestive paper, "On Fluxion-Structure in Till" (Report of the Brit. Assoc. for Adv. of Science, Montreal, 1884, p. 720; Geol. Mag., III, vol. i, 1884, p. 472).

[2]Am. Jour. Sci., III, vol. xxxvi, p. 56, July, 1888; Proceedings of this Society, vol. xxiv, p. 132, Dec., 1888.

a typical drumlin, was removed, its central portion contained, at an elevation probably ten feet above the present surface of Fort Hill Square, a bed of horizontally stratified clay, free from boulders and gravel, enclosed within the till, having an extent of a few rods, but not continuing in any direction to the natural surface on the slopes of the hill. In New Hampshire modified drift has been observed in several places enclosed in drumlins and in smooth rounded masses of till, nearly related to drumlins, which slope downward from prominent hills of rock, either on their stoss or lee sides or often on both these sides.[1] Professor Davis tells me, also, that in the southern part of the belt of very abundant drumlins in central New York, their sections frequently show stratified gravel and sand underlying the till, and that often the relationship of these formations is such as to prove that the stratified beds were somewhat eroded before the accumulation of the till, as by an advance of the ice-sheet over a preglacial or interglacial deposit. In this important respect these sections differ from those of Third and Fourth Cliffs; but the latter seem to be nearly allied, if not identical, in structure and origin with the massive rounded drift-hills, consisting of till on the surface and of underlying beds of gravel and sand, which President Chamberlin has called veneered hills. Excellent examples of these are found in Madison, Wisconsin, much larger than the drumlins of Scituate.

Thin layers, seams, or veins, of sand and fine gravel, deposited by water like all the modified drift, are occasionally found enclosed in the till of drumlins, but are rare, sections of these hills being usually composed wholly of the unstratified till, deposited directly from the ice-sheet. An instructive section, showing such a thin sand layer, was exposed last summer in the excavation of the northeast slope of Central Hill, Somerville, on the site of the new Winter Hill station of the Lowell railroad. The whole excavation, about twenty feet in height and several rods long, was ordinary till, excepting where it contains one seam of clean, coarse sand, from a half inch to three inches thick, which was seen along an extent of about fifty feet from northwest to southeast and also nearly as far in a transverse direction. Its elevation was two to six feet above the railroad track, with an inclination nearly like that of the hill slope. Throughout its whole area observed, it was continuous in a somewhat regular course, without crumpling or considerable dis-

[1] Geology of New Hampshire, vol. iii, 1878, pp. 289–291.

placements. This seam of sand was doubtless quickly deposited by running subglacial water; and it was thenceforward undisturbed while the deposition of the till continued over its whole extent. While the till both next below and next above, to a thickness varying from a few inches to two or three feet, but exceeding one foot only beneath the sand layer, was being deposited, sufficient percolation of water took place to produce an imperfect stratification, the clay commonly enclosing nearly the ordinary proportion of gravel and stones in the till. Very generally, however, this clay is finely laminated and free from gravel for two or three inches next below the sand and for a half inch to one inch above it; and in one place it was seen thus stratified and free from gravel for about a foot or a little more below the sand. Boulders and smaller rock fragments, occurring in contact with the sand layer, or in the associated more or less stratified part of the till, are enclosed by laminæ which bend down beneath and arch upward over them. Such seams of sand or gravel enclosed in till are often sources of water in wells; and a fine spring, situated only a few rods northwest from the Winter Hill station, probably issues from this porous layer. No other similar sand layer has been found during my examination of many extensive sections of the till forming drumlins in the vicinity of Boston; but seams of modified drift have been observed rarely in lenticular hills and slopes of till in New Hampshire, and they are frequently encountered in digging wells in the undulating drift-sheet of Minnesota, where in many districts they have so great extent as to supply artesian water.[1]

Besides the evidence in the structural features of the drumlins, indicating that they were accumulated rapidly during the closing stage of the last glacial epoch, a strong argument toward the same conclusion is afforded by the prevailing east-southeast trend of the longer axes of these hills about Boston, while the striation on the bed-rocks is mostly south-southeast, the difference between the two courses being forty-five degrees. Elsewhere in all the districts characterized by abundant drumlins in this country and the British Isles, their longer axes and the glacial striæ are parallel; and it seems sure that both were determined by the currents of the ice-sheet. Their difference in direction in the neighborhood of Boston, I believe to be due to a deflection of the motion of the ice there during

[1]Geology of Minnesota, Eighth annual report, for 1879, pp. 113, 114; Final report, vols. i and ii.

its final melting. Through the time of its maximum thickness and extent the ice-sheet moved south-southeastward across this area, and reached to the terminal moraine of Long Island, Block Island, Martha's Vineyard, and Nantucket; and onward the course of its border was probably east-northeast along the submarine plateaus of the Fishing Banks. But when a mild climate began to cause the glacial boundary to recede northward, the melting probably advanced fast r upon the area of the Gulf of Maine, than upon southern New England, so that the ice-front became indented by a deep embayment east of Massachusetts, toward which the latest glacial currents along the coast were deflected. The formation of the drumlins about Boston seems to have taken place wholly during this time of deflected glacial movements, the ground moraine being massed in these hills on account of inequalities in the force and direction of the currents of the over-riding ice-sheet, when its receding border was probably only a few miles distant. Fifteen to twenty-five miles west of Boston, Mr. George H. Barton finds the trends of drumlins prevailingly south-southeast, in parallelism with the striation, but with occasional exceptions where the longer axes of drumlins vary much from this course, perhaps because of small indentations in the glacial boundary and consequent divergence of the latest ice-motion from its previous course.

Fragments of interglacial marine shells occur in the till of the drumlins of Hull, Boston Harbor and Winthrop,[1] showing that while these hills were being accumulated marine beds on the northwest or west-northwest, probably within a distance of a few miles upon the harbor area or in the Charles and Mystic valleys, were being eroded; and this erosion was continued through the whole time of accumulation of these oval hills of till. That the shell fragments occur in the drumlins more plentifully than in the drift south of Boston, where none have been observed, may be partly explained by the fact that within the valleys and to a less degree in the basin of the harbor the interglacial fossiliferous beds had been somewhat sheltered from erosion by the ice-sheet while its motion was southward, but were more fully exposed to its deflected east-southeast current. It has seemed to me probable that the border of the ice during its recession, melted by the returning warmer climate, had generally a more steeply sloping surface than in its time of greatest

[1] Proceedings of this Society, vol. xxiv, pp. 127-141, Dec., 1888.

extent, and that consequently the rate of motion of the outer part of the ice-sheet was even increased during its final melting. This would still further explain the exceptional rates of both erosion and deposition that are indicated by the shell fragments contained in the till of some of these drumlins from base to crest, as on Peddock's Island, where also the dark bands showing stages of growth are very distinct.

Another indication of the late formation of the drumlins is found in the relationship of Third Cliff and Coleman's Hill in Scituate. A half mile west from the eroded sea-cliff of this drumlin is the east end of a notable kame or esker called Coleman's Hill, which extends about a mile, trending nearly due west, and terminating at Greenbush station (see fig. 1). It is a stratified deposit of sand and fine and coarse gravel, containing cobbles up to one foot in diameter, mostly somewhat rounded by water-wearing, but destitute of boulders. The top of this esker is flat upon a width that varies from two or three to ten or fifteen rods; and its height is 110 to 100 feet above the sea, declining slightly in its length of one mile from east to west. Its sides are steep, and the width across its base varies from a sixth to a third of a mile. On the south it is bordered by a broad salt-marsh, through which a creek meanders in a beautifully curved course; and on the north the adjoining low land is from ten to twenty feet above the sea. This esker was undoubtedly deposited by a stream that descended here, flowing east, from the surface of the melting and receding ice-sheet, laying down its coarse sediments in a broad channel bordered on each side by ice. Its origin was like that of the series of osars in Maine, in the Merrimack and Connecticut valleys, and in Sweden; or perhaps we might better say that it is intermediate in origin and character between these prolonged, narrow gravel ridges and the broad deposit of modified drift which forms the fore-arm of Cape Cod, north of Orleans. The structure of the till-covered hill of Third Cliff, and its topographic position in the same east to west line with Coleman's Hill, convince me that the two were formed in close succession during the retreat of the ice-sheet at the end of the latest glaciation of this area.

If the dark bands noted in the till of Third Cliff, Peddock's Island, and elsewhere, are marks of accumulation in successive years, which seems highly probable, the drumlins of Boston and vicinity received, at least in some instances, from one to six feet of till yearly deposited over their whole surface, so that the accumulation of these hills to their heights of 50 to 150 or 200 feet required only from two or three decades to a century of years. Indeed, where they exhibit no such banding, I have thought that sometimes their entire formation may have been more rapid, so that the most massive drumlins, like the largest esker ridges, were probably deposited in so short a time that their beginning, growth, and completion would occupy considerably less than a man's lifetime. The drumlins appear to have been heaped up beneath the ice-sheet within a few miles back from its margin, or perhaps occasionally within even less than one mile, as seems to be suggested by Mr. Barton's observations. Where they are scattered over any extensive area, as around Boston, probably they were not all in progress of deposition contemporaneously, but were successively accumulated as the ice-margin retreated. The plentiful occurrence of drumlins upon certain belts of country, as in northeastern Massachusetts, in southern New Hampshire, from Spencer, Mass., to Pomfret, Conn., and in central New York, may therefore contribute important information, when they shall be fully studied, concerning the outlines of the receding glacial boundary during the dissolution of the ice-sheet, supplementing the evidence supplied by marginal moraines and kames, eskers or osars, and deflected striæ.

While some steps of progress seem to be gained toward a knowledge of the manner and time of deposition of the drumlins, the questions as to how the ice-sheet could amass these hills, and why they are distributed in abundance upon some districts, but are absent or represented only by a few examples upon other large areas, remain still unanswered. Their distribution, however, is to so large a degree independent of topographic features, and of the character of underlying rock-formations, that the explanation of their origin and grouping appears more likely to be found in variable conditions of the glacial movements resulting from secular climatic changes during the final melting of the ice.

Mr. Geo. H. Barton then presented a preliminary paper on the "Drift of Certain Portions of Middlesex County."

Annual Meeting, May 1, 1889.

Mr. T. T. Bouvé in the chair.

The following reports were presented :

REPORT ON THE MUSEUM.

BY ALPHEUS HYATT, CURATOR.

The revival of interest in the work of this Society which was noticed last year has continued and the time is perhaps not very distant when we may hope to begin a new era in our history. The progress made towards the establishment of a series of Natural History Gardens has been slow, but not slower than can be shown to have been necessary for the attainment of success. The vote, finally taken, empowering the Council to take measures for the establishment of Zoölogical Gardens and Aquaria reads as follows :

Resolved, That this Society cordially and fully approves the steps taken by its Council in the matter of Natural History Gardens and Aquaria.

Voted, That the Boston Society of Natural History authorizes the Council of the Society on its behalf to proceed with the establishment of such gardens and aquaria, whenever the sum of $200,000 shall have been raised for that express purpose, provided that of that sum $100,000 be forever set apart as a guarantee fund of which the income only shall be available for current expenses, building and other items of maintenance or construction, and that after the fund of $200,000 has been raised and the reserved fund has been invested, the Council shall not incur an indebtedness beyond the sum of eight-tenths of the actual value of the investments of the reserved fund.

This conservative resolution seemed to meet the objections of all members who had been opposed to the scheme, and was satisfactory to those who believed in making the effort provided the existing funds of the Society could be secured in case of failure of the Gardens to meet expenses. It is certainly very creditable, that a conservative body of people having a fixed policy and a successful history could be moved to undertake a new enterprise involving so much labor for the benefit of the public and it is an unusual event in the history of similar institutions. The readiness with which this has been done can be in a measure accounted for by the fact, that the establishment of Natural History Gardens is a natural extension of the work this Society has been doing in two of its departments, the Museum and the Teachers' School of Science. We have been carrying on in a quiet but effective way a museum having in view the education of general students, teachers and the public. That we have not yet completed this department is due, in part, to the want of funds, and in part to the indifference of the community. This indifference arises partly from the fact that we are really in advance of the demands of the times. When the teaching of natural history in the public schools shall have reached an effective stage, the demand for such instruction as this Museum affords will far exceed what it is at present. This department will then command more attention and receive more patronage than it does now. Even now the visits of teachers and scholars to our collections are constant during the warmer months of the year, and this demand could be greatly increased at any time by lectures on the collections, by the publication of proper guides, or by warming the whole building during the winter months. The lectures in the Teachers' School of Science have been credited by the best authority, the late Miss Lucretia Crocker, with having created a favorable feeling towards natural-history teaching in the community and also with having prepared a large number of teachers for the teaching of natural science, thus opening the way and giving a basis for her great work, the introduction of science teaching into the curriculum of the public schools of Boston.

It might have been urged with great force that this Society was already doing enough and that it ought not to take upon itself any new burdens until its museum had been completed. This argument was, however, not discussed or even mentioned and it was decided that the Society held a position of responsibility towards the public, and that it ought not to refuse to do its part in trying to supply a real need, if its trust funds could be secured from peril, and, if the needs to be met were appropriate to its plan and objects. As long as such public spirit prevails in both young and old alike, this Society need never fear that it is becoming too conservative.

The connection, except in a very vague and general way, between the work being done by the Natural History Gardens and the almost exclusively educational work of our Museum and of the Teachers' School of Science, does not at once strike a person, owing to the fact that such gardens are usually looked upon as serving more for the amusement than the instruction of the public.

It is, however, perfectly feasible to establish a series of Natural History Gardens which shall coöperate with the Museum and other public work of the Society, and to form, perhaps, the most effective apparatus for public culture in natural history that has ever been planned before for any city in the world.

The connection between our work in the Museum and the proposed Gardens may be indicated by the following examples:

The introductory collection, now in course of preparation in the vestibule, will show, and in part now shows, the correlative character of all phases in the history and structure of the earth and what we have called its products, meaning thereby every inanimate and animate object. Among these relations there are certain correlations between the structures of organisms and the four different environments in which they live, namely, the salt waters, the fresh waters, the dry lands and the air. These correlations are neither so indefinite that they can be regarded as useless, nor so obvious that they can be neglected with impunity in any general work on animals, and yet a library of text books would hardly furnish any information of consequence upon this subject. The universal similarity, usually alluded to as analogy, between the organs of support or wings of aërial animals, whether mammals, birds, reptiles, fishes or insects, is a case in point. Though often cited in text books, I have failed in finding any adequate treatment of even these obvious facts and usually only very fragmentary mention of other structural correlations common in flying animals.

There is also a distinct tendency to similarity in the conformation of organs of support and motion in aquatic animals which can be illustrated more effectively in some respects with living examples than with lifeless specimens. The Cetacea, Sirenia and seals, whose proximate ancestors must have been terrestrial animals, can be used very effectively for such an exposition. In becoming suited to an aquatic life, they have still retained their air-breathing organs; in the Cetacea a fish-like form and propeller-like tail have been acquired. In the Sirenia similar changes, though in some respects less extensive, have taken place, whereas in the seals the position of the hind limbs and their modifications and effective use in place of a propeller-like tail fin are equally instructive. The last can be used to show how the habit of moving in a dense medium like the water may cause the modification and practically the substitution of a pair of organs like the hind limbs as a compensation for the absence of a propeller-like tail.

The example of the reverse of these adaptations in animals which were primarily water-breathers and subsequently became air-breathers is also easily illustrated. The evolution of lungs in addition to or in place of the gills has been graphically described by Semper and others among Crustacea and is well known to all students of the Dipnoans and Batrachians.

Many general and special correlations of similar kinds showing the similarity of the modifications due to the use of parts in the same environment will recur to every naturalist, and it will also occur to him, if he be of our way of thinking, that such facts, though sufficiently well known, have been quite as generally neglected, especially in the plans of museums and in teaching collections of all kinds, including zoölogical gardens and aquaria.

If our new gardens be wisely planned and intelligently followed out, there is no reason why we should not make expositions of the phenomena and laws of natural science as systematic and as effective as those which are supposed to be possible only when the lifeless and easily arranged materials of a museum are at command. They would necessarily differ very much and they would and should take very different ground, but there ought to be a choice of the materials as exacting and a plan of the principles of arrangement as unbending, as in the public exhibitions of any first-class museum.

We all know the magnificent circle of park ways and parks with which the centre of this city will eventually be surrounded if the existing plans of the Park Commissioners are carried out. The Park Commissioners have opened the way towards the occupation of three different places in this chain and these three places are so located that it is perfectly feasible to illustrate the relations of animals and plants to the four environments mentioned above quite fully and much more completely than would be practicable in any one of these localities if all the exhibits were brought together in any one place.

The marine park according to the special report made to the subcommittee on grounds by Dr. Fewkes will afford an excellent site for a Marine Aquarial Garden and for the exhibition of large marine animals like the whales, and some sharks and also seals in open air tanks which can probably be constructed near the Aquarial building. Professor Putnam examined the region northeast of Jamaica Pond and reported that, after the Park Commissioners should have carried out their proposed plans for the improvement of this part of the parks, it would become a very suitable place for the location of a Fresh-Water Aquarial Garden and for the establishment of a fish-hatching station, and also for an exhibit of other animals which, like the Batrachians, beavers and muskrats, and the like are either wholly or partly aquatic. It is proposed to place our exhibits of terrestrial and aërial animals at Franklin Park the third of the locations, and this will therefore become, if our designs are carried out, the zoölogical garden proper. The sub-committee on organization has had the benefit of a topographical map of the grounds at Franklin Park and this has formed the basis of a Natural History survey systematically made by Mr. Van Vleck for the location of pens, paddocks and other matters connected with the laying out of a zoölogical garden. According to this report the grounds will afford ample room and surpassingly fine accommodations for exhibits of certain kinds of mammals and other animals which could be appropriately kept there. The committee has also invited and received the benefit of a visit from an expert of experience, Mr. Arthur Erwin Brown, whose opinion was considered to be of great value on account of his success in conducting the operations of the Zoölogical Gardens at Philadelphia which are under his charge. Mr. Brown was very much pleased with the general aspect and facilities for the exposition of certain classes of animals at Franklin Park and gave the committee the use of his written opinions which will be published in the next reports or letters of the council. In fact it seems to be the general opinion that the way is clear for the establishment of a series of natural history exhibits which in certain features have never been equalled in any city in the world.

The largeness of the plan is no obstacle to practicability, and it is believed by those most deeply interested and at the same time having more or less knowledge of such matters that a series of establishments will be more easily supported than any single establishment, exception being made in favor of the Marine Aquaria. The founding of the Marine Aquaria would probably be followed by a financial success which would enable us to balance the deficiencies if any occurred in the budget of the Zoölogical Garden and in course of time and together with our invested funds secure this department against any chance of failure until it could be made self-supporting. The reasons commonly given for this opinion are as follows. The Pier at the Marine Park, South Boston, is already the resort of a very large and annually increasing multitude which seek its coolness during the summer months. The report of the special officer at the pier shows that the attendance of the public last year, though the attractions were very much less than they will ultimately be, amounted to between one and three thousand on week days, and on clear Sundays and holidays from ten thousand to fifty thousand. The Marine Aquarial Gardens, with such a stream of humanity flowing past its doors, could hardly fail to pay a large percentage of profit on all outlays, and thus help on the other branches of the Society's exhibits.

These remarks are not in any sense authoritative because no action has yet been taken by the council which commits the Society to this scheme of exhibits, and it is merely intended to give some information of the possibilities now opening before the Society in consequence of its vote for the establishment of Natural History Gardens. It only remains to add, that a definite plan is now being prepared by order of the Council and will be published probably in the form of a letter to the Park Commissioners. The sub-committee having this matter in charge had hoped to accomplish this in time for the present annual meeting, but, although every member of that committee has been doing his duty to the fullest extent this has not proved to be practicable.

Last spring a lady interested in the study of natural history expressed her desire to do something for the purpose of making the meaning of the exhibition collections more apparent to the public, especially to children. This finally resulted in the employment of a young gentleman as guide who served very acceptably but unfortunately for us soon received an appointment as teacher in a college in New York State. We employed a younger though well-educated person and again met with marked success for a time, but by an unfortunate accident the museum suddenly lost the benefit of the second employee's services just as they were beginning to be valuable. A third gentleman has been obtained and is now serving as guide to the museum. At present systematic work in appointing set hours for taking parties of persons around the Museum is not considered advisable but small parties are gathered, and then conducted through the educational collections. The matter has gone far enough to show, that if a regular office were made for this purpose and paid highly enough to secure a scientific man, or some person of sufficient scientific attainments, the results would amply repay the expenditure. Peripatetic lectures of this sort may attain a high value and do a large amount of good in the hands of a proper person.

The Woman's Education Association became desirous of continuing their spring courses of lectures in Natural History and applied to the Curator to give such a course upon insects. This was finally agreed to upon condition that the proceeds including the lecturer's pay should be donated to the introductory collections in the vestibule. The Association was pleased to consider this a worthy object, and the lectures were begun. They have been successful, and the proceeds will effectually help us to make progress where progress threatened to be impracticable on account of want of even the small sums of money needed for expenditure in this direction. Reports on the different departments in which work has been done are as follows.

Geology.

Mr. Crosby has completed the revision and re-arrangement of the lithologic collection in room B. The principal accessions to this collection are a fine series of polished marbles from western New England and New York and a series of polished granites from New England.

The petrologic collection which formerly occupied one of the central or floor cases in this room has been expanded, by the addition of the new material collected during the past six years, and re-arranged so as to fill both the central cases. This is now a very interesting and instructive exhibit.

Mr. Crosby's time has been largely occupied in the preparation of the guide to room B, on the same general plan as that for room A. The main part relating to the lithologic collection will be prepared early in the coming year. The explanatory text for two new numbers of the series of Guides, Dynamical geology and Structural geology, will then be ready for publication.

Botany.

Mr. John Cummings has supported this department during the past year as in many previous years, and the Society is indebted to him for this and important assistance in other departments.

The endogens have been finished by Miss Carter, thus completing the general revision of the entire collection. A more particular and final revision of the herbarium and its catalogue has been commenced with a view of making it as perfect as possible with the means at hand. The duplicates have been systematically arranged and packed away ready for exchanges. The work has been completed through the Polypetalæ. Progress has also been made in the poisoning of the herbarium. A revision of the Lowell collection has been begun and appropriate labels printed and in part placed with the specimens. The following accessions have been made during the year:—

Prof. Johann Müller of Geneva, one hundred and eight specimens of lichens.

Miss Mary Saunders, six specimens for New England collection.

Mrs. Caroline A. Kennard, a fine specimen of *Cordyceps Robertsi* from New Zealand.

Dynamical zoölogy.

The typical forms have been selected and placed on exhibition and considerable work has been done by the Curator and Mr. Henshaw in various ways which cannot be advantageously reported upon at present. Work has been done by the Curator in the preparation of a guide for this collection, and that of the introductory collections in general.

Synoptic collection.

The lower invertebrates of this collection have been revised, mounted and labelled. Miss Martin has made drawings of Volvox, Vorticella, Hydra, Astrangia and Perinopsis.

Mr. C. B. Cory has given us specimens of *Apteryx Oweni* and *Echidna hystrix*, and the Society owes him thanks for the loan of a series of models showing the development of the chick.

Anatomical collection.

Miss Martin has prepared skeletons of two amphibians (Necturus and Amblystoma) and six crustaceans (Homarus, Penæus, Alpheus, Cancer, Gecarcinus and Apus).

Paleontology.

Miss E. D. Boardman has done considerable work on the Curator's collection of Steinheim shells. Additions have been received from D. F. Lincoln, Henry M. Seeley, Warren Upham and A. Hyatt.

Mollusca.

The arrangement of the exhibition collection of lamellibranchs has been completed by Mr. Henshaw. According to Adam's Genera of Mollusca (our authority for the arrangement of the collection), the lamellibranchs are divided into forty-two families and two hundred and twenty genera. Of these we have on exhibition representatives of forty families and one hundred and seventy genera. There are 1,435 species, 4,110 specimens and twenty-seven models and preparations in this part of the collection. The series not on exhibition are arranged in drawers below the cases and are accessible for study. A systematic list has been prepared and the collection of data to be used for a guide has been begun.

Additions have been received from Henry Brooks, C. J. Maynard and E. W. Roper.

Insects.

During the summer large additions were made to the New England collection by Mr. Henshaw. These additions include partial or complete life histories of many species previously unrepresented in the Museum. The general collection of Coleoptera has been put in order, partly identified and labelled. This work can be finished early next year, and a final report upon all the insects will be presented in the next annual report.

The Fitch manuscripts presented to the library by Mr. S. H. Scudder have been assorted and about half of them are arranged.

Additions to this department have been received from J. H. Emerton, C. P. Gillette and H. A. Hagen.

Birds.

Mr. C. B. Cory, who has charge of this department, reports that he has catalogued and corrected the labelling of the mounted collection from the Turdidæ to and through the Mniotiltidæ,— nine families in all as follows: Turdidæ, Sylviidæ, Paridæ, Certhiidæ, Troglodytidæ, Mimidæ, Cinclidæ, Motacillidæ, Mniotiltidæ. The

Lafresnaye types have been catalogued and relabelled with special type labels by Mr. Cory who has also generously defrayed the extra expense of the necessary clerical work.

Mr. Robert Ridgway has returned the collection of skins of neotropical birds, having identified and labelled them.

New England vertebrates.

A list of all vertebrates known to occur in New England with annotations concerning such as are in the collection has been compiled by Mr. Henshaw.

Mr. Cory has given us some birds, and a few mammals have been added by purchase.

Teachers' School of Science.

The liberal action of the Trustee of the Lowell fund in defraying the expenses of the lessons and also in granting the use of Huntington Hall has enabled the Society to continue its efforts to extend the benefit of the instruction in this school to teachers in all the neighboring towns as well as to those living in Boston. The agents who acted in the adjoining towns and villages last year continued their kind offices, distributing and receiving applications and also tickets according to the plan which was described in a former report. The Superintendent of Public Schools in this city has also kindly assisted us by attending to similar technical details in Boston.

Prof. W. O. Crosby has given a course of ten lessons during the past winter upon the geology of Boston and vicinity. The primary object of the lessons was to acquaint the teachers of Boston and vicinity with the natural opportunities for geological study by which they are surrounded and especially to show them how to use these opportunities for their own culture and the benefit of their pupils.

The subject was treated in accordance with the following scheme :—

1. A general study of the physical features of the Boston basin and of the geological changes now in progress in this region.

2. A systematic study of the various minerals and rocks found in the Boston basin together with the more characteristic kinds of structure which they exhibit.

3. A summary of the geological history of the district so far as that is plainly recorded in the rocks.

The course was freely illustrated by maps and diagrams and also to a large extent by specimens which teachers were allowed to retain, and which it is hoped they will use as guides for the collection of others. More than 10,000 specimens in all were distributed. Especial pains were taken at every step of the work to indicate the localities where phenomena such as were described in the lessons might be most advantageously studied. The average of attendance was 300 persons, the smallest number present at any one lecture was 175 and the largest 450.

There has also been a special course upon zoölogy given to a limited class in continuation of the course given last winter by Mr. B. H. Van Vleck. The plan of this course was reported upon last year and it only remains to add that it was carried out in the same spirit and with equal facilities in the way of specimens for study and dissection, and there was an increase in the number of available microscopes. The average attendance at each lesson was 25 persons.

The following statistics refer to these two courses.

Number of tickets distributed.		To teachers.		To others.	
Zoölogy	36	Zoölogy	23	Zoölogy	13
Geology	901	Geology	634	Geology	267
	937		657		280

COURSE IN GEOLOGY.

GRADE OF TEACHERS.

Boston Public Schools. Tickets distributed to		Out-of-town schools. Tickets distributed to	Geology.
		Superintendents	3
Principals	9	Principals	31
Masters and Sub-Masters	43	Masters and Sub-Masters	11
Assistants	326	Assistants	190
	378		235

LIST BY TOWNS.

Abington	3	Belmont	1	Brockton	7
Auburndale	1	Boston	378	Cambridge	86
Bedford	1	Bridgewater	3	Cochituate	1

Everett	10	Melrose	6	Readville	1
Framingham	2	Milton	2	Roslindale	5
Hingham	4	Needham	2	Salem	5
Hyde Park	1	Neponset	1	Somerville	38
Malden	39	Newton	7	Watertown	1
Medford	1	Quincy	5	Wellesley	2

Total	613
Complimentary	137
Miscellaneous	130
Private Schools	21
	901

The above were given under the auspices of the Trustee of the Lowell Institute, but the following were paid for by the pupils themselves :—

A special course in mineralogy beginning in November and continuing through the winter was given by Mr. George H. Barton, instructor in geology at the Massachusetts Institute of Technology. The instruction consisted of twenty-one lessons accompanied by the use of specimens placed in the hands of the members of the class. They became familiar with about one hundred and sixty species and a large number of varieties. The total number of applicants for this course was sixteen and ten was the average of attendance. This work was in part an indoor continuation of the work of the class reported in the Annual Report for May, 1888, as having been begun by a series of geological excursions in April of that year. This was a very successful course, and some of the members requested that it should be continued by laboratory work during the winter months.

Laboratory.

In addition to the class of teachers in zoölogy, mentioned above, the laboratory has been used by a class in zoölogy from the Boston University under the charge of the Curator and Mr. Van Vleck, one in botany and another in zoölogy from the same institution under the sole charge of Mr. Van Vleck. A class in botany raised under the auspices of the Woman's Educational Association, and taught by Dr. R. W. Greenleaf, has also used this room and the microscopes.

Report on the Secretary's Department and the Library.

By J. Walter Fewkes, Secretary.

The Secretary has no important events to record in his department. A knowledge of the routine work derived from services as Assistant Secretary during a part of last year rendered it possible for the present incumbent to take up and continue the work of his predecessor with no marked change. During the summer vacation he visited some of the best known Zoölogical Gardens and Aquaria in France and England and was able to obtain information in regard to the organization of these institutions. Some observations then made were embodied in a paper on European Zoölogical Gardens and Aquaria read before the Society on November last.

Membership.

The membership of the Society has increased by ten members during the past year. Fourteen Associate and eight Corporate Members have been elected. There has been no Corresponding nor Honorary Member added to our roll.

Four Associate and one Corporate Member have resigned. Three Corporate Members have died. The Society has lost by death Dr. Samuel Kneeland a former officer and a frequent contributor to our meetings. Mr. Chas. L. Flint, Mr. T. B. Wales, Mr. Charles Carruth and Mr. Elisha Atkins, Life Members of the Society, have died. The late Mr. Chas. L. Flint has shown his interest in the Society in many ways and was a member of the Council at the time of his death.

Meetings.

Fourteen general meetings of the Society have been held during the past year. Those in October were omitted. The average attendance has been forty; the smallest thirteen, and the largest seventy-six. These figures are somewhat larger than last year and much larger than those for the years 1885–1888. Several of the meetings of the present year came on very cold or stormy evenings.

Thirty-six communications announced by card have been made to the Society. During the last year twenty-eight papers were announced. Five papers have been read by title. Numerous unannounced verbal communications have been made and two obituaries have been read.

Three papers have been illustrated by the stereopticon.

The section of Entomology has held five meetings.

The increase in membership and in the number of communications over last year certainly shows that interest in the Society has not decreased. It is thought that it shows an increased interest, and the fact that several of the papers were by those elected in the last year and by those who have hitherto not presented communications is significant for the future.

Numerous special meetings of the Council have been held to consider the reports of the different subcommittees of the Natural History Garden Committee on Natural History Parks and Aquaria. The nature of the changes proposed by the sub-committee on organization and that on grounds has necessitated frequent council meetings and prolonged discussions. The work of the Council and of the committee although as yet unfinished, is approaching a form in which it can be made public, at some of the early meetings in the autumn.

The various committee meetings and work necessitated by them have taken time which would otherwise naturally be devoted to the routine work of the Secretary.

Publications.

Two parts completing volume twenty-third of the Proceedings have been printed and distributed to our exchanges. The signatures of volume XXIV have been sent out as fast as published. The last signature (No. 10) thus distributed includes the records of the last meetings in March. With the exception of the communication read at the last meeting our Proceedings are in print to date.

There is a constant demand from our correspondents for our earlier publications and many of the older volumes are now becoming rare. At the rate at which they have been asked for during the last year, it is only a question of a short time when many volumes will be wholly out of print. Early in the year the Librarian requested members who had any of the earlier publications to dispose of to communicate with him in the matter.

Library.

Our library is rapidly growing in size and on many of its shelves the books are now two rows deep, so that the library committee will be forced to increase our shelf-room in the immediate future. A temporary means of relief is under consideration, but in no short time this also will be insufficient to meet the growing needs. Our library has to perform many functions some of which might be differentiated with profit. In serving as a committee room and offices it loses much of the quiet which a reading room demands.

The following additions have been made since the last annual meeting.

	8vo.	4to.	Fol.	Total.
Volumes,	236	60	6	302
Parts,	1,315	389	14	1,718
Pamphlets,	201	27	2	230
Maps,			3	3
			Total:	2,253

1,180 books have been taken out by 98 persons, during the past year.

119 books and 52 volumes of the Proceedings have been bound.

The following new exchanges have been added to our list:

K. geologische Landesanstalt und Bergakademie, Berlin; Royal Institution of Cornwall, Truro; Société des Naturalistes de Kiew; Marine Biological Laboratory, Plymouth, England; Australian Museum, Sydney; The Microscope; Elisha Mitchell Scientific Society; Biological Society of Liverpool; John Hopkins University; Sociedad Cientifica Antonio Alzate, Mexico; Société des Sciences et de Géographie, Port-au-Prince; Ungarischer Karpathen-Verein.

The Society has subscribed to the following new periodicals: American Geologist; Garden and Forest.

Walker Prize.

No subject has been announced and consequently no prizes awarded during the past year.

Annual Statement of Receipts and Expenditures, Boston Society of Natural History.

RECEIPTS.

May 1, 1888, to May 1, 1889.

Admission Fees	$50.00	
Annual Assessments	985.00	
Dividends and Income from General Fund	4,450.97	
Income from Walker and Walker Prize Funds	2,430.00	
" " Walker Grand Prize Fund	9.00	
" " Bulfinch St. Estate Fund	1,152.00	
" " Courtis Fund	394.00	
" " S. P. Pratt Fund	541.00	
" " Huntington F. Wolcott Fund	591.75	
" " Entomological Fund	22.50	
Laboratory from Boston University	2,505.00	
Balance	2,829.43	
		$15,980.65

Teachers' School of Science.

Received of Augustus Lowell, Trustee	1,000.00	
		$1,000 00

EXPENDITURES.

May 1, 1888, to May 1, 1889.

Publication and Printing	$987.71	
Museum	484.38	
Library	703 01	
Salaries and Wages	6,873.34	
Repairs of Building	123.20	
Fuel and Gas	271.49	
General Expense	902.27	
Insurance for five years	1,165.00	
Laboratory	2,720.25	
Purchase $17\frac{1}{2}$ Shares of new Stock in Everett Mills to make good loss in that investment.	1,750.00	
		$15,980.65

Teachers' School of Science.

Expended for Lectures, etc.	619.50	
Balance	380.50	
		$1,000.00

CHARLES W. SCUDDER,
Treasurer.

BOSTON, MAY 1, 1889.

[COPY.]

We have examined the accounts of Charles W. Scudder, Treasurer, for the current year and find them correct with proper vouchers. We have also verified the evidences of the property held by the Society and by the Trustees of the Walker Fund.

BOSTON, APRIL 13, 1889.

Signed, SAMUEL WELLS.
JOHN CUMMINGS.

The Society then proceeded to ballot for officers for next year. Mr. Samuel Henshaw was appointed to collect and count the ballots.

The Committee announced that the following officers had received the majority of the votes and they were declared elected :

OFFICERS FOR 1889–1890.

PRESIDENT,

FREDERICK W. PUTNAM.

VICE PRESIDENTS,

JOHN CUMMINGS, GEORGE L. GOODALE.

CURATOR,

ALPHEUS HYATT.

HONORARY SECRETARY,

JAMES C. WHITE.

SECRETARY,

J. WALTER FEWKES.

TREASURER,

CHARLES W. SCUDDER.

LIBRARIAN,

J. WALTER FEWKES.

COUNCILLORS,

Samuel L. Abbot.
George H. Barton.
Henry P. Bowditch.
William Brewster.
Edward Burgess.
James H. Emerton.
Edward G. Gardiner.
Henry W. Haynes.
Samuel Henshaw.
B. Joy Jeffries.
John Amory Jeffries.
Augustus Lowell.
Edward S. Morse.
William H. Niles.
Ellen H. Richards.
William T. Sedgwick.
Nathaniel S. Shaler.
Charles J. Sprague.
Balfour H. Van Vleck.
Samuel Wells.

MEMBERS OF THE COUNCIL, EX-OFFICIO.

Ex-President Thomas T. Bouvé.

Ex-President Samuel H. Scudder.

Ex-Vice-President D. Humphreys Storer.

Mr. J. E. Humphrey and Mr. Walter R. Davis were elected Associate Members.

The following reports were then read:

THE PALEONTOLOGICAL HORIZON OF THE LIMESTONE AT NAHANT, MASS.

BY AUG. F. FOERSTE.

I RECENTLY found fossils in the limestones near East Point, Nahant, in considerable abundance, of the genus *Hyolithes* — the same species as those discovered at Locality I, near Hoppin Hill, North Attleboro, by Prof. N. S. Shaler, nearly six years ago. In the Preliminary Description of Fossils from that region this form was referred to *Hyolithes princeps*, Billings. The Massachusetts specimens have the ventral side almost evenly rounded, but the lateral angles are of unequal curvature so that the bilateral symmetry usually found in this genus is entirely destroyed. The apical angle is very low, usually about 6°. The shells as found are often invaginated one within another, a feature which, although probably accidental, is very likely connected with some structural peculiarity which permitted ready invagination in this species, while apparently in others it is absent or rare. This fossil has been observed in Massachusetts in four widely separated localities. The Nahant specimens are usually smaller than those described from North Attleboro. In the collection presented by Mr. S. W. Ford to Columbia College, N. Y., there is a specimen labelled *Hyolithes Emmonsi*, Ford from Troy, N. Y., which does not accord at all with his description of that form but has the inequilateral outline of the Massachusetts specimens. Its apical angle is about 8.5°, as well as could be determined without actual measurement of the same. C. D. Walcott, in "Second Contribution to the Cambrian Faunas," figures on Plate XIV, two sections, *f* and *g*, under *Hyolithes communis*, Billings, which are to a certain extent inequilateral; it does not accord with my own observations on this genus to find the shells ever as much thickened as represented by these sections, and I venture as a suggestion the possibility of invagination in the specimens figured. The apical angle of *Hyolithes princeps* is so much larger than the Massachusetts specimens, viz.: 16°, that I suggest the separation of the Massachusetts specimens under a new specific name, *Hyolithes inæquilateralis sp. nov.*, and make the larger specimens found at Nahant the type of this species. The limestones of Nahant are repeated in a series of red slates northeast of Mill Cove in North Weymouth, as probably suggested by Prof. James Hall in his Pal. N. Y., Vol. III, and certainly very definitely stated by Prof. W. O. Crosby in his Geology of Eastern Massachusetts. The strike here is N. 57 W. and the dip is 70° south. The strike at the Paradoxides Quarry towards the west across the river is about east and west, and the dip is also south so that the red slates and included limestones of Mill Cove probably dip under those of the Paradoxides Quarry. The Paradoxides of the Braintree Quarry all lie on their backs in the argillite as tilted at the present time. Observations on the larger forms of this genus elsewhere agree pretty well that this is a common method of occurrence of these trilobites. We are therefore of the opinion that the *Paradoxides slates* are not a part of an overturn fold, but indicate by their present position what was the former succession of the beds now forming the quarry. With this as a guide it becomes probable that the red slates and included limestones underlie the Braintree Paradoxides beds stratigraphically. Since, however, the character of the limestones from Mill Cove identifies these red slates with the metamorphosed Nahant beds, and the *Hyolithes* found there is known to be a form belonging to the Olenellus Cambrian, the conclusion is that the red slates of Mill Cove are also of Olenellus Cambrian age, and that the Olenellus Cambrian underlies the Paradoxides Cambrian in Massachusetts. The general strike of the limestones at Nahant is N. 50 E. and the dip is about 45° toward the N. W. The nearest slates probably of Paradoxides Cambrian age are in Malden where they have a northerly dip and a strike varying from N.E. to E. and W. The general indication would be that the Nahant beds pass beneath the Malden slates but the exposures are too distant to make this observation of value. It is not likely the Olenellus Cambrian beds will be found near the coast of Massachusetts except in the regions mentioned, these rocks probably lying beneath the slates exposed in the harbor. That the slates of Boston harbor are of Paradoxides Cambrian age seems probable from the reported finding of *Paradoxides* in the drift of George's Island.

The Mill Cove slates are 12.5 miles distant from Nahant, and 27.5 miles from Locality I, North Attleboro ; the distance from Nahant to Locality I being 38 miles. The red slates of the intermediate region belonging to the Olenellus Cambrian were associated by Professor Crosby and Mr. Barton in their studies on the Geology of the Norfolk County basin with the Carboniferous rocks but are probably also of Olenellus Cambrian age so that the Olenellus Cambrian may be seen to be a series of considerable extent in eastern Massachusetts, where at one time it formed a continuous sheet now broken by intrusive granite and diorite masses of large extent, frequently faulted.

NOTES ON CLINTON GROUP FOSSILS, WITH SPECIAL REFERENCE TO COLLECTIONS FROM INDIANA, TENNESSEE AND GEORGIA.

BY AUG. F. FOERSTE.

INTRODUCTION.

In the summer of 1886 it was my privilege to examine various Clinton Group collections made by Prof. N. S. Shaler, now in the students' collections at Harvard University. A few species were from the Clinton of Anticosti. Two large trays of specimens had been collected in the Upper and Middle ore beds of Double Mountain in Claiborne Co., Tennessee, at the Crockett Furnace, in Lee Co., Virginia, and at other localities, chiefly in the immediate neighborhood of Cumberland Gap. Three large trayfuls came from Collinsville, Ala., where they were collected by the Alleghany Expedition of the Harvard Summer School of Geology.

Since the Georgia locality seems not to have been described, the following section is given in ascending order. Unfortunately, the relative thickness of each series is not preserved in the records: 1, hard, thick-bedded sandstone; 2, thick-bedded, yellow sandstone, a building stone, containing in great numbers the Clinton fossils here described; 3, sandstone; 4, shale; 5, dark, black shale, thin; 6, flinty limestone; 7, carboniferous rock. The section dips from 15° to 45° in a southeast direction. The results of my observations were not published at that time, since they were not of special value in identifying the Clinton fossils from Ohio, then under investigation. Recently, however, they have become of interest from this very fact as will be noted later. While engaged in labelling these same collections in the past year, the specimens have been reëxamined and a number chosen for illustration. In 1886 also, I received for study from Prof. W. S. Hoskinson of Wittenberg College, Springfield, Ohio, a number of corals found at Brown's Quarry, west of New Carlisle, Ohio, of which this paper includes a tardy account. Prof. Edward Orton, State Geologist of Ohio, also sent to me a number of corals from the Clinton group of Ohio, the precise locality of which had been lost, but the lithological character of which places their geological horizon beyond possibility of doubt. A very good series of specimens has been sent to me during the past year by Prof. A. H. Young of Hanover College, Hanover, Indiana. He has very kindly furnished me with a series of notes on the occurrence of these fossils near Hanover, accompanied by photographs of the fossil localities. Since this is the first instance in which the Clinton has been identified in Indiana by a careful study of its fossil remains, the following extracts from Professor Young's notes are added.

"Fossils are found at two localities: one is in front of the college building at Hanover, forming part of a very high bluff, overlooking the Ohio river, and one-fourth to a fifth of a mile distant from the same. The college is about six miles down the river from Madison, Ind. The hill is 315 feet high. In front of the college are several thin layers of white, non-fossiliferous limestone, resembling the typical white limestone of the Niagara found higher up the bluff. The Clinton fossils occur in a layer 10 to 14 inches thick about 275 feet above the river. Below this layer is a cherty stone, with conchoidal fracture, 6 or 8 inches thick, non-fossiliferous.

The same strata were traced along the side of a deep gorge to a waterfall, three-quarters of a mile from the river. At the top of the water-fall are several layers of limestone, passing at a still higher elevation into the Niagara limestones. Below this lies the fossiliferous Clinton rock, 12 to 20 inches thick. Next comes the cherty rock, 2 or 3 feet thick, supposed to contain stromatoporoids here. Below the cherty bed is a series of drab, non-fossiliferous limestones 20 feet thick, believed to belong to the Clinton. Beneath are 8 to 10 inches of a blue shale in which fossils were found by Prof. F. H. Bradley, several years ago, thought to belong to the Medina. From this point down to the river, a distance of 235 feet, the rocks all belong to the Cincinnati group, of the Lower Silurian. The Cincinnati beds are fossiliferous at the very top."

It would be of interest to determine the existence of the Medina in Indiana more definitely, since no very satisfactory paleontological evidence has ever been furnished of its occurrence on the Cincinnati anticlinal axis.

A few specimens were also loaned from the cabinets of Mr. B. B. Thresher and Mr. Ira Crawford of Dayton, Ohio, and a number of specimens were examined in the collection of Dr. S. B. Welch of Wilmington, Ohio. The types of Professor Hall, from the Clinton group now in the collection of the Central Park Museum of New York City, were kindly placed at my disposal for examination by Prof. R. P. Whitfield. Professor Newberry also permitted me to examine the Ohio Clinton specimens now in the cabinet of Columbia College. Finally, my own collections from the Clinton of Ohio, and the result of many years collecting have been freely used for comparison.

In the description of the fossils an attempt has been made to show the amount of variation of the more variable species. It may seem to some that too great a degree of variability has been allowed and that forms here considered varieties ought to have been retained as species. Those who have examined large collections from many localities will recognize that in such cases many intermediate varieties must be left undescribed or can not be referred to any particular species. In each case we have designated to the best of our ability the particular variety described, and advocates of either method will have no trouble in recognizing their forms no matter what their association.

Paleontology.

Calymene Blumenbachii, var. Vogdesi, Foerste.

This form was first described from the Clinton rocks of Centreville and Soldiers' Home, Ohio. It is to be distinguished from *Calymene Blumenbachii* chiefly by the broad anterior border of the head. This has usually a general flattened appearance, being elevated at a moderate angle. This single character is perhaps scarcely sufficient to distinguish a species. *Calymene Niagarensis*, Hall, presents a similar flattened, broad, anterior border in some New York Niagara group specimens at hand which is perhaps of equal morphological value, considering the generally much smaller size of this form.

An imperfect glabella from the Clinton of Hanover, Ind., differs from the Ohio specimens by being less curved antero-posteriorly, and having the frontal lobe less convex so that this lobe appears broader. From the occipital groove to the anterior margin of the head it measures 20.6 mm.; across the frontal lobe 15 mm.; across the posterior lobes 22.3 mm.

Near Wilmington (Todd's Fork?), Ohio specimens having this form of glabella are common.

At Collinsville, Ala., a few small pygidia of some form of Calymene were found which perhaps belonged to this variety.

At Catoosá Station and Dug Gap, Ga., Vogdes found what seems to be the same form, although at first referred to *Calymene Clintoni*.

This same form occurs again at Cumberland Gap, Tenn., in such numbers that the following description is drawn up entirely from them:

Glabella moderately convex, not much elevated above the plane of the fixed cheeks and anterior border of the head. Posterior pair of lobes semi-globular, very distinct; median pair about half the size of the latter, also quite distinct, sometimes also semi-globular, but usually more of an ovoid form with the longer axis almost perpendicular to that of the glabella. Anterior lobe small, weakly separated from the frontal lobe by a groove of variable distinctness. Anterior margin of the glabella of moderate curvature, separated from the anterior upturned border by a deep groove which also defines the anterior margin of the fixed cheeks. Dorsal furrows very well marked and usually fairly deep and quite narrow. The fixed cheeks usually projecting slightly towards the glabella at the middle pair of lobes. The occipital furrow also distinct. There is scarcely any curvature of the head antero-posteriorly.

The measurements of a typical specimen are as follows: Length from occipital margin to anterior margin of glabella 11.3 mm.; to anterior margin of groove 12.7 mm.; to anterior margin of head 15 mm. Width of glabella including posterior lobes 11.7 mm.; at frontal lobe 6.5 mm. Width between palpebral furrow of the fixed cheeks 16.2 mm.

The pygidium is semi-circular anteriorly, almost straight along the posterior margin, there being a moderate curvature forward along the lateral extremities. Lobes, segments and pleuræ are all well defined by grooves, and the furrows along the backs of the pleuræ are all distinct. The following measurements will show the range of variation:

LENGTH IN MM.	BREADTH IN MM.	WIDTH OF MEDIAN LOBE.	NO. OF SEGMENTS ON MESIAL LOBE.	NO. OF PLEURÆ.
17	27.6	10	8–9	5
14.5	24	8.2	8–10	5
11.5	18.7	6.7	9–10	5
10.5	16.7	6.5	7–9	5
9.1	13.4	5	5–8	5
7.5	13	4.3	7–10	5

Calymene Clintoni, Vanuxem, is readily distinguished from the above variety by the decided contraction of the glabella antero-posteriorly, the narrow anterior border of the head, and the comparatively smooth lateral lobes of the pygidium; sometimes faint indications of segments may be noticed upon these. We have seen no authentic specimens from localities outside of New York.

Calymene rostrata, Vogdes.

Calymene rostrata, Vogdes, was briefly described in the Am. Journ. Sci. Arts. 1879, for December. It was found originally in the Clinton Group at Catoosa Station, Georgia. Later it has been found elsewhere in Georgia and also in the arenaceous Clinton beds of New York.

Calymene nasuta, Ulrich, was described in the Cincinnati Journ. Nat. Hist., 1879, for October, which however was not received at the Harvard Libraries until Feb. 19, 1880, about which time it probably was published. This form was found at Osgood, Ripley county, Indiana, in the lower beds of the Niagara group. Not having seen the Indiana specimens we find it impossible to pronounce upon the identity or similarity of these species. The angle at which the head of the Indiana forms is figured does not assist us. It may be remarked, however, that these forms are very closely related, that the New York specimens are often quite large and that the end of the snout is not so pointed as a rule, as the first published figure would indicate.

Illaenus ambiguus, Foerste.

Two glabellæ presenting all the interior and exterior aspects of the Ohio forms have been found at Hanover, Indiana. The one best preserved is 19 mm. long and 22 mm. broad, across the palpebral lobes.

We have seen specimens from the Niagara of New York, usually referred to *Illaenus barriensis* or *Ioxus* which we cannot distinguish from the forms described by us under *Illaenus ambiguus*. This form is so similar to *Illaenus insignis*, Hall, that it may prove to be not a distinct species.

Illaenus Daytonensis, Hall and Whitfield, does not seem to occur in the Clinton outside of Ohio, and probably Indiana, although it occurs at a somewhat higher horizon farther westward. Figs. 9, *c*, *d*, of Pl. A, 66, Pal. N. Y., Vol. II, belong to this second and distinct species.

Illaenus Ioxus, Hall.

(PLATE III, FIG. 20.)

This species is figured from the Clinton of New York under Figs. 9, *a*, *b*, Pl. A. 66, Pal., N. Y., Vol. II; and also from the Niagara of that State.

A very unsatisfactory fragment of a glabella, not presenting the strong dorsal furrows of *Illaenus Daytonensis* nor the narrow curved dorsal furrow terminating in a pit of *Illaenus ambiguus*, but apparently having the long palpebral lobes of *Illaenus Ioxus*, is placed here as a last resort. The figure of this specimen will explain our hesitation. A large pygidium found here shows affinities, rather with *Illaenus Daytonensis*. Outside of New York and this doubtful locality, the species is not known to occur in the Clinton Group, but occurs in Wisconsin.

The specimens from the Niagara of Waldron, Indiana, identified with this species, do not clearly belong here.

Phacops pulchellus, Foerste.

(PLATE IV, FIGS. 20, 21.)

Specimens of the following description were found at Cumberland Gap, Tennessee. Glabella strongly divided from the occipital ring by the occipital furrow, which is deepest laterally, leaving a short, narrow, strongly convex connection between the occipital ring and the glabella. Glabella moderately convex above, strongly convex at its contours. Dorsal grooves narrow but very distinct, of fair depth, straight, forming angles of about fifty degrees with one another. On a glabella 6 mm. long the posterior furrows were .7 mm., the middle 2 mm., and the anterior 3 mm., distant from the posterior margin. All of these furrows are very shallow, and the inner detached extension of the anterior furrows could not be distinguished at all. The fixed cheeks are strongly convex, and sharply defined posteriorly by the extension of the occipital furrow. A specimen retaining the glabella, occipital ring and fixed cheeks is 5.2 mm. in length and 7.3 mm. broad.

The corresponding proportions for a specimen, similar to our largest glabella, would be a length of 7.5 mm, and a breadth of 10.5 mm.

The pygidium found with this head is strongly convex, semi-circular, broader than long, with the median segment very well defined from the lateral lobes.

The following measurements will perhaps sufficiently illustrate the character of this pygidium. The posterior segments and pleuræ become rapidly indistinct; this is especially true of the pleuræ which are rarely well marked beyond the fourth pair.

LENGTH IN MM.	BREADTH IN MM.	WIDTH OF MEDIAN LOBE.	NO. OF SEGMENTS OF LOBE.	PLEURÆ DISTINCT AND INDISTINCT.
5.3	8	2.9	7–8	6–7
6.3	9.8	3.3	8	5–7
5.1	8	2.9	6–7	4–6
4.8	7.3	2 4	6	5–6
5.2	8.2	2.5	7–8	4–7

In all essential characteristics these specimens agree very well with the types already described from the Clinton Group at the Soldiers' Home, near Dayton, Ohio.

Encrinurus punctatus, Wahlenberg.

Encrinurus punctatus was described by Hall from the Clinton Group of Indiana. It is cited by E. Billings from East Point and the Jumpers on Anticosti, but I have not had access to collections containing the same. At Collinsville, Alabama, a few pygidia were found. At Cumberland Gap, Tennessee, the pygidia are very numerous and the glabellæ occur in moderate numbers. Free cheeks are more rare. *Encrinurus Thresheri*, Foerste, is represented by pygidia in the Clinton Group of Dayton, Ohio. Only two or three specimens have been found and these seem to be the same as the specimens here cited as *E. punctatus.*

The following description has been drawn up from the abundant material found at Cumberland Gap, Tennessee.

Glabella anterior to occipital groove obovate, width five-sixths of length, the sides slightly incurved, the anterior end forming a semicircle; the surface covered with medium-sized tubercles; along the sides four much more prominent tubercles occupy the distance from the occipital groove to the anterior margin; between the two anterior lateral tubercles, sometimes a moderate but distinct groove proceeds, following the anterior outline of the glabella; anterior to this groove, there is usually an even row of smaller tubercles, flanked at either end by the anterior one of the lateral larger tubercles already mentioned; including the two lateral tubercles, this row, in a glabella 7 mm. broad, would contain about ten or eleven tubercles. Posteriorly to this groove, the smaller tubercles are of more irregular arrangement, excepting that anterior to the occipital groove two smaller tubercles usually occupy the space between the posterior, larger tubercles thus giving rise to a row of four here. Occipital furrow distinct. Dorsal furrows between the glabella and the fixed cheeks very deep and fairly narrow. Extension of occipital furrow along the posterior margin of the fixed cheeks very distinct near the dorsal furrow, less distinct toward the lateral extremities. Tubercles of the fixed cheek only distinct near the dorsal furrow. Movable cheek with continuation of dorsal furrow, well-marked, being thus divided into two parts; the anterior convex, the posterior slightly convex, both with tubercles. A lateral groove defines a marginal rim along the fixed cheeks, which narrows anteriorly and is supplied with tubercles of variable distinctness. The eyes are raised on long and slender stalks. On a fixed cheek 16 mm. long, the eyestalk was 1.3 mm. in width, and 4 mm. in length. This eye is the distinctive feature of the specimens here described, but is not always so greatly elevated.

The pygidium is slightly broader than long, triangular, strongly convex anteriorly, with eight lateral pleuræ, and twenty or more median segments, the last often very indistinct. The median line along these segments in our specimens (casts?) is either depressed and vacant or occupied by tubercles. These tubercles occur at variable intervals, most commonly at every fourth segment, but with sufficient irregularity to discredit the value of such features for specific distinctions. The pleuræ are sharply defined, narrower than the intervening grooves, and show traces of tubercles arranged in rows longitudinally. One of these begins near the middle of the anterior pleuræ, the other nearer the median lobe of the pygidium, and both rows converge posteriorly; the inner pair of rows usually having reached the dorsal furrows at the fifth pleuræ, beyond which this row does not usually extend.

The following measurements show the variability of this pygidium.

LENGTH IN MM.	BREADTH IN MM.	NO. OF PLEURÆ.	NO. OF SEGMENT AT WHICH FIRST TUBERCLE IS SITUATED.	SECOND TUBERCLE.	THIRD TUBERCLE.	FOURTH TUBERCLE.	FIFTH TUBERCLE.	NO. OF SEGMENTS FIRST NO. DISTINCT. SECOND NO. INDISTINCT.
10	11.7	8	2	6	10	14	—	15–21
8	9	7	—	5	9	13	—	16–18
9.2	11	8	—	5	10	14	—	16–19
8	9.2	8	3	6	10	14	18	18–21
8.5	9.5	8	—	6	10	14	17	17–21
7.3	8.5	8	2	5	9	13	—	15–20
7.3	9	7	2	6	10	—	—	13–19
8	9.5	7	—	6	10	14	—	16–18

Direct comparison with the pygidia from the siliceous bands of the Clinton at Lockport, New York, shows no distinctions, but it will be remembered that the eye-stalks of the Tennessee forms seemed longer. *E. Thresheri*, Foerste, has been separated from this species on insufficient grounds, since the pygidia alone are known. Only seven pleuræ are found on the lateral lobes of the pygidium, but the eighth pleura of the Tennessee forms can often not be distinguished, and the number of pleuræ on the pygidium of the New York specimens is often seven. Considering that only two or three specimens are known from the Clinton of Ohio, this distinction has scarcely local value, and for the same reason the numerical arrangement of the tubercles along the medium lobe of the pygidium means but little since this was well determined only in the type specimen, and experience shows that the numerical arrangement of these tubercles is not inviolable.

The two pygidia from Collinsville, Alabama, show only seven well marked lateral pleuræ. The rows of tubercles on these pleuræ are perhaps a little more distinct than usual but the distinctness of these tubercles we have found to be exceedingly variable.

All of these Clinton forms belong to one species and none of the material at hand permits us to draw any distinctions between our American and the typical European forms. Professor Hall, in the second volume of the Paleontology of Ohio, distinguishes the New York Clinton specimens formerly described under *E. punctatus*, from the European types, and associates it with a larger form from the Guelph of Ohio, from which he establishes a new species, *E. ornatus*. Whether the Ohio specimens of *E. ornatus*, Hall, should also be associated with *E. punctatus* as known to us at least from the numerous Clinton localities, we cannot say, although I have seen *E. ornatus* in various sizes. The spaces between the lateral pleuræ of the pygidia seem to us relatively much larger, and we acknowledge that this, in conjunction, with the larger size of the pygidia and the higher geological position to which they attain, has rather prejudiced us in favor of considering them distinct.

Lichas Boltoni, var. occidentalis, Hall?

A single pleura, which is easily recognized to be that of some species of Lichas, was found at Cumberland Gap, Tennessee. From its size, shape and ornamentation, I should judge it to be identical with or closely allied to *Lichas Boltoni*, Bigsby, var. *occidentalis*, Hall. The shallow groove along the median line of the pleura rapidly disappears where the pleura makes its falchion-like curve. The tubercles are small but very numerous, and closely set.

Cyphaspis Clintoni, sp. nov.

(plate iv, fig. 22.)

There has been found at Anticosti a glabella of irregular oblong ovoid form, widening below, the postero-lateral portions being almost cut off by a deep groove, thus forming ovate lanceolate, convex lobes, which still remain attached to the glabella at their anterior extremity, the defining groove being here suddenly obsolete. Antero-posteriorly the convexity is slight; from side to side, considerable. A sharp and very distinct, but quite narrow, groove divides the glabella from the occipital segment. A deep groove separates the glabella from the anterior raised border of the head. The border is narrow but strongly defined, its margin rounding into the facial sutures, which anteriorly to the palpebral lobes pass close to the glabella, and along the palpebral lobes follow pretty closely the outline of the anterior half of the glabellar lobes. The length of the entire head is 4.8 mm.; of the glabella alone 3.1 mm.; the width of the glabella including its lobes is 3.1 mm. excluding these lobes, 2.5 mm. A faint transverse furrow near the middle of the glabella may represent one of the normal glabellar furrows. At Cumberland Gap, Tennessee, a specimen occurs of the same size and proportions, having the same broad occipital segment and the moderately broad groove defining the anterior border from the glabella. Occurring in sandstone the transverse glabellar furrow just described is not seen, and the sharp furrow defining the postero-lateral lobes of the glabella seems to separate these entirely from the glabella. *Proetus* ———, Foerste, of the Denison Univ. Bull., Vol. II, Pl. VIII, fig. 5, if not identical is at least a closely related type. The sharp groove defining the postero-lateral lobes, suddenly becomes obsolete anteriorly so as to leave the anterior edge of these lobes attached to the glabella; posteriorly they also decrease somewhat in distinctness. The rounding of the anterior edge of the head into the facial sutures is very well shown indeed. The chief difference between this form and those previously described is in the character of the groove between the anterior border of the head and the glabella, which is considerably broader than in the specimens just described. Thus this groove which in the Anticosti and Tennessee specimens is scarcely one-third of a millimeter broad, in the Ohio specimens is about .6mm. wide. Our studies on other genera, however, have led us to believe that the width of the groove defining the anterior border of the head of tribolites is perhaps their most variable feature, depending usually upon a slight difference in the inclination of the anterior border.

Another feature which leads us to believe that these forms are alike is the fact that both the Anticosti and the Ohio specimens have the glabella and head regions ornamented by fine microscopic transverse close striæ, which can be seen only when well preserved and with a good lens. The Ohio specimens are taken as the type of the species.

Cornulites distans, Hall.

(PLATE V, FIG. 7; PLATE VI, FIGS. 11, 19.)

Tentaculites distans, Hall, has later been identified by the same author as a species of *Cornulites*. It is found in the Clinton of New York.

In the Cumberland Gap, Tennessee, collections, this species occurs in moderate numbers, the largest specimen observed attaining a length of 16 mm. and a width of 3 mm. Their form is inverted conical, tapering equally throughout. The cone is externally marked by annulations which are sharply defined on the side towards the apex, but usually less distinctly defined towards the opposite extremity, although specimens occur in which these annulations are fairly distinct also on the oral side, when the subimbricated structure gives way to a rather more annulated type, and they have more the appearance of *Tentaculites*.

With growth the annulations become more distant, so that seven may occur in a length of 5 mm. in specimens 11 mm. long; six towards the mouth of specimens 16 mm. long; and in fragments which represent perhaps an original length of 20 mm. five and one-fifth annulations occur in a length of 5 mm.

At Collinsville, Alabama, the same species occurs. A very typical specimen is 15.5 mm. long, 3 mm. broad at the oral extremity, with four and one-half annulations in a length of 4 mm. The annulations are sharply defined towards the pointed extremity and slope gradually towards the oral extremity, presenting a sort of subimbricate appearance.

Cornulites serpularius, Schlotheim, var. clintoni, Hall.

(PLATE V, FIG. 8; PLATE VII, FIG. 8.)

Cornulites flexuosus, Hall, from the Clinton of New York, is now placed by the same author under *Cornulites Clintoni*, Hall, the other name having been preoccupied by a Lower Silurian species.

Cornulites Clintoni is represented by a single specimen in the Cumberland Gap, Tennessee, collections, a cast of the interior. It is 11.3 mm. long, 4 mm. wide at one end and 6 mm. at the opposite extremity. This fragment consists of five segments, separated from each other by constrictions; the different segments increase moderately in width towards the aboral extremity, then bending sharply down to the next annulation. A cast of the outer surface shows a much more even surface broken by annulation of a less marked character, the depressions separating them being broad and shallow instead of sharp and abrupt as in the cast.

Cornulites Clintoni also occurs in the collections from Collinsville, Alabama.

The exterior of the New York specimens shows usually but a moderate amount of vesicular tissue in the walls of the tube defining the interior annulations. Usually the interior casts if well preserved show one — perhaps more — longitudinal striæ, sunk in a narrow groove. The exterior has the same number of annulations as the interior cast. These exterior annulations are never as sharply defined on the aboral side, as are the interior casts, but still they are usually more distinct on that side.

This species differs from *Cornulites proprius*, Hall, from the Niagara of Indiana, in having far more regular annulations, and the exterior annulations corresponding much more closely with those of the interior casts. There are also less transverse striations, and those that do exist are not so coarse. Longitudinal striations are also less evident. The young of *Cornulites proprius* are also curved.

Both *Cornulites serpularius*, Schlotheim, as identified by Sowerby, and *Cornulites Clintoni* as described by Hall, contain two forms, one in which the annulated casts are straight or nearly so and their rate of increase is quite regular, and another in which these casts are more or less bent and in which the rate of increase is quite irregular. These shells are apt to be more bent towards the smaller extremity. In the New York Clinton the bent forms are quite rare, at least as far as I have learned. In the Clinton of the southern states we have found only straight forms.

It is difficult to identify the young of *Cornulites Clintoni* in New York. While I have not been successful I have at least a few suggestions to make. It is probable that the young of the adult curved forms of *Cornulites serpularius* of Europe are curved. May it not be the case that on account of the comparative scarcity of the adult curved form in New York the small curved young have escaped detection? On the other hand, there seem to be straight young specimens both in this country and in Europe which might prove to be the young of those which are straight when adult. In the collections from New York, *Cornulites distans* is such a small, straight form. In Tennessee and Georgia, forms identified with *Cornulites distans* are found associated with adult, straight types of *Cornulites serpularius* and are very much more common than *Cornulites distans* in New York. *Tentaculites anglicus*, Salter, occurring in the Llandovery rocks and, apparently much like *Cornulites distans* of America and scarcely to be distinguished from the same — if indeed, a *Cornulites* — might be considered the young form of the straight varieties of *Cornulites serpularius* as found in Europe.

What makes these suggestions more probable is the fact that the greatest amount of contortion in the curved form is near the base of the specimens and indicates that curvature is greater in the younger individuals and hence curvature may be looked for in the young of curved specimens. On the other hand small specimens of the straight varieties have been found in which the diameter is quite small, so small as at least to suggest that the young might have been straight, and to make this view a little more probable than the suggestion that they also were curved. If both straight and curved forms be considered comparatively unimportant variations from some curved young form, then we scarcely see in what the distinction between *Cornulites serpularius* as described by English palæontologists and *Cornulites Clintoni* of Hall would consist. If the straight adult forms of both the European and American forms be considered to be derived from comparatively straight young forms, and curved adult forms from curved young individuals, then it would be possible to call all the straight forms, large and small, *Cornulites Clintoni*, Hall, and the curved forms, *Cornulites serpularius.* If however, as seems to me more probable, the curved and straight forms are both specifically related, then the straight forms might still be maintained as a variety *Clintoni*, and *C. distans* probably suppressed. As we, however, can only offer these as suggestions we must leave collectors more fortunately situated to determine the matter definitely.

Cyrtoceras? subcompressum, Hall.

(plate vii, fig. 7.)

The type specimen was found at Brown's Quarry, west of New Carlisle, Ohio. The specimens found are all fragments. The outline drawing of the completed specimen is only conjectural, being taken chiefly from the published figure of *Gyroceras Elrodi*, White, of Indiana, in order to show, where in the complete specimen the two largest fragments probably belonged. The sides of the specimens are moderately convex, rounding regularly into the stronger convex inner portion of the coil, and more suddenly into the decidedly flattened, scarcely convex, outer part of the coil. The septa are moderately concave, forming an arc of about 103° in both the small specimen, the type, where the vertical diameter of the shell is 57 mm., and at the smaller end of the larger specimen, probably the living chamber, where the vertical diameter of the shell was 70 mm. The siphon lies within two-fifths of the vertical diameter of the shell from the dorsal or outer side of the coil. The siphon is strongly nummulated, the annulæ being 12 mm. in diameter where the shell has a vertical diameter of 60 mm. The annulations become regularly contracted towards the septa, the connecting aperture being 4 mm. in diameter. The fold formed by the contraction of the siphon at the septa bends back slightly into the previous annulation in each case, forming what might be described as a short flaring funnel with a wide aperture. The shell preserved on the type specimen is 1 mm. thick, and is marked by slightly concave spaces, readily seen, but not very distinctly differentiated, forming intersecting oblique rows across the shell, decreasing in size towards the inner side of the coil. These have something of the form but not the distinctness of the accompanying figure of the surface of the shell. When the diameter of these irregularly rhomboidal spaces, along the longitudinal axis of this part of the coil, is slightly increased, these spaces then have very much the form of *Glyptodendron* scars, but much smaller. Along the middle of the side of the type specimen where the vertical diameter of the shell is 51 mm., there are five of these diagonal rows of rhomboidal markings in a length of 11 mm., along either diagonal. In the larger specimen these markings are much more imperfectly preserved; where the vertical diameter of the shell is 80 mm., five of these markings occupy a length of 18 mm. along either diagonal. In case of the smaller type specimen, a few transverse striæ are noticed crossing these rhomboids at one place near the umbilical or inner side of the coil. The character of the surface markings will readily distinguish this species from any other known to me.

The living chamber of a large nautiloid shell in which the end of the aperture becomes free, bending back slightly from the coil at its extremity, was found in the same locality. The specimen has a vertical diameter of 95 mm. and is marked by oblique, low, transverse annulations, of which five fall in a length of 50 mm. The shell varies from 1 to 1.5 mm. in thickness, and shows numerous coarse transverse striæ, following the direction of the annulæ. The character of the striæ is so distinct from that of *C. subcompressum* as unhesitatingly to indicate a distinct species (Pl. VII, fig. 16).

Orthoceras (eu-orthoceras?) virgulatum, Hall?

(plate VII, fig. 5.)

A single specimen found at Soldiers' Home, near Dayton, Ohio, is referred to this species. Should it prove to be distinct, the name *tenui-siphonatum* is suggested. It is 26 mm. long, and contains in that length, eleven chambers and twelve septa. The septa are all about 2.5 mm. apart, and are moderately concave, forming an arc of about 84°. The siphon very narrow, being about .8 mm. wide near the upper part of each chamber, tapering gradually towards the lower septum, and rapidly at the upper septum to a diameter of about .5 mm. The siphon also does not seem to be perfectly symmetrical on all sides, but held in one position, it shows a straight or even slightly concave outline within each chamber, while the opposite side is convex in outline. Turned at an angle of 90° the siphon shows bilateral symmetry, the outline line on each side being as described when the size of the siphon was stated. The surface of the Ohio form is not known, and the number of septa and the character of the siphon of the New York form, seem also unknown.

Orthoceras (eu-orthoceras?) rectum, Worthen, var. junior.

(plate VII, figs. 1, 2.)

A small fragment was found at Hanover, Indiana, in which the septa are 7 mm. apart, while the shell has a diameter of 15 mm. The septa are quite strongly concave, forming an arc of about 123°. The siphon is central, but a section of the specimen did not reveal the siphon in any recognizable form between the septa. In a specimen 25 mm. long, the rate of tapering of the specimen was scarcely appreciable.

In a specimen associated with this form, perhaps for no very good reason, the smaller end has a diameter of 17.4 mm., and the larger end 20 mm., the specimen being 50 mm. long. No septa are shown on this specimen. What seems to be the surface of this specimen is smooth.

ORTHOCERAS (EU-ORTHOCERAS?) IGNOTUM, sp. nov.

(PLATE VII, FIG. 4.)

Several specimens of this species have been found at Hanover, Indiana. The type specimen is 34.5 mm. long and contains in that length eleven chambers and twelve septa. The septa are 3.2 mm. apart, where the diameter of the shell is 11.2 mm. The specimen has a diameter of 14 mm. at the larger end. In a specimen 19 mm. long, 12.5 mm. broad at the larger end, and 11 mm. at the smaller extremity, there are six chambers and seven septa. The septa are of medium convexity, forming an arc of about 100°. The siphon is almost central, and has a diameter of about 1.8 mm. where the diameter of the shell is 11.5 mm. The greatest diameter of the siphon seems to be near the upper part of each chamber, each annulated portion tapering rapidly towards the upper septum, and slowly towards the lower septum, the connecting aperture having a diameter of 1.3 mm. The character of the surface could not be satisfactorily determined but seems to have been smooth. This species may belong to the larger subgenus *Geisonoceras.*

If fig. 2 *c*, Pl. 29, Pal. N. Y., Vol. II, does not belong to *O. virgulatum*, then scarcely any Clinton form could more appropriately be identified with that species than the Indiana form.

ORTHOCERAS (EU-ORTHOCERAS?) RHYTHMOIDES, sp. nov.

(PLATE VIII, FIG. 2.)

A single fragment was found at Brown's Quarry, near New Carlisle, Ohio. In a length of 29.2 mm., there are ten chambers and eleven septa. The specimen has a diameter of 28 mm. at the smaller extremity and shows no appreciable increase in size in a distance of 30 mm. What seems to be a portion of the siphon was almost central in position. As nearly as could be determined from the small portion of a septum shown, the convexity of the septa does not exceed 96°. Perhaps this form belongs to the larger subgenus, *Geisonoceras.*

It is readily distinguished from *Orthoceras clavatum*, Hall, from the Clinton Group of New York, by means of its much smaller apical angle, the sides in the Ohio form, in the short distance preserved, being almost parallel.

ORTHOCERAS (EU-ORTHOCERAS ?) HANOVERENSIS, sp. nov.

(PLATE VI, FIG. 6.)

The type specimen was found at Hanover, Indiana. It is 43 mm. long and contains in that length twenty-seven septa, the septa at the smaller end being 1.4 mm. distant from each other, those of the larger end, 2 mm. It has a diameter of 9 mm. at the smaller end, and 15.2 mm. at the larger extremity. A cast of the interior of the shell shows a faintly raised straight line along one side of the cast, scarcely .13 mm. wide ; on account of the curvature of the chambers of the shell along their lower edge this line is often not distinct except along the upper half of the cast of each chamber. The exterior of the shell is not well preserved. It certainly does not seem to have been strongly corrugated in any direction but appears to have been smooth, in the small portion preserved. More specimens are needed to decide this point. The septa are moderately concave, forming an arc of about 75°. The siphon is central and is composed of small oval-oblong annulations, placed between the septa. These annulations have a diameter of about 1.3 mm., near the middle, decreasing in size as they approach the septa, through which they are connected by an aperture scarcely exceeding .75 mm.

On the casts of the interior of the shell from a point 5 mm. on either side from the raised longitudinal line already described, the cast of each chamber is crossed by an oblique groove, which originates at the lower side of the cast of the chamber and passes obliquely upward, reaching the upper side of the chamber after a distance of 10 mm. from the raised longitudinal line. It has been suggested that this groove corresponds to a similar groove on the surface of the shell, but no evidence for this statement is found in the specimen. The grooves just described are measured at a point where the shell is 40 mm. in circumference. Therefore the inference is permissible that the structure just described is duplicated on the other side of the shell and that the groove after crossing the septal line continues for 5 mm. on either side until it reaches the upper septum of the chamber above. In that case it would be possible to conceive of this groove as continuous around the inner cast of the shell, beginning near a septum at the longitudinal raised line of the cast already referred to, and continuing to a point on the opposite side two septa above. A peculiar scalloped appearance on one side of the section of the shell is due to a concave edging to each chamber, at a definite distance from the outer surface. At another place where the shell is worn, this concave edging to the chambers is noticed to consist of a large number of concave depressions around a part at least of the edge of each chamber. This structure was not observed in the section already referred to, but on a worn surface of the shell. It is impossible to determine whether this represents genuine structure of the shell, or an accident of fossilization; perhaps the latter view is the safer for the present. Possibly it belongs to the larger subgenus, *Geisonoceras*.

This species can readily be distinguished from *O. Crawfordi*, by the oblique groove of the cast, and the greater number of septa; the septa being 1.7 mm. apart in *O. Hanoverensis*, where the shell has a diameter of 12 mm., while at the corresponding diameter of *O. Crawfordi*, the septa are 2.5 mm. distant.

Orthoceras (cycloceras) nova-carlislensis, sp. nov.

(Plate V, fig. 25; Plate VIII, fig. 1.)

The type specimen was found at Brown's Quarry, two miles west of New Carlisle, Ohio. It is 68.5 mm. long and contains in a length of 54.6 mm., nine chambers or ten septa. The remainder of the shell, above the chambered portion may have been once septate, or it may have been the base of the living chamber. The smaller end of this specimen has a diameter of about 28 mm., and the larger end, 33 mm. These measurements are not altogether accurate, on account of a slight crushing of the specimen. Another specimen, probably the living chamber, has a length of 102 mm., well preserved. It has a diameter of 36.5 mm. at the smaller end and 46 mm. at the larger end. The exterior of the shell is striated transversely, the striæ being very regular in size and in the frequency of their occurrence, about forty striæ occurring in a length of 20 mm. or four in a length of 2 mm.

In examining the character of the surface ornamentation, it is always necessary to be certain that the surface is really being examined and not the exterior of some inner layer of the shell. Thus in the longitudinally striated *O. Crawfordi* the inner layer is smooth, and in the transversely striated *O. Nova-Carlislensis*, the inner layer is very finely striated, twelve to thirteen striæ occupying a length of 2 mm. The septa are of medium concavity, forming an arc of about 123° in the type specimen, and at the base of the specimen thought to be a living chamber. The siphon of this form is not known with absolute certainty, although it is undoubtedly central or subcentral.

Associated with this specimen are others which seem to belong to the same species. One of these specimens is 70 mm. long, having a diameter of 26.2 mm. at the smaller extremity and of 30 mm. at the larger end. It seems to have been a living chamber. The surface of the inner layer of the shell is finely striated transversely, about sixteen striæ occupying a length of 2 mm. This specimen, however, differs from the typical forms of this species in having more strongly concave septa, these forming an arc of 128°. The stronger concavity is no doubt chiefly due to the smaller diameter of the circle through which it passes, owing to the smaller size of the specimen. Another specimen in the same piece of limestone as the type, having a diameter of 27 mm., with three chambers in a length of 17 mm., also having septa forming an arc of 128,° shows the siphon. As far as may be judged from the specimen, the siphon is cylindrical, scarcely suffering any contraction at the septa, and presents an almost uniform diameter of 2.8 mm. for the three chambers in which it is exposed. Since we do not hesitate to associate these specimens with the type, this siphon is considered characteristic for the species.

This form differs from *Orthoceras rigidum*, Hall, originally described from the Lower Helderberg of New York, but recently also identified by Newell in the Upper Niagara of Indiana, by the smaller apical angle of the Ohio form, and the correspondingly smaller increase of the distance between the septa, with age, as compared with the *O. rigidum*. Although readily distinguished from *O. rigidum*, the Ohio species is probably a closely related form. A knowledge of the siphon of the New York specimens is necessary to determine how close this relationship might be.

Orthoceras (Cycloceras) annulatum, Sowerby.

(plate viii, fig. 5.)

A single specimen from Brown's Quarry, near New Carlisle, O., not very well preserved, is very similar to specimens from the Clinton of New York usually referred to this species. It is quite strongly annulated transversely, there being nine annulations in a length of 43 mm.; the annulations are scarcely .7 mm. high, and are separated by equally curved grooves so as to give the longitudinal outline of the shell an undulate appearance. The specimen shows no signs of tapering in the length preserved, being 26 mm. in diameter. The finer, transverse striæ of this species were not noticed.

Orthoceras (Spyroceras?) Jamesi, Hall and Whitfield.

(plate vii, fig. 3.)

The specimen here described was obtained from the same locality as the type, the iron ore beds of the Clinton group, at Todd's Fork, Clinton County, O. It is 11 mm. long, has a diameter of 13.7 mm. at the smaller end and of 15 mm. at the larger extremity. One septum is noticed at a distance of 3 mm. above the smaller end of the specimen, this end having separated along one of the septa. Another septum is indicated at a distance of 6 mm. above the smaller end. The breaking away of the shell for a short distance along a line 9 mm. above the smaller end suggests that a septum also existed here, so that it is pretty fair to infer that septa in specimens of this size occur at intervals of 3 mm. It is believed that intermediate septa do not occur since the cast of the interior of the shell near the smaller end of the specimen, exposing all the space between the first two septa described, does not give any indication of any intermediate septa. The septa are moderately concave forming an arc of about 86°. The siphon, as well as can be determined, is apparently central or sub-central. Its character could not be ascertained. The surface of the shell is ornamented by transverse striæ, stationed at not very regular distances apart. These striæ also vary somewhat in size, the various sizes irregularly alternating. About eight of these striæ occupy the length of three chambers in our specimen. Corresponding to the stronger of these striæ on the surface of the shell, are similar transverse, but usually broader elevations on the casts of the interior of the shell. The transverse striæ are crossed by longitudinal striæ, much more regularly disposed, usually 1 mm. apart in specimens of the size described. Alternating with the longitudinal striæ are single, much finer striæ. A few indications of finer, transverse striæ were found, but nothing comparable to the numerous, regularly-disposed transverse striæ, figured in the type specimen, was seen.

Orthoceras (Kionoceras) Crawfordi, sp. nov.

(plate v, fig. 26.)

The type specimen was found by Mr. Ira Crawford, at Soldier's Home, Ohio. It is 46 mm. long and contains in that length eighteen septa, the septa at the smaller end being 2.5 mm. distant from each other, those of the larger end 3 mm. It has a diameter of 11.7 mm. at the smaller end and 20 mm. at the larger extremity. A cast of the interior of the shell shows a faintly raised straight line along one side of the cast, scarcely .2 mm. wide, similar to that figured by Hall and Whitfield under *Orthoceras Duseri*. The exterior of the shell is finely striated longitudinally, the striæ being sharp and distinct, nine or ten striæ occupying a width of 2 mm. The exterior of the inner layer of the shell is smooth. The septa are moderately concave, forming an arc of about 76°. The siphon is central and is composed of small, oval annulations placed between the septa. These annulations have a diameter of about 2 mm. near the middle, decreasing in size as they approach the septa, through which they are connected by an aperture scarcely exceeding 1.2 mm.

Orthoceras (Actinoceras) Youngi, sp. nov.

(plate viii, fig. 3.)

A small fragment from Hanover, Ind., presenting, however, all the characters necessary for the identification of a species, is taken as the type. The specimen is 33 mm. long and contains in that length seven chambers and eight septa. The chamber near the larger end is 4.2 mm. deep between the septa and the distance between the septa at the smaller end does not show any appreciable difference. The diameter of the shell at the smaller end is 27 mm., at the top of the fifth chamber of the specimen 32 mm., at the top of the specimen it is calculated to have been 34 mm. The shell has a thickness of about .5 mm. Its exterior surface is smooth, showing neither longitudinal nor transverse striations. The septa are of medium concavity, forming an arc of about 115°. The siphon is central and is composed of strongly marked annulations, these annulations having a transversely, elliptical section, having a diameter of about 7 mm., where the shell is 29 mm. broad, and the septa are 4.2 mm. distant; above and below these annulations contract regularly, connecting through the septa by apertures about 3.2 mm. in diameter.

ORTHOCERAS (ACTINOCERAS) LATA-NUMMULATUS, sp. nov.

(PLATE VIII, FIG. 4.)

The type specimen was found at the Soldiers' Home, near Dayton, O. In a length of 44 mm., it has nine chambers and ten septa. At the smaller end it has a diameter of 44 mm.; at the larger extremity the specimen probably had a width of 53 mm., as far as may be judged from the condition of the fragment at hand. The septa are strongly concave, forming an arc of about 134°. The siphon is central, having broad annulæ between the septa, 11 mm. broad where the diameter of the shell is 47 mm.; the corresponding height of the annulæ being 4.2 mm., the distance between the annulæ .4 mm., the siphon narrowing abruptly between the annulæ to a width of 4.2 mm. The entire margin of the annulæ above the middle is sometimes notched by an annular groove, along which a suture often divides the annulæ into upper and lower halves. The surface of the shell is unknown.

This species may be distinguished from *O. Youngi* by means of the much broader annulations of the siphon, a slightly smaller apical angle and a greater concavity of the septa.

ORTHOCERAS (ACTINOCERAS) TURGIDA-NUMMULATUS, sp. nov.

(PLATE VIII, FIG. 7.)

The type specimen was found at Soldiers' Home, near Dayton, Ohio. The specimen is 38.5 mm. long and contains in that length ten chambers and eleven septa. The diameter of the shell at the smaller end is calculated to be 8.2 mm., as far as may be judged from the remainder of the shell preserved. The diameter of the larger extremity is 23 mm. The septa are moderately concave, forming an arc of 118°. The siphon is central or almost central, forming annulations between the septa having a diameter of 5 mm. where the diameter of the shell is 8.2 mm., and the distance between the septa is 3.4 mm.; where the diameter of the shell is 19 mm., and the distance between the septa is 3.8 mm., the diameter of the annulation of the siphon is 5.6 mm. The siphon decreases so abruptly in size between the annulations that the annulations seem to be separated only by a distance of .2 mm. along plane surfaces at the end of the annulations. The connecting tube of the siphon has a diameter somewhere near 2 mm.

From *O. Youngi* this species is readily distinguished by the much smaller apical angle.

Orthoceras (Actinoceras) Daytonensis, sp. nov.

(plate viii, fig. 6.)

The type specimen was found at the Soldiers' Home, near Dayton, Ohio. It is 24 mm. long and has in that length eight chambers and nine septa. The diameter of the shell at the smaller end is 22.2 mm., at the larger extremity 26 mm. The septa are about 3 mm. distant from each other where the diameter of the shell is 23 mm. The septa are moderately concave, forming an arc of about 108°. The siphon is almost central, the annulations between the septa being 5.5 mm. wide where the diameter of the shell is 23mm. The height of the annula is about 2.5 mm. the siphons continuing for the remaining .5 mm. between the septa, as an abruptly narrowed tube, 1.4 mm. in diameter. The surface of the shell is unknown.

Orthoceras (Discosorus) conoideus, Hall.

Forms essentially like those figured from New York are not uncommon in the Clinton group, at Todd's Fork, near Wilmington, Ohio. All specimens seen are from the cabinet of Dr. L. B. Welch of Wilmington, Ohio.

Orthoceras (peculiar type) inceptum, Foerste.

Since this species was published nothing new has been added to our knowledge of this form. The position of the siphon where it passes through the septa is correctly described, but its character between the septa, I have now reason to believe was incorrectly identified and still remains to be determined. The structure along one side of the casts of the interior of the shell, suggests relationship with *Bathmoceras;* the position of the siphon is however more central than I have seen in that genus and I have not had any opportunity for several years to collect more material.

Conularia Niagarensis, Hall.

(plate v, fig. 16.)

A single specimen was found at Todd's Fork, near Wilmington, Ohio, and a cast presented to me by Dr. G. M. Austin of that city. The specimen is 37 mm. long. It once had probably four sides and each one of these sides had a width of 5.7 mm. at the smaller end of our specimen and of 12.8 mm. at the larger extremity. Towards the base, each of the sides is moderately angulate along the median line, these angles apparently becoming obsolete towards the larger extremity. Along this median line also the transverse striae form an angle of 135°, towards the smaller extremity, this angle diminishing towards the larger end, the striæ becoming almost transverse in a direct line near the top. The furrow separating the sides is strong and deep below, growing less prominent above in our specimen, but whether this is due to distortion or not we do not know.

There are eight and one-half or nine transverse striæ in a length of 2 mm. Crossing these striæ are much finer longitudinal striæ, about fifteen in a width of 2 mm. These may usually be detected by the unassisted eye, but require a low power lens to be readily seen. The longitudinal striæ, being almost perpendicular to the transverse striæ, seem to originate near the median line of each side and to pass diagonally towards the furrows; but towards the top of the specimen where the transverse striæ are less curved near the median line, the longitudinal striæ are more in line with the longitudinal axis of the shell. The longitudinal striæ are prominent between the transverse striæ, but on the transverse striæ they form only slight crenulations, these appearing towards the larger extremity of the shell as a row of minute dots on the transverse striæ.

It has been more than a year since I saw authentic specimens of *Conularia Niagarensis* from the Niagara of New York, but to the best of my recollection the Ohio Clinton forms are not distinct from the smaller specimens of that species.

Bellerophon fiscello striatus, Foerste.

This species was first found at Soldiers' Home near Dayton, Ohio. Two specimens with slightly coarser striæ were found at Brown's Quarry, near New Carlisle, Ohio.

Five specimens were found in our meagre collections from Hanover, Indiana, so that it seems to occur there in greater abundance. The largest specimen is 13 mm. in diameter and 12.2 mm. wide at the mouth.

The cast figured by Hall under *Bucania stigmosa*, figs. 8 *c*, *d*, *e*, Pl. 28, Pal. N. Y. Vol. II, is identical in form and size with our specimens. Figs. 8 *a*, *b*, of the same plate, and forming the type of *B. stigmosa* differ from our specimens in the possession of a low mesial carina, and apparently also in the shape and rate of increase of the shell, but this cannot be definitely determined at present since the type specimen is crushed and no perfect specimens of this form have been seen. The type specimen has a slit band identical in all characteristics with the Ohio specimens except in the fact that it is elevated on a carina. The same number of longitudinal striæ, the same angle with the carina among the lateral striæ, and the same wavy or curly structure among these striæ are found in *B. stigmosa* as in *B. fiscello-striatus*.

As a rule the mere elevation of the slit band into a carina is not sufficient to distinguish a species. The same would also be true in this case but for the fact that in three localities as far distant as Brown's Quarry, Soldiers' Home, in Ohio, and Hanover, Indiana, no carina has been found. Until the carinated New York species is shown to be similar in *form* with the uncarinated type, it seems possible to distinguish these forms as species.

BELLEROPHON (BUCANIA) EXIGUA, Foerste.

(PLATE VI, FIG. 3.)

The Ohio types of this species were only internal casts. The Hanover, Indiana, specimen presents the same features, and in like manner develops no carina except a faint indication of one along the last three-fourths of the last coil. Its greatest diameter is 15 mm., the least diameter of the coil is 12 mm., and the width at its mouth was at least 11 mm., but the aperture has been broken away. The only Bucania known to me from the western Clinton which preserves its exterior markings is a single imperfect specimen from the Todd's Fork section near Wilmington, Ohio. The diameter of this specimen is at least 15 mm., but at a small distance above the aperture it has a diameter of 14 mm. In this specimen the carina however is not so indefinite but is seen to be more angular along the median line. Only transverse striæ are present. These are low and more of the nature of undulations, three in a length of 3 mm. toward the mouth. The striæ bend backwards in passing over the carina, and meet at an angle of perhaps 135°.

Cyrtolites Youngi, sp. nov.

(plate vi, fig. 7.)

The single specimen at hand from Hanover, Indiana, presents marked characteristics distinguishing the same from any species of this series of rocks. It is composed of three to three and a half whorls or coils, the outer continually embracing the inner, leaving the latter however exposed on each side thus giving rise to a shallow umbilicus on either side of the shell. The shell is very much compressed laterally, the sides meeting under very acute angles forming a sharp keel. The surface of the shell is ornamented by fine not very distinct striæ, visible under a lens, which bend backwards towards the keel. The specimen has a longest diameter of 6.8 mm., a shortest diameter, vertical to the last of 5.8 mm., and a width near the aperture of 1 mm.

Pleurotomaria labrosa, var. occidens, Hall.

(plate v, fig. 14.)

Specimens of the following description are common at Collinsville, Alabama. Shell with the spire moderately elevated; composed of three volutions, with occasionally a part of a fourth volution; the last one rapidly expanding, subangular, the angle formed by the slit band which is situated a little above the middle of the volution. The shell above the slit band is somewhat flattened; below this band the shell is rounded, or even ventricose towards the mouth. At the mouth the shell below the slit band descends almost perpendicularly for some distance before it curves inwardly towards and into the umbilicus. The slit band is usually a groove defined above and below by strong revolving striæ and ornamented by transverse striæ which in the groove have a lunar form, the concave side being directed towards the mouth.

In one of our specimens the slit band, for some reason, has been reversed so as to form a raised, flattened ridge, bordered on each side by a moderate groove, instead of a well marked groove bordered by raised striæ. The remainder of the shell, both above and below the slit band, is ornamented by revolving and transverse striæ, the former being usually much stronger.

The largest specimens are 42 mm. in diameter horizontally. A smaller, but quite typical specimen, is 29 mm. in diameter horizontally, the spire is elevated 6 to 7 mm. above the slit band of the last volution, the height of that volution below the slit band being 16.5 mm. There were three and a half volutions.

This form is represented in the Clinton by a single specimen from Cumberland Gap, Tennessee. The same form occurs in the Niagara of Wisconsin, Iowa and Ohio, and differs from the species as represented by the Lower Helderberg forms in the less vertical height of the oral end of the outer volution. The Ohio specimens are still more depressed than the other forms, referred to variety *occidens*.

CYCLONEMA BILIX, Conrad.

(PLATE V, FIG. 15.)

At Brown's Quarry, near New Carlisle, Ohio, specimens are found which cannot be distinguished specifically from *Cyclonema bilix* of Lower Silurian strata. It consists of three and a half volutions, increasing rapidly but regularly in size. The spire is elevated 14.5 mm. above the oral end of the last volution of a specimen whose total height is about 30 mm., and whose greatest diameter transversely is 35 mm. The volutions are convex, the upper part of the volutions however, being obliquely flattened, especially toward the aperture. The surface is marked by numerous revolving striæ, some of these larger and coarse, between which the remainder are intercalated. The latter, although not always so readily seen at first sight, can be easily found on examination. Fine, close, and evenly developed transverse striæ cross the revolving striæ, curving obliquely backwards. In addition to these striæ, the shell is more or less wrinkled in the same oblique direction as the transverse striæ. While the transverse striæ often require a low power lens, the wrinkles are readily seen with the unassisted eye. The peristome shows no evidence of folding.

This species occurs not infrequently in the upper courses of the Clinton Group, at Soldiers' Home and Centreville, Ohio.

HOLOPEA OBSOLETA, Hall, var. ELEVATA, var. nov.

(PLATE VI, FIG. 17.)

A small gasteropod shell is found in considerable numbers at Cumberland, Gap, Tennessee. It is composed of two and a half volutions. The first volution is very small, 1.3 mm. in diameter. The second volution increases in size moderately, attaining a diameter of about 4.8 to 5 mm. The last half volution increases in size very rapidly, so as to give the entire shell a greatest diameter of 9 mm. This last half volution, in addition to being so ventricose, has another distinctive feature in being quite oblique towards the aperture, owing to an oblique flattening along the upper side of the volution. This, in some specimens, is very marked, in others it is not so noticeable. In some of the largest specimens, attaining a diameter of 15 mm., this oblique flattening towards the aperture of the shell is very marked. The spire, as a rule, is low, the older volutions rising but slightly above the level of the newer volutions in some specimens; in others, the spire has quite an elevation considering the few volutions and their rapid increase in size.

The largest elevation of any spire noticed was 2.5 mm. above the oral end of the last volution for a shell with a total height of 8 mm., and a diameter of 8.7 mm. The least elevation of any spire noticed was 1.3 mm. above the oral end of the last volution in a shell 11 mm. high and 11.3 mm. in diameter. In the latter case, a view of the specimen with the aperture turned from the observer, could not be distinguished from Fig. 3 *a*, pl. 28, Pal. N. Y. Vol. II, representing *Holopea obsoleta*, Hall. As a rule, the spire of our specimens is more elevated. *Holopea Guelphensis*, Hall, from the Niagara of Wisconsin seems to us, judging from the figure published, to belong rather under *H. obsoleta* as an extreme form of our variety *elevata*, than under the Canadian species described by Billings. In the Canadian species the increase in size of the volution is much less rapid, the same obliquity of surface is not noticed, and the vertical height of the shell is relatively greater.

The same obliquity of the shell and rapid increase in size of the volutions, readily distinguish this from the small forms of *Platyceras* (*Platyostoma*) *Niagarensis* so characteristic of the Clinton strata of Ohio.

HOLOPELLA? *cf.* LOXONEMA SUBULATA, Conrad.

(PLATE V, FIG. 21.)

At Todd's Fork, near Wilmington, Ohio, was found a single specimen with a long, conical spire, composed of seven or eight volutions, increasing regularly in size; the spire having a total height of 17 mm., the last volution having a diameter of about 7 mm. The volutions are evenly convex, and show no trace of a slit band in our specimen, nor of any surface ornamentations, except a few striæ at the upper part of the last volution near what appears to have been the oral aperture. These striæ are directed obliquely forward and do not reach beyond the middle of the volution, making it impossible to tell even with moderate confidence, to what genus this species belongs. We have referred it to Conrad's species from the Clinton of New York, chiefly on account of agreement in form but not in size, our Ohio specimen being considerably smaller. Judging from the few striæ left on this specimen, it is not a *Murchisonia*. Somewhat similar markings, at least in direction, are indicated in Conrad's published figure.

Euomphalus *cf.* sinuatus, Hall.

(PLATE V, FIGS. 10-12.)

Two fragments of a species of *Euomphalus* were found at Collinsville, Alabama. One appears to have belonged to an evolute shell. The other, which was far more satisfactorily preserved, was undoubtedly involute. Only parts of two coils remain in this fragment; judging from these, the completed shell consisted of perhaps three volutions, the spire was very low and the umbilicus broad and open. The figure representing the completed shell, viewed laterally is entirely conjectural, although having as a basis the elevation of the second volution in one fragment above the third or outer volution. From this fragment, we however know with certainty, that the sinus was situated on the exterior side of the volutions, slightly above the middle. The position of this sinus is indicated on the shell by a narrow and not always very distinct raised line, bordered on the upper side by a very shallow groove and on the lower side by one somewhat more distinct. This lower groove extends in width almost to the middle of the volution.

From the raised line marking the sinus, fine striæ pass obliquely forwards. Those above this line continue to curve forward obliquely until quite close to the inner margin of the volution where the curvature becomes lateral or slightly backwards. Below this line the striæ also pass obliquely forwards for a short distance along the side of the volution, but along the lower side of the volution the course of the striæ is transverse to the volution; here the striæ are also almost straight, scarcely curved, but at the inner margin a slight posterior curvature is noticeable.

The volutions have a transversely elliptical section, the flattening below slightly exceeding the flattening of the upper side of the volution.

I have never seen *Euomphalus sinuatus*, Hall, from the Lower Helderberg of New York, but the striæ as figured would agree precisely with those of our specimens if the upper side of that specimen were called the lower, and the reverse.

The Lower Helderberg form, is however, figured as a sinistral shell, while mine is undoubtedly dextral, but this very fact might account for the reversed character of the striæ. No sinus similar to that in the Alabama specimens seems to have been noticed. My specimens are too fragmentary to warrant a new specific name.

Leptæna transversalis, Dalman.

A, var. elegantula ; *B*, var. Alabamensis ; *C*, var. prolongata.

(*A*, plate vi, fig. 6 ; *B*, plate v, fig. 9 ; *C*, plate v, fig. 13.)

Leptœna sericea, from the Trenton Group of New York, agrees quite well in size and degree of curvature with the more convex European types, with very fine radiating striæ with which are intercalated at intervals of six to eight striæ, single inconspicuous striæ of greater width and elevation. Slightly less curved shells with about ten equally fine striæ, in a width of 1 mm., occur in the same group. With the flattening of the shell, however, as a rule an increase of the size of the striæ seems often to be correlated. Thus at Cincinnati, Ohio ; along the Ohio, opposite Maysville, Kentucky ; near Huntingdon, Pa.,—all of the Hudson River Group, the curvature of the shell is only of a medium degree, the more prominent striæ occur at intervals of four to six of the finer striæ, and eight to eight and one-half striæ occur in a width of 1 mm.

Between Millheim and Centrehall, Pa., and at Pointe Claire, occur specimens with but moderate convexity, usually quite decidedly flattened for this species, with six and one-half to seven striæ in a width of 1 mm., the intercalated coarser striæ recurring at intervals of four to six, oftener four striæ. At Rowland's Mills' Quarries near Saratoga, New York, a quite flat form occurs with about the same number of striæ. In a specimen from Tennessee, also with but moderate convexity, there are six striæ in a width of 1 mm., and the stronger striæ recur at more irregular intervals, of from two to four striæ. Correlated with the increase of the size of the radiating striæ seems to be the development of concentric striæ which are never very evident except along the ridges of the radiating striæ.

All of these forms agree in having no beak rising conspicuously above the general surface of the shell or extending beyond the cardinal margin; indeed, the curvature at the beak is nothing more than a continuation of the curvature of the remainder of the shell. Internally they all agree in having the muscular scars of the dorsal valve strongly defined along the median region of the shell by two raised ridges, slightly diverging anteriorly. Anteriorly the limitation of the muscular scars is less distinct, and laterally it may be quite faint. Even when well defined the lateral limitations of the scars are not linear and sub-parallel but strongly curved. In this they agree well with the typical forms of *Leptæna sericea*, Sowerby.

1. *Leptæna glabra*, Shaler, from Ellis Bay, Anticosti, has an average length of 11 mm. and a corresponding width of 21 mm., or slightly more. The convexity of the ventral valve is almost if not quite equal to that of *Leptæna sericea*, Hall, from the Clinton of New York. The beak extends a little beyond the hinge line and is not broad. The surface of the shell is marked by numerous, very fine, radiating striæ, ten or eleven in a width of 1 mm., interspersed with which at quite narrow intervals are others, singly, and but moderately larger, never prominent as in forms of *Leptæna transversalis*, so that the general surface appears in effect quite smooth as the name implies. It is evidently a form intermediate between *Leptæna sericea* and *L. transversalis*, but until the interior is better known it may perhaps be best correlated with *Leptæna transversalis*, as a variety *glabra*, on account of the more distinct beak and the greater convexity.

2. *Leptæna sericea*, Hall, from the Clinton green shale at Rochester, New York, has a length equal to .6 the width. The anterior margin of the shell is rounded, often almost semi-circular, rounding evenly into the lateral margins and forming a more acute angle with the cardinal margin. The ventral valve is strongly convex, the beak curving slightly beyond the cardinal margin and having but moderate breadth. The dorsal valve is less curved than the ventral, concave, leaving considerable space for the viscera. The surface is marked by fine, radiating striæ, intercalated with which at quite regular intervals are others, much broader and strongly elevated, so that the spaces occupied by the intervening finer striæ often appear slightly concave.

2. This form was described by Hall, in 1843, as *Strophomena elegantula*, although the accompanying figure of that date suggests rather the *Leptæna sericea* of Lower Silurian strata. The figures published in 1851, show affinities with *Leptæna transversalis* as the earlier description suggests.

2. In the collections from the Clinton of Indiana, a similar form is quite common. The largest specimen is 10 mm. long and 17 mm. broad. The interior of the shell is punctate, the punctæ being connected with the exterior striæ, therefore occurring in rows. Occasionally a very irregular and indistinct set of lines pass between these punctæ, but this seems an accidental feature and not at all comparable with the figure published by Hall under *Leptæna transversalis.* The ventral valve is strongly convex, the dorsal moderately concave.

The stronger radiating striæ are very prominent and the intermediate regions are often faintly concave. The beak is slightly broader than in the New York Clinton specimens. These Clinton specimens of New York and Indiana are placed under *Leptæna transversalis*, as variety *elegantula*, adopting Hall's earlier specific name It includes those forms with a moderately distinct beak, a shell of medium convexity and prominent, strongly-elevated intercalated striæ. The interior I have not seen.

Leptæna quinque-costata, McCoy, has most of these features.

2. A small *Leptæna*, of which an average specimen is 11 mm. broad and 6 mm. long, is found at Collinsville, Ala. The dorsal valve is of about the same convexity as the variety *elegantula* from New York, but the cardinal extremities are more prolonged, somewhat after the fashion of the variety *prolongata.* The surface is marked by fine radiating striæ with stronger, more prominent, single striæ interspersed, in one individual leaving the intermediate area slightly concave by way of contrast with their own elevation. This form we consider a depauperate representative of the variety *elegantula* in the same way that the variety *Alabamensis* hereafter to be described is considered a depauperate representative of the more typical forms of *Leptæna transversalis.* It has also features similar to *Leptæna quinque-costata*, McCoy, especially in the strong elevation of the prominent intercalated striæ.

3. *Leptæna transversalis*, Hall, of the Niagara strata of New York, has a more strongly convex ventral valve, the beak being strongly incurved, extending beyond the cardinal margin and ap-

pearing much broader as seen from above. The anterior margin of the shell is semi-circular. The cardinal extremities are but moderately extended.

The length varies from .62 to .79 of the breadth, usually nearer .62. The surface is rarely marked by strong radiating striæ of considerable elevation as in the Clinton group specimens, bnt usually these striæ are of more frequent occurrence on the shell, and the intercalated striæ are still strong enough to be a prominent feature.

3. *Leptœna tenera*, Shaler, from Anticosti, I have not seen, but judging from the description, it represents some form intermediate between the more common New York specimens and variety *elegantula*.

4. Typical forms of *Leptœna transversalis* are found not infrequently in New York. The ventral valve is very convex, the length being about .75 of the breadth. The beak is strongly incurved and broad. The intercalated striæ are more prominent than in the less convex associated forms and are also often less numerous. Forms very similar to the typical *L. transversalis* of Europe are found.

5. *Leptœna arca*, Shaler, from Anticosti, is a small form also belonging to the type of *L. transversalis* rather than *L. sericea*. Average sized specimens are 5.7 mm. long and 8.3 mm. broad, if the postero-lateral angles are moderately developed; and 9.1 mm. broad if these angles are more prominently developed. The shell is quite strongly arched anteriorly, about as much as is usual in ordinary New York specimens of *L. transversalis*. The surface appears quite smooth, excepting in one specimen where ten radiating striæ are readily seen with the unassisted eye. With the lens the customary finer striæ may be distinguished. Internally, a number of longitudinal thickenings may be seen on the dorsal valve. The form next to be described is similar but much more strongly arched.

5. At Collinsville, Ala., in the Clinton group, are found numerous specimens of a very convex form of small size, the largest being 7.6 mm. long and 11 mm. broad. The more frequent forms are 7 mm. long and 8.6 mm. broad. The form is therefore seen to be laterally much contracted. The dorsal valve is of medium concavity with the surface rather flattened near the beak. The cardinal extremities of both valves slightly exceed the general width of the shell. The surface is marked by fine radiating striæ, every

third or fourth of which is more prominent and distinct, but not more strongly elevated than in most forms of *Leptœna sericea*. For this form I suggest the name *Leptœna transversalis*, var. *Alabamensis*.

6. *Leptœna transversalis*, var. *intermedia*, Ringueberg, published as a variety under *L. sericea*, is found in a hard limestone of bluish-green tinge, between the Clinton and Niagara strata proper at Gasport and Lockport, N. Y. The cardinal angles are rather prominently prolonged from the otherwise quite regular but strongly convex body of the shell. The beak is of medium width. The type specimen does not show striæ, but others from the same locality show fine radiating striæ with a few more prominent striæ intercalated. This form is quite small, the specimens seen from Ringueberg's collection have a length of 4.7 mm. and a width of 9.8 mm.

7. *Leptœna prolongata*, Foerste, from the Clinton group of Ohio, is represented perhaps in the Indiana collections by a fragmentary specimen with a width of 24 mm. and a length of, I think, at least 10 mm. The anterior part of the shell is gone. It shows the elongated lateral angles and a trace of a median elevation.

7. In collections made at Wildwood Station in Georgia, this form is very common, far more so than in Ohio, where it was first noted. It is characterized by the great lateral extension of the shell, the width equalling from 2.25 to 2.5 times the length of the shell. The ventral valve is much less convex than in *Leptœna transversalis*, less convex at times indeed than in the variety *elegantula*. But still the valve is quite convex, especially towards the cardinal margin, where the shell is quite strongly curved. The anterior and lateral margins form a continuous regular curve, meeting the cardinal margin at angles of about fifty degrees. In many specimens there is a faintly developed, broad median lobe. This lobe becomes fairly distinct, although always low in some specimens, in others it is entirely absent. The surface is marked by fine radiating striæ, interspersed with which at quite regular intervals are single, broader and more elevated striæ, which have about the same frequency of occurrence as in specimens of *Leptœna transversalis* of the New York Niagara. A feature noted in the Georgia specimens, but apparently not very constant, is the existence of corrugations along the cardinal margin, parallel to each other on each side of the valve, and having about the same direction as the lateral margins where

they meet the cardinal line. These corrugations become longer and more distinct towards the cardinal extremities. These forms are now placed under *Leptæna transversalis* as var. *prolongata*, although more distinct than most of the other varieties of this variable species.

In our conception, therefore, *Leptæna sericea* is a Lower Silurian species of wide distribution in North America, and presenting moderate degrees of variation, distinguished chiefly by the moderate convexity of the ventral valve and the convex lateral outlines of the muscular scars of the dorsal valve. *Leptæna transversalis*, occurring in Upper Silurian rocks of North America, presents a very great range of variation, and is distinguished in part by the greater degree of convexity of the ventral valve but chiefly by the parallel sublinear lateral outlines of the muscular scars of the dorsal valve. The internal characters, however, of so many of our American forms are unknown, that their relationships are confessedly impossible definitely to determine. The variety *prolongata* has its counterpart in the variety *Duvalii*, Davidson, of Great Britain.

STROPHOMENA RHOMBOIDALIS, Wilckens.

This species was described by Hall from the Clinton of New York under *Leptæna depressa*, there considered a distinct species.

Leptæna quadrilatera, Shaler, of Anticosti, is the same form, also of small size. The corrugations of the surface are well marked and the geniculation near the anterior border is sharply defined and abrupt.

Strophomena rhomboidalis is represented in the collection from Cumberland Gap, Tennessee, by one characteristic specimen, 5 mm. long and 8 mm. broad. The surface—not considering the six concentric folds—of the valve is quite flat until the last fold at the anterior geniculation is reached, which fold is so high as to give in general a somewhat concave aspect to that part of the shell which lies posterior to the geniculating border. From the geniculation the shell descends almost perpendicularly for 1.4 mm. to the anterior margin. A number of shells occur which suggest the young of this species. One small specimen is 8.5 mm. long and 10.8 mm. wide, has four radiating striæ to each 2 mm. in width, small faint striæ alternating with these. In some of the larger specimens no surface features at all are preserved. These valves seem to preserve all their youthful characteristics, except size. All the valves found are ventral and convex. The convexity over the greater part of the shell is moderate, and near the lateral margins, and still more towards the anterior margin, it becomes strongly convex, but scarcely geniculate. The length of one of the largest specimens is 14 mm. and the width 20 mm.

At Collinsville, Alabama, this species occurs frequently, is of medium size, strongly corrugated and geniculate and shows fine muscular impressions in the ventral valve. Medium sized specimens are common at Hanover, Indiana, also at various localities in Ohio. Near Dayton, Ohio, a larger, more obese variety (to be described under the following notes on growth variations) occurs.

The following notes are chiefly based on the Indiana collections. Small specimens 9 mm. long and 16 mm. broad, have a moderately convex ventral valve, curving rapidly anteriorly near the margin, forming a descending border 2 mm. long. There are either no concentric wrinkles at all, or they are but faintly developed. Specimens 10 mm. long and 18 mm. broad, having a slightly increased convexity of shell, rounding anteriorly, strongly, but not abruptly into a descending border 3 mm. long. Concentric wrinkles distinct, but very low, appear over the entire valves, except on the geniculate border. Examining this area at a later stage, it will be readily seen that portions of the shell not wrinkled early in life become wrinkled, often quite strongly, as the shell reaches maturity. This wrinkling involves contraction of the shell antero-posteriorly, and this is readily permitted by its extreme thinness. When the shell has attained a length of 12 mm., and a width of 21 mm., a very strong wrinkle is often seen at the beginning of the anterior border, which now may be called the geniculating ridge. The shell is still convex along the main body of the valve, but appears depressed within the borders of the geniculating ridge, on account of the moderate elevation of the latter. Anterior to the geniculating ridge, the border descends abruptly for a length of 3.5 mm. Examining the later stages of the shell, it will be noticed that this geniculating ridge remains, but becomes more prominent, that the anterior border becomes gradually longer, that the shell posterior to the geniculating ridge remains convex but depressed just within the same, and that all this interior area is more or less strongly concentrically wrinkled. It becomes evident in measuring the specimens that the geniculating ridge continually assumes a more advanced position than formerly, and that the old ridges apparently remain behind as so many concentric wrinkles. It is often possible to find on the anterior border, just beneath the geniculating ridge, a low wrinkle which will be the geniculating ridge of the next season. This method of growth often seems to continue through life, but in the Clinton Group of Ohio and in the Niagara of Indiana, specimens are found in which this process of the retraction of the anterior border to the plane of the original shell has ceased and the anterior border continues growth without further wrinkling. A specimen from Huffman's Quarry is 22 mm. long as far as the geniculating ridge, and has an abruptly descending, perfectly unwrinkled border 23 mm. long. The shell is 38 mm. broad.

Strophomena patenta, Hall.

(plate v, fig. 22.)

This species was described by Hall from the Clinton Group of New York, and by Hall and Whitfield from the Clinton at Dayton, Ohio. It is also found at Fair Haven and Fauver's Quarry, Ohio, and at Hanover, Indiana. A fragment from Collinsville, Alabama, offering no distinguishing features is also placed here. The geniculation of the New York forms amounts only to a well developed but not strong double curvature of the shell. In the Alabama specimen this double curvature is even less marked than in the New York specimens. In specimens from Fair Haven and Fauver's Quarry, and in those from the Soldiers' Home Quarries, the curvature is about the same as that of the New York specimens. At Soldier's Home is also found another form in which the double curvature is very pronounced and the reversed curvature anteriorly amounts almost to geniculation.

The variation in the amount of the anterior curvature can be in part accounted for by the fact that the more strongly curved shells are more apt to be the dorsal valves, and those less curved the ventral, but a little study will show that the more strongly curved shells have, as a rule, slightly finer striations, and consist of both ventral and dorsal valves, while the less curved shells have somewhat coarser striæ and agree more readily with the New York specimens, taking an intermediate position as to the coarseness of the striæ.

This shell begins its existence with the ventral valve convex and the dorsal concave. Later the anterior and lateral margins of the ventral valve become concave or turned up, and that of the dorsal valve convex or turned down. Since this is likewise true of *Strophodonta striata* and only the exterior of these specimens is found as a rule, these species would be difficult to distinguish, were it not for the fact that neither the convexity of the ventral valve, nor the point of strongest concavity of the dorsal valve lies ever so near to the cardinal line in *S. patenta* as in *S. striata*. In other words *S. patenta* remained for a longer time a shell of simple curvature.

Several flattened dorsal valves of the *S. patenta* type which have a sickly appearance have been found at Hanover, Indiana. The shell is concave near the cardinal margin, the curvature changing to convexity at about 9 mm. from the cardinal line, convexity and concavity together producing a flattened shell. Anteriorly along the median line, there is a bend in the shell producing there a low, undefined median elevation. The surface is marked by radiating striæ. It is possible that these may be sickly distorted forms of *S. patenta* (Plate IV, fig. 2).

Strophomena Hanoverensis, sp. nov.

(PLATE VI, FIG. 1.)

Among the Clinton Group fossils found at Hanover, Indiana, is a species perhaps most closely related to *S. profunda*, Hall. The dorsal valve is concave, and the ventral valve convex from the very first, and remains so through life, increasing however in degree of curvature with age. It will be seen then that in their young stages *S. rhomboidalis*, *S. patenta* and *S. Hanoverensis*, all agree in having concave dorsal and convex ventral valves of simple character, and that other variations result from subsequent processes of growth. *S. profunda* has a low but readily recognized beak on the ventral valve. The corresponding surface of the ventral valve in *S. Hanoverensis* is flattened or even contains a very slight median depression of very short length. This feature will readily distinguish the Clinton species of Indiana from the species immediately above in the Niagara.

The most elevated or convex portion of the ventral valve varies in position from slightly more than one-half to slightly less than four-fifths the length of the shell from the beak. This simply means that the greatest convexity if not elevation of the shell is about 9 mm. from the cardinal margin and that the anterior parts of the shell thereafter are less strongly convex. Owing to this reason also the general height of the shell is not proportionate to its size. A medium sized specimen 19 mm. long and 25 mm. broad has a convexity of almost 5 mm. The largest specimen seen is 23 mm. long and 37.5 mm. broad and has a convexity of almost 6 mm. The cardinal extremities slightly exceed the width of the shell. Only radiating striæ are present. These are distinct, about four and one-half or five occupying a width of 2 mm.

On a piece of Clinton limestone from Ohio (but from what precise locality is unknown) belonging to the Ohio State University, a specimen is found precisely like the Indiana Clinton forms, excepting perhaps for the fact that the curvature antero-posteriorly is more regular than in most Indiana specimens. It is a ventral valve 19 mm. long, 26 mm. broad along the cardinal line, and 5 mm. deep. The highest point on the valve is slightly posterior to the middle of the same. The very faint mesial depression near the beak is also noticed. The surface striæ are the same. Another valve on the same piece of limestone, is very much flattened, the curvature being very moderate for a distance of 10 mm. from the beak then becoming a little more distinct for the remaining 6 mm. The mesial depression near the beak is also much more pronounced although still very shallow, being 5 mm. long and about 2 mm. broad. The surface striations are the same.

Figure 31, Pl. VIII, Vol. II, Bull. Lab. Denison Univ., represents a specimen similar to the last from the Soldier's Home quarry, in Ohio. It is also a flattened valve, the convexity being very moderate everywhere, but slightly stronger a little anterior to the middle of the shell. In Indiana, specimens intermediate between the very convex and those in which the convexity is very moderate occur, so that it seems impossible to distinguish these shells on the basis of convexity alone. The character of the striæ is the same. We believe they are both ventral valves. The dorsal valves we believe to be concave and one specimen seems very decidedly to corroborate this view.

Two other suppositions are possible: the flattened valves might be dorsal valves, and the so-called dorsal valves might be the casts of ventral valves, and casts of the exterior are very difficult to distinguish from the real surface of the opposite valves when the substance of the shell itself is not preserved in any distinct and recognizable form. This, however, we do not believe to be the case, since intermediate forms are found and a quite satisfactory concave valve is known.

The flattened valve might also be a young dorsal valve of *Streptorhynchus tenuis*, Hall, but the striæ of that species are coarser at the same distance from the beak; and moreover the cardinal line of that species seems to be always less than the general width of the shell, while in the forms here described the cardinal line always exceeds the general width of the shell. Moreover the flattened ventral valves of that species, with the moderately elevated beak are unknown in the Indiana collections so that this lends additional evidence in favor of the views here taken. Persons, not conversant with the manner in which many of our Clinton fossils of the limestones of Ohio and Indiana are preserved, would scarcely understand the difficulties attending such a usually simple problem as this.

Strophomena corrugata, Conrad.

(PLATE VI, FIG. 25.)

Conrad's type seems to have been a broad form similar to the second form of Hall, but to have had the coarser striæ of Hall's first form, as here designated.

Strophomena corrugata, Conrad, as figured by Hall, consists of two forms; one represented by Figs. 2, *a*, *b*, *c*, the other by Figs. 2, *d*, *e*, of Pl. 21, Pal. N. Y. Vol. II.

A single specimen of a ventral valve referred to the first form was found at Cumberland Gap, Tennessee. The valve is 18.7 mm. long and 20 mm. wide. It is moderately convex, rather flattened; the sides are subparallel for about 13 mm. from the beak, the anterior margin is semi-circular, the postero-lateral angles are slightly produced and slight corrugations, poorly defined, are noticed along the hinge line. The surface is ornamented with radiating striæ, about seven in a width of 2 mm. The striæ are distinct and large, with fine and less distinct striæ intercalated in alternate order.

The second form, found in New York, differs from the first chiefly in the relatively shorter length and corresponding increased breadth of the shell. There is also a difference in the character of the striæ, which are usually finer, consisting of two to four fine striæ intercalated between each pair of somewhat coarser striations. This feature is not very conspicuous in the New York specimens observed, but in a form from Cumberland Gap it forms such a prominent feature as to suggest a separation from the species.

Strophomena corrugata var. pluri-striata, var. nov.

(PLATE VI, FIGS. 26, 27.)

Shell broader than long; the cardinal margin equal in width to the shell or slightly produced, forming small acute ears; the sides subparallel posteriorly, anteriorly rounding into the semicircular anterior margin of the shell; occasionally with faint, almost obsolete folds along the cardinal margin, corresponding in direction to the lateral margins of the acute ears when present.

Dorsal valve flat in some specimens forming almost a plane surface. In one specimen, a cast, there are depressions corresponding to two short cardinal teeth forming an angle with one another of about one hundred and twenty degrees, and a third depression between about twice as long as the teeth, corresponding to a mesial ridge.

Ventral valve flattened, moderately convex, greatest convexity near the beak, thence sloping gradually towards the front and sides and more rapidly towards the postero-lateral margin. In casts of this valve two depressions are found forming an angle of about eighty degrees with one another, becoming indistinct a short distance from the margin. These correspond to the cardinal teeth of the ventral valve, outlining the posterior sides of the muscular depressions.

VALVE. D, DORSAL; V, VENTRAL.	LENGTH.	WIDTH.	RATIO OF LENGTH TO WIDTH.	NUMBER OF STRIÆ IN TWO MM.	INTERVALS OF MORE PROMINENT STRIÆ.
v.	14.8	17.6	.841	9	3—4
v.	13.0	15.5	.838	9—10	4
d.	18.7	22.6	.827	8—9	4—6
v.	17.1	21.0	.814	8—9	4—6
v.	20.0	24.9	.803	8—9	3—4
d.	16.2	20.2	.802	9—10	5—8
v.	14.7	18.5	.794	10—11	4—5
d.	19.1	24.3	.786	9	4—6
d.	22.7	29.0	.783	10—11	4—5
d.	16.0	20.5	.780	9—10	5—8
d.	—	18.8	—	10—12	6—11

The surface of both valves is covered with fine radiating striæ, abouteight or nine within a width of two millimeters; at more or less regular intervals, varying usually from four to six or seven, certain of the striæ are slightly broader, and decidedly more elevated and prominent. Concentric striæ, where preserved, are always less prominent than radiating striæ and are closely set; some disposed at irregular intervals, and more prominent, form "striæ of growth."

The more prominent radiating striæ are usually best marked near the anterior border of the shell; when they occur at greater intervals than one in four, one of the intermediate striæ is apt to be more or less conspicuously developed. In the preceding table both the number of the striæ and the intervals at which the more prominent striæ occur are measured along the anterior border. Measurements are in millimetres.

Professor Whitfield called my attention to the fact that in the genus *Strophomena* it is not infrequent that dorsal valves differ more or less from the ventral valves in the character of their ornamenting striæ. In our specimens it seems as if the same feature could be noticed. Thus the ventral valves of the Tennessee variety as a rule show stronger prominent striæ and fewer intercalated finer striæ than the ventral valve, while the dorsal valve never has the stronger striæ very prominent, but these striæ are only a little broader, and the intercalated striæ are almost always abundantly developed. In the table just given this fact does not become prominent since the slight variations in the character of the striæ are not so much regarded, whereas this character becomes prominent chiefly through the median intercalated striation of the ventral valve becoming slightly more prominent than the remaining intercalated striæ.

Specimens occur in the Clinton group at Fauver's Quarry and Soldier's Home, O., which cannot be distinguished from *S. corrugata*, var. *pluri-striata*, except in size. As to their relative length and breadth there is a certain amount of variation. The character of the striæ is much as in certain forms of var. *pluri-striata*. They have the corrugations which are supposed to characterize that species, but in reality belong to almost any thin-shelled form. We consider them as the young of *Strophomena patenta*, since they do not retain this character beyond a certain size but merge imperceptibly into the forms with double curvature placed under *S. patenta*.

On Pl. VIII, Vol. II, Bull. Denison Univ., Fig. 35 represents such a young ventral valve, Fig. 37 a dorsal valve, and Fig. 36 one of the intermediate stages of the ventral valve. If those forms attained to a large size without becoming doubly curved, we are sure we should not know how to distinguish them from var. *pluri-striata.*

Strophomena obscura, Hall (?).

(PLATE VI, FIGS. 15, 16.)

Specimens of this species are common at Cumberland Gap, Tenn. Shell broader than long, the cardinal margin exceeding the width of the shell; the sides forming angles of about eighty degrees with the cardinal margin, near this margin perhaps a little produced, towards the anterior margin rounding into the semicircular curve of the same.

Dorsal valve moderately convex, greatest convexity near the beak, thence sloping gradually towards the anterior margin and the sides, forming a more or less flattened surface between the beak and the anterior margin which is usually most marked in the anterior half of the shell. The cast of the valve shows only two short depressions at the cardinal margin forming angles of about eighty or ninety degrees with one another and in the specimens at hand not sufficient to determine their dorsal character.

Ventral valve moderately, but quite evenly convex, the highest part of the valve lying between the posterior third of the shell and the middle, thence sloping quite regularly to all parts of the valve, except perhaps near the postero-lateral portion of the shell which is slightly flattened or evenly very moderately concave; two short impressions at the cardinal margin, forming angles of about one hundred degrees with one another and a faint mesial depression fails to distinguish this definitely as the ventral valve.

The surface of both valves are covered with radiating striæ, which are quite sharp and prominent in the casts of the valves; of these there are usually five in a width of two millimetres; between these there are more or less regularly appearing smaller striæ, also much less prominent, so that the number of striæ is thus usually increased to seven in two millimetres. When these smaller striæ occur with any regularity the small and large striæ alternate, but between two larger striæ, the smaller often fails to appear.

In the following table the last column gives the number of only the larger striæ in a width of two millimetres; the second last column includes all.

Valve. V, ventral; D, dorsal.	Length.	Width.	Ratio of length to width.	Number of striæ in two mm.	Number of prominent striæ in two mm.
v.	15.3	21.7	.711	8	5
d.	18.0	25.6	.703	5.5—6.5	5
v.	12.0	17.4	.689	6—7	6
v.	15.3	22.3	.686	5.5—7	5
v.	16 6	24.6	.675	5.5—6.5	5
v.	9.2	13.7	.671	6.5—7	5.5
v.	14.6	21.5	.669	6.5—7	5
d.	16.0	23.7	.649	5.5	5

We have not seen any of the typical forms from the Clinton of New York, but judging from the published figures it is possible that the Clinton forms from Tennessee may prove to be the same.

Orthis elegantula, Dalman.

Of twenty-six specimens found in the collection from Hanover, Ind., thirteen ventral and seven dorsal valves do not exceed 6 mm. in length. They correspond to the Ohio forms described under *Orthis elegantula*, var. *parva*. Three specimens are 7.5 mm. long, two ventral valves are 9 mm. long and one dorsal valve reaches 9.6 mm. in length. The larger individuals of this species seem comparatively rare both in the Ohio and in the Indiana Clinton limestones.

In the collection from Cumberland Gap, Tenn., specimens of the following description are found. Dorsal valve convex or moderately convex, not flat or concave in the specimens found. Two deep, strongly marked pits in these casts, making angles of eighty degrees with one another locate the short brachial processes. A much more shallow impression between these, nearer the cardinal margin, locates the cardinal process.

From this a median groove extends forward, at first well-marked, but vanishing at or beyond the middle of the shell; this places the median ridge in the interior of the dorsal valve and separates the muscular scars. Radiating striæ are fine and closely set.

Ventral valve strongly convex, especially near the beak and as far as the middle of the valve. Both exterior and interior casts were found. Hinge teeth, shown by the impressions in the cast to have been sharp and strong, are near the cardinal margin; thence they extend as much less elevated ridges forwards, continually curving towards each other so as almost to meet at the median line in one of the specimens. The enclosed space is ovate-circular and contained at one time the muscular impressions.

The muscular impressions of neither valve are distinctly preserved.

The cardinal angles are more or less rounded. The radiating striæ are fine and close, varying from seven to eleven in a width of 2 mm.

The average specimen is 10 mm. long and 10 mm. wide for ventral valves, although one specimen with dimensions of 11 mm. has been found. The dorsal valve is usually a tenth or a ninth shorter in length as compared with the width.

At Collinsville, Ala., similar specimens with more or less convex dorsal valves are found. Seven and three-tenths radiating striæ are found in a width of 2 mm. The largest specimen is 11.4 mm. long and 13.2 mm. wide.

In the Niagara at Waldron, Ind., this species has also a more or less convex dorsal valve, with a pretty well marked median depression. The radiating striæ are somewhat stronger than in the forms just described.

Specimens from the Niagara of New York show the characteristic mesial depression of the dorsal valve. In many specimens the anterior part of this valve is concave. The dorsal valve has not been observed to be ever as convex as in the forms just described. The striæ are fine.

All of the American specimens which have come under our observation differ from the typical European forms in having much finer radiating striæ. Indeed, for this class of Orthidæ, the striæ of the typical European forms might be called coarse.

ORTHIS CALLIGRAMMA, Dalman.

(PLATE VI, FIGS. 4, 5.)

Orthis calligramma, Dalman, is characterized by the anterior outline of the muscular scars in the ventral valve being approximate and rounded, or at least not spreading; the ventral valve is convex, the muscular scars of the dorsal valve form a semicircular outline of which the concave side lies towards the beak.

Orthis flabellulum, Sowerby, has muscular scars in the ventral valve with their anterior outline spreading, forming a concave curve, the entire form being subquadrangular, instead of circular or subtriangular as in the last, the ventral valve is frequently flattened anteriorly, the anterior margin of the muscular scars of the dorsal valve being more distinctly defined and approaching closer to the beak. The postero-lateral angles of the shell are as a rule more rounded.

Orthis flabellulum, Pal. New York, Vol. II, Pl. 52, Fig. 6, combines features of both of these forms. The ventral valve is decidedly flattened, especially anteriorly, but still slightly convex, and never concave anteriorly as in *Orthis flabellulum*, Sowerby. The muscular scars of the dorsal valve anteriorly are quite prominent, but do not approach one another closely; they take a position intermediate between those of the two species above cited. The muscular scars of the ventral valve correspond exactly with those of *Orthis calligramma*. In the angularity of the postero-lateral margins the New York specimens exceed the typical forms of *Orthis calligramma*, but may be compared with the otherwise very different variety *proava*, Salter. It undoubtedly belongs to *Orthis calligramma*, Dalman.

Specimens illustrated by fig. 7 of the same plate, cannot be distinguished from those of fig. 6, as a rule, except by the slightly greater convexity of the ventral valve, if our determinations are correct.

Orthis fasciata, Hall, illustrated by fig. 8 on the same plate, I know only from a single cast of the dorsal valve. In it the cardinal line is but slightly extended beyond the general width of the shell and does not form acute wings. The muscular impressions suggest *Orthis calligramma* as just identified, but the elevation separating the same is more prominent and extends farther towards the anterior margin. The valve is somewhat flattened anteriorly. As regards the fasciation of the radiating striæ, they present no features not found in finely striated forms of *Orthis calligramma* from Alabama, later to be described, and the produced cardinal line is also occasionally found in these. While I am therefore not at all prepared to place *Orthis fasciata* under *Orthis calligramma*, I suggest that their relationship needs further investigation.

Two forms of *Orthis calligramma* are found at Colinsville, Alabama. The first is more typical of the species than are the New York representatives. Specimens are often 25 mm. long and 30 mm. broad. The ventral valve is decidedly convex, not flattened anteriorly, and the muscular scars are like those of variety *virgata*, Salter, excepting that the low mesial elevation, separating the same, is not produced anteriorly. The dorsal valve is convex, the convexity not equalling that of the ventral valve. The muscular scars are not strongly defined anteriorly, but are separated by a low mesial elevation, and posteriorly form a concave curve. The radiating striæ are coarse and distant, in the internal cast, more frequent and less distant on the exterior frequently.

The second form found at Collinsville, Alabama, has a moderately convex ventral valve, more or less flattened anteriorly. The muscular impressions are the same as those of the first form, or are somewhat more triangular or rather rhomboidal. The dorsal valve is moderately convex. The muscular scars anteriorly are well defined, and separated by a mesial elevation, which is also quite prominent anteriorly. The muscular scars approach nearer to the beak than in the first form. The cardinal line not infrequently exceeds the width of the shell slightly. The plications are usually much more numerous in this form than in the first, and there is less disparity between the number of striæ suggested by internal and exterior casts. The increase in striæ is mainly effected by rapid intercalation towards the anterior margins.

In the possession of flattened ventral valves and angular postero-lateral margins, the second form approaches the New York specimens, but differs from the same in the more numerous striæ and the occasional extended hinge line, thus apparently forming a passage to *Orthis fasciata*, Hall. In the character of the muscular scars of the dorsal valve the form approaches *Orthis flabellulum*, and the flattening of the ventral valve tends the same way. The character of the muscular scars of the ventral valve is totally unlike that of *Orthis flabellulum*, but entirely like well known forms of *Orthis calligramma*, to which it is referred. As will be seen by the foregoing, the different characters are combined in different ways so that the only means of distinguishing *Orthis flabellulum* from *Orthis calligramma* are the character of the muscular scars in the ventral valve which are rather sub-quadrangular, and the concavity of the anterior portion of the ventral valve.

At Hanover, Indiana, specimens are found of two forms. In the first form the striæ are coarse and distant. The dorsal valve is moderate convex, and the ventral is depressed anteriorly or even a very broad and very shallow sinus is formed. In the second form the striæ are not so coarse and are less distant. The dorsal valve is more convex, and the ventral valve is moderately convex or flattened anteriorly. Specimens of the first form are about 25 mm. wide and 20 mm. long. Those of the second form are somewhat smaller. The muscular scars of the ventral valves of both forms are of the *Orthis calligramma* type, but the anterior margin of these scars is often more prominent and sharply defined than in specimens heretofore seen. The muscular impressions of the dorsal valve resemble those of the New York forms.

The first form of the Collinsville, Alabama, specimens, is also found at the Soldiers' Home Quarries near Dayton, Ohio, where specimens 43 mm. in breadth are seen. The dorsal valve is but very moderately convex and has a mesial depression or shallow sinus as in the Indiana specimens, but the ventral valve is always strongly convex, especially toward the beak, which is curved. This is also placed under *Orthis calligramma*. The species is therefore seen to be very variable. We find the flattening of the ventral valve a very common variation and where several varieties occur these forms are apt to be easily connected by intermediate stages with those with strongly convex valves. There is a similar variation of the convexity in the dorsal valve which is apt to be connected with the development of a shallow mesial sinus. The angularity of the postero-lateral margins is also very variable. The muscular scars of the ventral valve and the fact that ventral valves are never concave are the only constant features. For those with flattened ventral valves,—including *Orthis flabellulum*, Hall, Pal. N. Y., Vol. II, Pl. 52, fig. 6, of New York, the second form described from Collinsville, Alabama, the first form (PLATE IV, FIGS. 4, 5), and perhaps, also, the second form described from Hanover, Indiana—we suggest the name *Orthis calligramma* var. *flabellites*. This may be the species indicated by *Orthis flabellites*, Hall, 20th Regents Rep. N. Y. State Cabinet, but we do not know. Intermediate forms connecting the variety with the species are not infrequent, as already suggested.

According to our conception of the species, *Orthis calligramma* is a frequent species in the Upper Silurian rocks of North America, while *Orthis flabellulum* is unknown from the same horizons.

We are not, however, equally certain that *Orthis flabellulum* is unknown from the Lower Silurian strata of this continent. *Orthis pectinella*, Conrad, of New York, has muscular scars in the ventral valve, very well agreeing with similar scars described from typical European specimens. The surface of the ventral valve is also more or less flattened, but this flattening generally takes the form of a very broad and very shallow mesial depression, noticeable usually only along the anterior half of the shell and is not connected in any specimens examined with a concavity of the same region of the shell as in *Orthis flabellulum*, Sowerby.

ORTHIS BIFORATA, Schlotheim.

This species is of such great geographical and stratigraphical distribution that it is scarcely worth while to mention localities. It is abundant in the Clinton of New York. A single specimen is found in the Cumberland Gap, Tennessee, collections. Its cardinal angles were rounded ; seven radiating plications occupied each lateral lobe, two plications being on the strongly elevated mesial lobe, a faint third ridge lying in the space between. Presumably only one plication would be found in the sinus of this particular specimen, but this was not exposed. The specimen is 9 mm. long and 12.6 mm. wide.

At Collinsville, Alabama, eight specimens were found, in all of which the hinge-line is narrower than the general width of the shell. The largest specimen here found is 18 mm. wide. Three dorsal valves have three plications on the mesial fold, four ventral valves had two, and one ventral valve, four plications in the sinus.

In Ohio two forms occur, one, *f. Daytonensis* is the local representative of the Tennessee and Alabama specimens ; another *f. reversata* is the local designation for a larger form, more like the larger Clinton forms from New York. In both of these forms the odd number of plications on the mesial fold and the even number of folds or plications in the sinus is the striking feature.

At Hanover, Indiana, specimens of the same size as *f. Daytonensis* occur. The hinge line, however, usually exceeds the general width of the shell. Ten dorsal valves have three plications on the mesial fold ; eight ventral valves have two plications in the sinus, and one ventral valve has three plications.

Platystrophia regularis, Shaler, is a form of *Orthis biforata*. Here again the mesial fold is occupied by three plications, and the sinus by two.

It will be seen, therefore, that in the Clinton specimens which have actually come under my observation, an odd number of plica-ions usually occupies the mesial fold, and an even number the sinus.

Now this is all reversed in the Lower Silurian forms at hand. Taking all the different varieties of *Orthis biforata* now in the students' collections at Harvard University I found that 128 specimens had an even number of plications on the mesial fold, and an odd number in the sinus, while only five showed the reverse arrangement. While it is almost absolutely certain that these distinctions between Lower and Upper Silurian forms of this species will not prove constant even in American forms, still the fact, that they have borne all the tests I have been able to apply to them with a moderate degree of success, is worthy of mention.

Spirifera radiata, Sowerby.

(PLATE V, FIG. 6.)

Spirifera radiata is figured by Hall from the Clinton Group of New York. It is of about the same size as the typical European forms; the striæ are usually a little finer.

Spirifera tenuistriata, Shaler, from Anticosti is a somewhat smaller form with very much finer striæ, eight and one-half in a width of 2 mm. This smaller form occurs also at Cumberland Gap, Tennessee, but the striæ are here coarser, from six to seven, occupying a width of 2 mm. thus approaching a little towards the coarser striated Clinton forms of New York. In fact it seems impossible to establish a species on the basis of finer striæ although it might prove a convenient varietal designation. The Tennessee specimen is 11 mm. long, 15.5 mm. broad; the greatest width of mesial lobe is 4.5 mm. The mesial lobe is defined from the lateral lobes of the shell chiefly by shallow but distinct grooves. The mesial lobe itself is low and gently rounded. *Spirifera radiata* is perhaps more correctly placed as a variety under *Spirifera plicatella*, Linnæus.

Spirifera (Cyrtia) rostellum, Hall.

(PLATE V, FIG. 5.)

This species was first described from the Niagara of Louisville, Kentucky. Specimens which cannot be distinguished from it specifically occur at Collinsville, Alabama. Interior and exterior casts of the ventral valve have been found. The mesial sinus is moderate; bordered on each side by strong radiating plications, rounded on top. In addition to these two plications two more occur, one on each side of the shell, not originating at the apex of the beak, but at some distance below the same; these plications are well defined on the side towards the sinus, but not very distinctly on the opposite side. Faint indications of a third plication exist, and sometimes an obsolete fourth one at the postero-lateral margin. The surface of the valve is marked by numerous, fine, radiating striæ.

The length of the largest ventral valve is 16.5 mm.; the width 15.5 mm.; the width of the sinus at the anterior margin of the shell, 5 mm.; the elevation of the beak above the postero-lateral angles about 4.5 mm.

Atrypa reticularis, Linnæus.

Atrypa reticularis is described by Hall from the Clinton Group of New York. *Atrypa impressa*, Shaler, from Anticosti, is a form of the same size as the figured New York specimens or even twice their diameter. It belongs to the medium striated forms, about two and one-half striæ occupying a width of 2 mm.

At Cumberland Gap, Tennessee, this species is found, with an average length of 13.3 mm. and a breadth of 15 mm. The ventral valve is of medium convexity, with twenty-four to thirty-six radiating striæ, crossed by concentric striæ, forming slight thickenings of the plications as they pass over them, giving rise to the concentric rows of low elevations so characteristic of this species. The dorsal valves are not represented in our collections.

Atrypa marginalis, Dalman.

(plate vi, figs. 8, 9.)

Atrypa marginalis, Dalman, was described from Sweden, but is also plentiful in Great Britain.

At Brown's Quarry, near New Carlisle, Ohio, substantially the same species is found, having the following characteristics. Shell of about the same length and breadth or the breadth slightly exceeding the length. From the beak to the postero-lateral angles, the posterior margin of the ventral valve is slightly incurved, the beak of the dorsal valve extending a moderate distance beyond a line connecting the postero-lateral angles, and the beak of the ventral valve extending beyond the latter, and moderately curving over, but not covering the same. Dorsal valve convex, with a medium fold clearly defined up to the very beak by a groove on either side, the grooves becoming strongly marked anteriorly.

Ventral valve convex, with a well marked median sinus, well defined on either side by one or two stronger striæ, further defined by the fact that from these striæ the lateral lobes slope abruptly to the lateral margins thus increasing the prominence of these limiting striæ, as well as of the beak, of which they form the most prominent part. The surface of both valves is marked by radiating striæ and also by concentric striæ often almost obsolete. About six or seven radiating striæ are found in a width of 4 mm., usually six and three-tenths striæ. The sides of the sinus make with each other angles of about 27.° The largest specimen is 11.8 mm. long and 12.2 mm. broad. The specimens differ from the typical forms in their smaller size and the fact that fine radiating striæ are absent, only one or two coarse striæ of growth being occasionally present.

A broader form of this type was correctly identified by F. Roemer from the Silurian strata of western Tennessee.

Atrypa nodostriata, Bull. Denison Univ., Vol. I, Pl. XIII, fig. 9, from Soldiers' Home, near Dayton, Ohio, is a ventral valve of this species.

A single specimen 8.5 mm. long and 7.5 mm. wide, was found at Collinsville, Alabama; apparently the specimen is slightly contracted laterally. It resembles the smaller forms of *Atrypa marginalis* from Brown's Quarry, but is narrower as already stated. The mesial fold and sinus are defined in the same way but are both narrower, about two radiating striæ occupying the fold and a faint indication of one the sinus. Concentric striæ exist and are rather far apart.

The specimen of *Rhynchonella plicatula*, Hall, figured in Pal. New York, Vol. 2, Pl. 23, fig. 9, *g*, suggests in the possession of postero-lateral angles some form of *Atrypa marginalis*, but the type specimen has not been seen. The species itself is undoubtedly a *Rhynchonella*.

Atrypa marginalis, var. *imbricata*, Sowerby, was described from Great Britain. It is readily distinguished from the species by the more rounded postero-lateral angles, the strongly incurved beak of the ventral valve, the strong concentric striæ, and the slightly stronger radiating striæ.

Atrypa nodostriata, Pal. Ohio, Vol. II, Pl. VII, figs. 12–14, is a cast from Yellow Springs, Ohio. It is rather gratuitous labor to refer it to any distinct type, but its more rounded postero-lateral angles, the somewhat coarser radiating striæ, and the fact that the muscular impressions of the ventral valve are not so elevated but that the beak may have been incurved over the dorsal valve, make it possible that the shell may have belonged to a variety of *A. marginalis*. It is evident that casts of the exterior are necessary to determine the relationship of this form.

Atrypa marginalis, var. *multi-striata* var. nov. Under this name is placed a single specimen from Hanover, Indiana (Plate IV, fig. 8). It is 9.1 mm. long and 9.8 mm. broad. It differs from the species already described in the larger angle, about 40°, formed by the sides of the sinus, and in the much finer radiating striæ, of which eight and one half to ten fall in a width of 4 mm. The postero-lateral angles are also somewhat more angular than in most specimens of the species, and the concentric striæ corresponding to the finer radiating striæ, take an intermediate position between those of the species and the variety *imbricata*, about seven or seven and one-half occupying a length of 4 mm. Its affinities are apparently nearer to the typical forms of the species.

Rhynchonella Janea, Billings.

(PLATE V, FIGS. 23, 24.)

At Collinsville, Alabama, casts of a species of Rhynchonella are found in great abundance. Young specimens have both valves moderately convex, the convexity increasing with age. In specimens 7.5 to 8 mm. long and 9 mm. broad the thickness is 3.6 mm. In specimens 9 mm. long and 9 mm. broad, the thickness is 6 mm. In specimens 10 mm. long and 11.3 mm. broad the thickness may be as high as 9.2 mm. As a rule the dorsal valve is more evenly convex than the ventral, the ventral valve near the centre appearing slightly flattened on account of the elevation at that point of the lateral lobes above the sinus. The apical angle varies from 80° to 90° the more obese specimens usually showing the higher angle. The mesial fold has four plications as a rule, and the mesial sinus contains three plications. Frequently the two outer plications of the mesial fold are less elevated than the other two plications so that the fold appears rounded. In other shells it projects boldly from the surface of the shell although the elevation above the lateral lobes attained is not likely to exceed 1.8 mm. for specimens 11 mm. long. The mesial sinus is always well-defined, but not very deep. Occasionally three plications occur in the dorsal fold, and two in the ventral sinus. From five to six plications occur on the lateral lobes. The character of these plications is somewhat variable, in some specimens being quite angular, in others being broad, flat, and very much rounded. All gradations between these forms occur. Casts of the exterior of the shells show occasionally traces of concentric striæ, but these are usually obsolete. It must be remembered, however, that even fine sandstone is not the best element for the preservation of the fine concentric striæ of most species of *Rhynchonella*.

The beak of the ventral valve in case of the more flattened specimens is apt to be more erect, and although curved does not cover up the beak of the dorsal. In the more obese specimens, however the ventral beak is strongly curved, almost, and frequently entirely, covering the beak of the dorsal valve.

Direct comparison with Canadian specimens of *Rhynchonella Janea* from Anticosti, having the concentric striæ usually obsolete, show no appreciable differences between it and the Alabama specimens, although the Anticosti form occurs at a somewhat lower horizon.

It is not so well determined, however, that this species is distinct from *Rhynchonella neglecta*, Hall, of the Clinton group. The only appreciable difference seems to be the greater development of the mesial fold and sinus in *Rhynchonella Janea*. As species of *Rhynchonella* are now defined, it is to be doubted if the Clinton types of *Rhynchonella neglecta*, Hall, will not come to be distinguished from the Niagara species, and since the Clinton types were described first, it is presumed that the Niagara forms will receive a new name. In the case of the species next to be described, however, the Niagara forms are taken as the type of the species as is customary, for some reason unknown to us, in American literature.

RHYNCHONELLA NEGLECTA, Hall.

(PLATE VI, FIG. 12.)

This species occurs in moderate abundance in the Clinton at Hanover, Indiana. On direct comparison with New York Niagara specimens no differences can be noted. The largest specimen is 6.9 mm. long and 7.2 mm. broad.

Rhynchonella scobina, Meek, from the Ohio Clinton is a much larger species, often attaining a length of 15 mm. and a width of 18 mm. With the increase of size the mesial sinus and fold are much more prominent. The peculiar surface ornamentation, connected with a series of fine close concentric striæ, which has given name to the species, will also serve to distinguish it.

At Cumberland Gap, Tennessee, were found a number of valves in which the plications were well defined but showed no sharp differentiation into side and mesial lobes; there is also no good mesial sinus. The largest specimen seen has a length of 6.2 mm. and about the same width. There are about thirteen plications on each valve. These specimens are here doubtfully referred to *R. neglecta*.

Rhynchonella acinus, var. convexa, var. nov.

(Plate VI, fig. 13.)

The result of observations on that division of the genus *Orthis* known as *Platystrophia* has been to place little value upon the number of striæ on the mesial fold or in the sinus, except as varietal distinctions. Davidson in his studies on British brachiopods has arrived at similar conclusions in regard to the genus Rhynchonella. Thus under *R. borealis*, Schlotheim, are placed forms having from two to seven radiating striæ or plications on the mesial fold. Our own experience with American forms does not admit of similar sweeping generalizations. Yet there is no doubt that the number of striæ vary in those forms having many striæ, and that in those forms which have the number of striæ typically reduced to two on the fold, careful search will always result in finding at least a rudimentary third plication on some specimen. We do not find any great difficulty in separating these forms from those in which the number of striæ is typically greater.

Rhynchonella bidens, Hall, is found in the Clinton Group of New York. It is a small species, length and breadth about the same, with a subcircular outline, both valves strongly convex, beak closely incurved, the concentric striæ very fine. About five plications are found on each side of the mesial fold. *Rhynchonella bidentata*, as identified in the Niagara group of New York, is also a small species. The general outline of the shell is however more triangular, due to the beak of the ventral valve which is acute and not strongly incurved. The dorsal valve is more convex than the ventral. The concentric striæ are neither fine nor coarse. Neither the mesial fold nor the sinus is strongly developed. The plications are angular. *Rhynchonella acinus*, Hall, of Indiana, is also a small species. In its typical form it has an ovate quadrate outline with a sub-attenuate beak. The plications are thick and broad; there are no concentric striæ, or perhaps they are very faint.

The dorsal valve is somewhat flattened along the middle and the ventral is more convex. The plications of the median fold do not usually differ conspicuously in size from the lateral plications, and may even be slightly narrower. The median sinus is also rather deeply impressed, and the plication within it is as narrow as, and often narrower than the lateral plications. The most marked feature is the strong lateral compression of the shell. In typical specimens this is emphasized by the fact that the anterior of the shell is abbreviated so as to give a subquadrate outline to the shell. In the type specimens figured by Hall, representing as a rule the more mature state, the anterior outline is more produced, the lateral compression is still marked, but the general outline of the shell is more ovate.

In a third form from the same locality, representing perhaps the adult of this species, the form is subtriangular, or broadly ovate, and rather flattened, with no lateral compression. In this the two plications on the mesial fold are often broader than the lateral plications and the dorsal valve presents a rather flattened surface.

The young of *Rhynchonella Whitii*, Hall, also from Waldron, Indiana, are often difficult to distinguish from *R. acinus*. In typical specimens, it is ovate triangular, there is no lateral compression, the shell is not obese, and the dorsal valve is convex, not flattened. In more adult specimens these features become more prominent. The plications are quite angular, and the two on the mesial fold are usually approximate.

In large collections *R. Whitii* and *R. acinus* are difficult to distinguish. If my conclusions are correct *R. acinus* is distinguished by the flattening of the dorsal valve, not always well marked, and the low, broad plications which become indistinct toward the beak, and frequently obsolete at the beak. *R. Whitii* has a more convex dorsal valve, the plications are angular, almost sharp, and are distinct even at the beak. In both species the plications of the mesial fold may be approximate or divergent. *R. bidens* differs from *R. Whitii* by its greater convexity, and more circular outline. I have no means of determining the relationship of *R. bidentata* of New York with Swedish specimens of the same name. Hisinger says the Swedish form is smooth, and Dalman emphasizes that fact, saying that numerous specimens he had examined are about of the same size and are all without concentric striæ, and the plications are quite thick. The New York specimens are certainly supplied with sufficient concentric striæ. The literature and specimens at my command are not sufficient to decide the matter.

At Hanover, Indiana, a form is found in the Clinton group, which agrees with *Rhynchonella acinus*, Hall, in having broad, coarse plications, with no concentric striæ or only very faint ones; the plications become indistinct at the beak. The general form is ovate triangular or broadly ovate, much as in the third form of *R. acinus* described from Waldron, Indiana. Neither young nor old specimens are laterally compressed to any very marked degree, although one or two approach the figured forms of *R. acinus* at Waldron. The youngest specimens are usually flattened horizontally, rather than obese, but soon become strongly convex, the convexity being especially marked in the dorsal valve, which in *R. acinus* is flattened. This increase of convexity is accompanied by a greater distinctness of the mesial fold and sinus towards the beak than in *R. acinus* of Waldron. The Clinton specimens may be conveniently separated from the Niagara forms as *Rhynchonella acinus* var. *convexa*.

Rhynchonella decemplicata, Sowerby.

(plate vi, figs. 23, 24.)

Specimens of the following description are found at Cumberland Gap, Tennessee.

Dorsal valve with the two median plications becoming more elevated and wider anterior to the centre of the shell, forming a distinct mesial-lobe of moderate breadth.

Ventral valve having a corresponding depression or sinus along its median line, of the same width anteriorly as the mesial lobe of the dorsal shell; along its median line in the sinus a single plication of ordinary size is found.

Lateral lobes of both valves with five or six plications. Plications acute but rounded along their summit. The convexity of the valves is such that the anterior portions of the same in the complete shell must have met at an angle more or less acute, especially along the median lobes. The posterior half of the margin on either side of the beak is more or less straightened, sometimes giving a sort of triangular appearance to the shell. Length of an ordinary sized individual, 7.1 mm.; width 8.2 mm.

We fail to find any satisfactory American form with which to associate these specimens and *Rhynchonella decemplicata* of the Upper Llandovery possesses at least the advantage of being an old and well recognized species from a somewhat similar horizon. *Rhynchonella bidens*, Hall, is a smaller species, and more ventricose. *Rhynchonella Whitii*, Hall, of the Niagara, has a more sharply elevated mesial fold, and more angular plications. Those found in the Lower Helderberg and usually associated with *Rhynchonella formosa*, Hall, have also a more elevated mesial fold. More specimens are needed to decide their identity with the British species.

A small specimen was found at Cumberland Gap, presumably of this species, 4.8 mm. long, and 5.3 mm. broad. The five plications of each lateral lobe are almost obsolete, only the inner one or two plications of each lateral set being at all readily seen. The two plications of the median lobe, scarcely distinguishable for two-thirds the length of the shell, along the anterior third become very prominent and project boldly beyond the margin of the lateral lobes.

Rhynchonella Salteri, Davidson, has some features comparable with this specimen. Hall figures from Waldron, Indiana, under *Rhynchonella Indianensis*, Hall, a specimen which is still more like the Tennessee form. The Tennessee form, as already stated, is probably the young of the larger specimens previously described.

Stricklandinia lens, Sowerby.

(plate v, figs. 1-4.)

Stricklandinia lens in its typical form has the cardinal margin of the dorsal valve straight, about five-eighths of the width of the shell, the lateral margin making angles of about 120° with the cardinal margin. The beak of the ventral valve is fairly elevated, the posterior margin of the valve being in consequence curved. It represents one of the largest of the species of which it is a type.

Pentamerus microcamerus, McCoy, is a smaller form, with a relatively much shorter length; the length being said to equal only

.55 of the breadth. The greatest convexity of the valves is near the cardinal margin and there are indications of a mesial fold. Placing this form as a variety under *S. lens* it will represent the opposite extreme. In our American Clinton fossils we have several forms that may be considered as filling the gap.

In the collections from Cumberland Gap, Tennessee, there are ventral valves which approach variety *microcamerus*. One of these is 18 mm. long, 29 mm. broad and 3.2 mm. deep. It has a very shallow mesial depression, and several irregular radial elevations, broad, flat, and indistinct. The curvature of the shell antero-posteriorly is quite regular. The other specimen is 13.7 mm. long, 22 mm. broad, and 2.2 mm. deep. It has a fairly distinct mesial depression, and several indistinct radial raised patches on the rest of the valve. Two dorsal valves of a very different type occur. They are both gently curved except near the cardinal margin where the curvature is decidedly increased. One specimen is 22 mm. long and 22 mm. broad, with a depth of 3.2 mm. The other is 24 mm. long and of about the same width. They are both casts of the interior and show the muscular scars well. In general the length of the shell increases with age, forms 13.3 mm. long having a length equal to .87 the width, forms 21 mm. long having a length equal to .93 the width of the dorsal valve.

At present the discrepancy between the measurements of the dorsal and ventral valves of the Tennessee specimens cannot be accounted for, they never having been found connected.

In his Catalogue of Silurian fossils of Anticosti, Billings cited *S. lens*, Sowerby, but this was subsequently found to be an error and *Stricklandinia brevis* became the name of the Anticosti specimens. *Stricklandinia Salterii*, Billings, also of Anticosti, was described at a later date. In the typical specimen the length is equal to .78 of the width, being thus one of the intermediate forms between *var. microcamerus* and the species. In one of the specimens at hand the hinge line is 27 mm. long, the length of the shell is 26 mm., the general width of the shell is 32 mm. and the thickness is 13 mm. The dorsal valve has a low mesial fold scarcely visible along the posterior third of the shell, moderately distinct anteriorly, where it is about 10 mm. broad. The ventral valve has a corresponding depression less distinctly marked. The surface is finely striated radially and finely wrinkled—sometimes with a few coarse wrinkles—concentrically.

The relative length of a specimen increases with age. A specimen 14.5 mm. long has a length equal to .85 the width; 20 mm. long, a length equal to .83 the width; 26 mm. long, a length equal to .81 the width; 52 mm. long, a length equal to .78 the width. A characteristic feature of this form is the slight difference between the elevation of the dorsal and ventral beak. It is here placed as a variety under *S. lens.*

Stricklandinia triplesiana, Foerste, is another species, closely related to variety *Salterii*. Figure 14, of Plate XIV, Bull. Denison Univ. Lab., is very similar to forms of the Anticosti variety at hand, except in length and the slight anterior extension of the margin at the mesial fold, which is less pronounced in variety *Salterii*. It is 28 mm. long and 30 mm. broad. Fig. 13 of the same plate is more like *S. melissa*, Billings, in the character of the postero-lateral angles, but otherwise closely resembles the other specimen. This is placed as a variety under *S. lens.*

Stricklandinia Melissa, Billings, is another Anticosti form known only from the description of a single specimen. Like figure 13 of the plate just cited the postero-lateral angles at first form almost a right angle, after which the lateral margins diverge to about mid-length, after which they curve inwards and around the anterior margin of the shell, the curvature being regular except at the anterior margin which is somewhat pointed, but very obtusely. This form again seems to have been quite convex along the cardinal margin. There does not seem to have been a mesial fold or sinus; these however are sometimes obsolete in the forms already described. The length of the shell is about 42 mm., the width apparently 40 mm., the length of the cardinal line 27 mm., and the thickness about 14 mm. These measurements are taken from the published figure. This form is also placed as a variety under *S. lens.*

At Collinsville, Alabama, numerous casts of a form occur presenting all the features of the interior of *S. lens* in the typical European forms. The character of the outline of the shell varies. In one specimen the square postero-lateral angles with divergent lateral sides, and other features of var. *melissa* are well shown, but these valves are all either flat or very moderately convex; indeed they are all so flat as to lead to the idea that this flattening was due to causes subsequent to death since there is scarcely any room for the viscera. In other specimens the cardinal line is scarcely shorter than the width of the shell, in younger specimens at least, and the postero-lateral angles and the general form are more like var. *Salterii* but with the angles nearer a right angle. In one specimen, at a distance of 17 mm. from the beak, the shell bends downwards for 1 mm. and then outwards at an angle of 15° to its former course, thus increasing the convexity of the shell. There is no indication of a mesial depression or fold. The dental lamellæ in a finely preserved specimen are seen to project into the shell, forming a small angle with each other. They are flattened above, and medially show the impression of a narrow groove. Within 2 mm. of the dental lamellæ are two muscular impressions divided by a narrow ridge. The muscular impressions or scars are sharply defined posteriorly but become indistinct after a length of 3 mm., as does also the dividing ridge. These scars are the most variable feature of the shell and may often be entirely obsolete, all intermediate stages being found. For the present we designate these flattened specimens as *Stricklandinia lens* var. *planus*, although if our interpretation of them be correct they perhaps belong more correctly to variety *melissa*, which also seems to be destitute of mesial fold and sinus.

Pentamerus ovalis, Hall.

(plate V, figs. 17, 18.)

This species was described by Hall from the Clinton Group of New York.

Specimens were found at Cumberland Gap, Tennessee, which we place under this species. They certainly do not bear the closest resemblance to the published figures of that species; but no direct comparison with the New York specimens having been made, we are not prepared to pronounce them distinct. The best preserved specimen is 17 mm. broad and long. A dorsal valve is 21.3 mm. broad and long. One ventral valve may have had a faint mesial fold, but is imperfect anteriorly.

This same form is very common at Collinsville, Alabama, and from the specimens here found the following description is prepared.

Shell small, our specimens not exceeding 22 mm. in length and breadth. Both valves moderately convex in general, the ventral valve strongly convex at the beak. The beak of the casts of the dorsal valve scarcely distinct, that of the ventral valve far more prominent, apparently at one time having curved over and more or less concealed that of the dorsal valve.

The mesial septum of the ventral valve was very strong, extending in the largest specimens not quite one-half the length of the shell. The two hinge teeth, whose continuation anteriorly forms the single median septum, enclose a triangular space marked in the casts by a triangular projection.

The dorsal valve has two hinge teeth continuing anteriorly as two median septa, forming a very low angle with each other, and usually extending in maturer shells a third or slightly more the distance of the shell toward the anterior margin.

These two median septa are usually the only parts distinctly preserved in the dorsal valves; but a third scarcely distinct median septum is not infrequently found; this septum ought perhaps to be called merely a low mesial ridge or striation. It lies between the two median septa already described, beginning at about half their length and extending between and beyond them to slightly more than half the length of the shell. In shells or casts still better preserved two oblong muscular scars are seen, one on each side of this mesial striation, and just beyond the two more distinct median septa. In the very best shells or casts the mesial striation is seen to divide at its tip, the divisions outlining the median anterior part of the muscular scars; in the centre of the fork thus formed a faint mesial groove originates, extending to almost within a third of the distance of the length of the shell from the anterior margin. These characters can only be noticed in well preserved specimens and the two median septa first described are the only characters of the dorsal valve universally present.

Leptocœlia hemispherica, Sowerby.

(PLATE VI, FIGS. 18, 19.)

Leptocœlia hemispherica is described by Hall from the Clinton Group of New York.

Atrypa flabella, Shaler, from South-west Point, Anticosti, is the same species.

At Collinsville, Alabama, the species is common. From Ringgold, Georgia, the same form has been collected, and at the Cumberland Gap localities it occurs in great abundance. In view of its great abundance and its great geographical range it seems strange, that it should not have been found either in Ohio or Indiana, in any of our collections. As far as we can learn, the species does not show any great degree of variability, and in all our forms presents characteristics much the same as in the European types.

The following description is drawn up from the forms found at Cumberland Gap, Tennessee, where it is very abundant.

Dorsal valve flattened, with a straight hinge line for five-sixths the width of the shell, the postero-lateral margins however rounded, and the anterior margin of the shell semi-circular. There is a faint median depression increasing in depth towards the anterior margin, and which may gain still further in distinctness by a slight increase in width and depth of that one of the grooves separating the radiating plications which occupies a median position. Some of the specimens show two small projections along the hinge margin near the beak. The beak does not extend beyond the hinge line.

Ventral valve convex, with often a moderate tendency towards the formation of a median ridge along the back of the shell, from the beak to not quite the middle of the shell.

In many specimens this incipient ridge is entirely wanting, and in none is it well characterized. The beak always projects beyond the hinge margin, and is evenly incurved. The postero-lateral angles are rounded and the anterior margin is semi-circular.

Measurements of a considerable number of valves show that in both valves the length does not equal the width of the shell. In about 50% of both valves the ratio of the length to width of the shell varies from 8 to 10 to 9 to 10. While 30% of the dorsal valves show a relation of the length to the width, varying from 7 to 10 to 8 to 10, this is not true of a single specimen of the ventral valve. Moreover while 50% of the ventral valves show a relation of length to width varying from 9 to 10 to 9.5 to 10, only 10% of the dorsal valves show a similar ratio. These measurements show that the comparative length and breadth of the valve are very variable, but that the extremes of variation in the dorsal valve tend towards an increase in the width of the shell while that of the ventral valve expresses itself in the increased rotundity of the valve. No relationship between these variations and the size of the valves can be traced.

The surface of both valves is covered with simple radiating plications, varying from eleven to seventeen. The far greater number of valves, more than 80%, show from thirteen to fifteen plications. Shells having seventeen plications are almost invariably those in which the ratio of length to width is less than the ratio of 8 to 10, and hence are confined almost exclusively to dorsal valves.

The radiating plications are crossed by concentric striæ, usually not visible in our specimens except on top of the plications where they become elevated folds or even have the aspect of tubercles. These tubercles may be fairly distinct on the anterior half of the shell. The plications are all unbranched.

The average size of specimens would be perhaps a length of 7 mm., and a width of 8.1 mm. Specimens, are, however, frequently much larger and may be 8.5 mm. long, 10.2 mm. wide.

Fenestella.

A single specimen was found at Cumberland Gap, Tennessee, which is readily referred to this genus but its specific identification is more difficult. Six branches occur in a width of 2 mm. and four and one-half, sometimes five dissepiments in the same length. The fenestrules are short and narrow. No pores can be seen. The dissepiments are rather thick.

Ptilodictya expansa, Hall and Whitfield?

The single fragment found at Cumberland Gap, Tennessee, is 23 mm. long and 10 mm. broad. From nine to ten rows of cells are found in a width of 2 mm., and from six to six and a half cells in a length of also 2 mm. As well as may be determined from the specimen the cells are four sided, rhomboid, arranged in longitudinal rows and also in horizontal rows which run from a few median rows of cells to the lateral edges of the frond, forming angles of 15° with the median rows. The state of preservation of the specimen was not sufficient to determine whether these median rows were differentiated in size and form from the lateral rows, as is usual in this species; nor could it be determined whether the lateral edges were strictly parallel, but it is not uncommon to find the same species at Dayton, Ohio, with the lateral edges fairly irregular, at least not parallel. It is possible that the forms with irregular edges should be separated from those in which the edges of the fronds are parallel as a distinct species. This idea is strengthened by the fact that in the Ohio specimens the forms with parallel edges have flat fronds and in my own experience have been found only at Todd's Fork, while those with irregular edges have a tendency towards undulate fronds, especially in the larger individuals, and are of much wider distribution.

PTILODICTYA EXPANSA, EMARCESCENS var. nov.

(PLATE VI, FIG. 30.)

A single specimen was collected at Eaton, Ohio, by Mr. J. M. Nickles, which is so readily distinguished from all other forms known, as to warrant its description. It belongs to the type of *Ptilodictyœ* already known from the Clinton of Ohio from *Ptilodictya expansa*, Hall and Whitfield. The frond is composed of two layers of cells united by their epithecal membranes. The sides of the frond are parallel, the fronds are very much flattened, very moderately convex from side to side, about 3.6 mm. broad. There is a central band composed of about five rows of cells, 1 mm. broad, the cells being shorter longitudinally than the lateral cells, about eight cells occupying a length of 2 mm. These cells have a tendency of being arranged more directly across the fronds than the lateral cells; the central band is not well differentiated from the lateral rows of cells, sometimes encroaching upon the latter, sometimes the reverse.

On the right side of this band in the frond here described there are eight rows of cells; on the left side, also eight rows. These rows are always readily distinguished from the fact that the cells are longer, six cells occupying a length of 2 mm.; they are also narrower, six cells occurring laterally in 1 mm. They are also distinguished from the fact that these cells are arranged in very perfect rows diagonally, the diagonal rows forming an angle of about 15° with a line drawn transversely across the frond. This specimen is distinguished from *Ptilodictya expansa* solely by its small size, the young specimen of that species which have come frequently under our observation always having greatly exceeded the Eaton form in size.

PTILODICTYA FARCTUS, sp. nov.

(PLATE VI, FIG. 31.)

Another form of *Ptilodictya* found at Eaton, Ohio, by Mr. J. M. Nickles is also represented by a single and very unique specimen. It is about 9 mm. long. The average width is 2 mm. and the average thickness, 1.4 mm. Indeed the frond looks like an almost cylindrical stem a little flattened transversely. A low-power lens will reveal on either side of this stem a sharp line which marks the position of the epithecal membrane, and is ready evidence of its being a true *Ptilodictya*. Examined in the same way low elevations or knobs are noticed, which apparently have no great structural value. The cells have oval apertures. There are six rows of cells on each half of the frond, or twelve rows completing the entire circuit. About three and three-fifths cells occupy a length of 2 mm. The great thickness of the frond compared with its width will readily distinguish this form from any other known.

Ptilodictya famelicus, sp. nov.

(plate vi, fig. 32.)

This species apparently occurs in considerable numbers at Eaton, Ohio, considering the number of specimens submitted to me by Mr. J. M. Nickles. The fronds are dichotomously branched, the branches not occurring as a rule at less intervals than 4 or 5 mm. They also vary somewhat in breadth, from 2 mm. to 3 mm., the average is about 2.5 mm. In thickness the fronds vary between .75 mm. and 1 mm. There are about seven or ten longitudinal rows of cells on each branch, according to size, and the edge of the frond is non-celluliferous for almost, if not quite, a width equal to the width of a row of cells. In addition, the cells are also arranged in diagonally-crossing rows on the stem. In form the cells are oblong oval at their apertures. About five cells occur in a length of 2 mm., sometimes almost five and one-half cells. The number of longitudinal rows of cells in 2 mm. of width is usually about seven, sometimes nearer eight. The surface is perfectly normal, having neither elevations nor suppressions of cells. This species also occurs in the cementing material of the Clinton conglomerate at Belfast, Highland County, Ohio.

Ptilodictya rudis, sp. nov.

(plate vi, fig. 33.)

This species occurs in considerable numbers at Eaton, Ohio, judging from the number of specimens submitted to me by Mr. J. M. Nickles. The fronds are dichotomously branched, the branches apparently at greater intervals than 5 mm. The fronds vary in breadth from 2.3 to 3.5 mm.; in thickness, from 1 mm. to 1.3 mm.; in the number of longitudinal rows of cells, from six to eight according to the width of the branches. In a length of 2 mm. the number of cells varies from four in the far greater number of cases to three and one-half in a few instances. In a width of 2 mm. the number of cell rows varies from five and four-fifths as the usual number to four and four-fifths as a rare occurrence. The non-celluliferous margin is usually quite narrow. The cells are arranged in longitudinal and in diagonally-crossing rows. Their form is oval, often broadly oval. Although this form is chiefly to be distinguished from *Ptilodictya famelicus* by the greater size of its cells, the fact that owing to the greater width of the cells the longitudinal lines separating the cell rows are not quite so distinctly straight lines, especially when examined with a low-power lens, is of some value. This species also occurs in the cementing material of the Clinton conglomerate at Belfast, Highland County, Ohio.

Stictopora similis, Hall.

In the cementing material of the conglomerate at Belfast, Highland county, Ohio, a single specimen of the following description was found. Fragment of a frond 8 mm. long, once dichotomously branched; the branches 3 mm. broad. The branches moderately convex from side to side; their thickness, the character of their edges, whether celluliferous or not, could not be determined. About nine or ten rows of cells occupy the branches, horizontally, having at the same time a diagonal arrangement. About five cells occupy a length of 2 mm. The mouths of the cells are surrounded by a raised border or lip; cell apertures are oval in form, and are separated from each other by distances varying from one-fourth to almost three-fourths their diameter in different parts of the frond; normally, perhaps, one-third their diameter. Direct comparisons with *Stictopora similis*, as originally described from the Niagara of Indiana, have not been made, but the published description and figures of the latter, render the identification of the Ohio Clinton form quite safe.

Phænopora fimbriata, James.

In the cementing material of the conglomerate at Belfast, Highland county, Ohio, numerous fragments of a narrow form of *Phænopora* occur in considerable abundance. These almost uniformly show the exterior surface. The specimens are usually 2.5 mm. wide; one of them is 14 mm. long; none of them are branched. Eight or eight and a half cells occupy a length of 2 mm., and ten cells occupy the same distance in width. The cells are arranged in longitudinal rows, there being two interstitial cells, one on either side, between the ends of the cell apertures. Cells oval. The edges of the fronds along a narrow border are non-celluliferous, the non-celluliferous border being more or less irregularly striated longitudinally, the striæ not conspicuous. No well defined elevations or monticules are found upon the surface of the specimens. Although the specimens in question do not branch, their evidently fragmental character warrants us in unhesitatingly referring the same to *Phænopora fimbriata*, a common species in the Clinton of Ohio, but elsewhere so far unknown from surface views; the surface being usually attached to the matrix, the fronds parting and becoming exposed along the epithecal membrane.

PHÆNOPORA MAGNA, Hall and Whitfield.

In the cementing material of the conglomerate at Belfast, Highland county, Ohio, occur a few fragments, with seven cells in a length of 2 mm. and nine and a half cells in the same width. The surface shows low, indistinct elevations, usually 3 mm. apart. The fronds are broader, usually about 4 mm. in width. In other respects these fragments agree with *Phænopora fimbriata* just described.

PACHYDICTYA.

A small fragment was found at Cumberland Gap, Tennessee, 15 mm. long, bifurcating twice in this distance. The branches 4 to 5 mm. broad and at least 1.5 mm. thick. The cells are of oval form, and are arranged in well marked longitudinal lines along the frond and in less evident diagonal rows across the same. There are five cells in a length of 2 mm. and six in the same width; from nine to fourteen cells occupy the width of a branch; perhaps the very edges of the fronds were destitute of cells and formed a narrow non-celluliferous margin.

At Collinsville, Alabama, forms of the same general description as the Tennessee specimens were found.

At Collinsville is found also another bryozoan having fronds 4 mm. wide, unbranched in a length of 18 mm.; frond moderately curved however in that length. About fifteen rows of cells occupy the width of the frond; of these, six cells occupy a length of 2 mm. near the margin of the frond, and seven cells near the centre of the same. About four and three-tenths cells occupy the width of 1 mm. near the margin of the frond and five and three-tenths cells near the centre of the same. The character of the frond and the number and arrangement of its cells indicate some species of *Phaenopora*, but the interstitial cells of that genus were not seen. This, however, is not surprising since the sandstone would scarcely preserve such delicate features.

It is scarcely worth while to describe such specimens except in order to show what class of bryozoa exists in these localities.

RHINOPORA VERRUCOSA, Hall.

Specimens of the following description were found at Cumberland Gap, Tennessee. Fronds thin and flat, only one face seen in any of the specimens as preserved in the ferruginous sandstone. The cell apertures raised into low monticules, which are distant from one another for a distance equal to or slightly exceeding their own diameter. The average number of cells in a length of 3 mm. is six. On different parts of the same frond the number of cells in 3 mm. frequently fall to five and a half and rise to six and a fourth; they may even fall to five and rise to six and a half, but these limits do not seem to be exceeded in this locality. The cells are arranged in diagonal rows. It is not possible to say whether these specimens are further ornamented by branching furrows or ridges, or monticules. Some fronds, and even these are fragments, show a length of 50 mm. and a width of 30 mm.

Similar specimens are found at Collinsville, Alabama. From five and one-half to six cells are found in a length of 3 mm.

In Ohio, this species has usually a somewhat greater number of cells in the same length, varying from six to seven and one-fifth cells in 3 mm.

At Hanover, Indiana, the fronds usually remain attached by their cellular sides to the rock, and only the epithecal layer is exposed. The cells can usually, however, be seen through this layer, the limestone being sometimes translucent, and sometimes the epithecal layer is slightly worn away.

This species was originally described from the Clinton Group of New York. We suspect that most specimens of *Lichenalia concentrica* identified from the Clinton of Ohio, will prove on further examination to be the epithecal exposures of *Rhinopora verrucosa*.

HELIOLITES SUBTUBULATUS, McCoy.

This species is found in considerable abundance at Ludlow Falls, Ohio. It consists of broad horizontal sheets, often 11 mm. thick near the centre, gradually decreasing in size towards the extremities, often continuing for some distance with a thickness of less than 3 mm. In the specimen described a layer 11 mm. thick near the centre, at the periphery 100 mm. off is 1 mm. thick. On the surface of these sheets knobs are formed by the irregular growth of the zoarium. Sometimes this increased activity in growth takes another form and instead of knobs being formed the zoarium grows rapidly along some line horizontally until a new layer is formed which continues to grow rapidly horizontally and vertically until a new sheet is formed entirely covering the old one but often separated from the same everywhere excepting along the line of origin.

In this way a zoarium may come in time to consist of five or six layers or sheets. The visceral tubes are small, .6 to .75 mm. wide and occur on the average at a rate of five in a length of 8 mm. The visceral tubes are circular and form little pits on the surface crenulated by twelve marginal septa. Between the visceral tubes are numerous minute tubes, of which ten are found in a length of 2 mm. The visceral tubes are crossed by horizontal diaphragms. Our specimens are more readily compared among American forms with the species as figured by W. J. Davis, from the Niagara near Louisville, than with Rominger's forms from Drummond's Island, Michigan, or Masonville, Iowa.

Favosites favosus, Goldfuss.

A single specimen was found at Collinsville, Alabama, a cast of the tubes, best comparable in size with fig. 4, pl. iv, of Rominger's Fossil Corals. The tubes are polygonal, unequally pentagonal or hexagonal, having an average diameter of 3 mm. The fragment is 40 mm. long and 30 mm. broad, and evidently belonged to a large massive specimen.

At Fair Haven, Ohio, was found a specimen of the same variety, showing the crenulated walls of the tubes, and horizontal diaphragms at the rate of about ten in 10 mm.

At Brown's quarry, west of New Carlisle, another species of the same variety was found.

Favosites favosideus, Hall.

At the Soldiers' Home near Dayton, Ohio, is found a small subspheroidal form of *Favosites*, usually not over 35 mm. in diameter, often parasitic, one of our specimens being attached to the edge of a frond of *Rhinopora frondosa*, another having apparently attached itself to the broken end of a crinoid stem. On account of this habit it might be compared with *Favosites parasiticum*, Hall, of the Niagara of New York. The tubes are, however, of larger size and the spiniform processes of that species are wanting. Spiniform processes are also described in the case of *Favosites favosideus* of the Clinton of New York, but they are also stated to be obsolete in that species, and since the type of that species is properly represented in that case by the form first figured, fig. 2*a*, pl. 17, Pal. N. Y., Vol. II, may be considered the type of that species. Such an interpretation would undoubtedly include the Ohio Clinton form. The tubes vary from 2 to 3 mm. in diameter, the fully developed tubes of each specimen being subequal, a few younger tubes of smaller diameter being interspersed. The walls are moderately crenulated; there are five diaphragms in a length of about 2.8 mm. Probably these specimens are the young of *Favosites favosus*.

Favosites Niagarensis, Hall.

Several specimens were found at Collinsville, Alabama, casts of the tubes having very much the same size as fig. 1, pl. v, of Rominger's Fossil Corals. The tubes are irregularly hexagonal and have an average diameter of 1.6 mm. These specimens seem to have occurred in flattened masses. The fragments are 25 mm. across and have a thickness of 12 mm.

This is the most common species of the Clinton Group in Ohio, forming large flattened or sub-hemispheric masses 100 mm. across. It occurs at Fair Haven, showing crenulated tube walls, the tubes 2 mm. in diameter and the horizontal diaphragms at the rate of five in 5.6 mm; at Brown's Quarry with tubes 1.8 mm. in diameter, and five diaphragms in 2 mm., also with crenulated tubes 1.8 mm. in diameter and five diaphragms in 4 mm.; also with very distinctly crenulated tubes 2 mm. in diameter and five diaphragms in 5.7 mm. At the Soldiers' Home with tubes 1.3 mm. in diameter with moderate but distinct crenulations and others with more distinct crenulations and tubes 1.8 mm. in diameter. At Ludlow Falls the form with numerous diaphragms is common.

At Ludlow Falls is also found a flattened spheroidal form, about 75 mm. in diameter and 35 or 40 mm. in height with tubes 2 mm. in diameter, moderately crenulated, with quite distant diaphragms, five occupying a length of about 7 mm.

FAVOSITES VENUSTUS Hall.

At Collinsville, Alabama, numerous specimens of a species are found, casts of the tubes having very much the same size as those figured by Rominger in his Fossil Corals, pl. v, fig. 3. The tubes are irregularly hexagonal, and have an average diameter of 1 mm. The original form of the specimens, judging from the fragments, seems to have been irregularly spheroidal, the specimens having a diameter of perhaps 40 mm. It is just as possible that the specimens may have been much larger.

In one specimen the casts have preserved the position of the rows of spiniform processes, so that the casts appear as cylindrical bodies deeply furrowed all around by sharp grooves. At first sight they suggest rather some species of *Lyellia* or *Heliolites* with but little space between the tubes of the polyps.

At Ludlow Falls, Ohio, the normal species with tubes 1 mm. in diameter occurs, the tubes showing the sharp spiniform crenulations, and frequent diaphragms.

At Ludlow Falls occurs also a form in broad, flat or hemispherical radiated masses, in which the tubes vary from 1.2 mm. to .6 mm. in different parts of the same zoarium. Pieces from the more finely tubed portion, and young specimens look very much like *Favosites discus*, W. J. Davis. But until the descriptions of that species are published we are in no position to judge as to their identity. The walls not infrequently show crenulations but we have been unsuccessful in finding the spiniform crenulations of *Favosites venustus*. The diaphragms are also much farther removed than is usual in that species, five diaphragms occupying a length of from 2.4 to 3.2 mm.

This species is found at Fair Haven. At the same locality forms are also found having tubes 1.3 mm. and less in diameter, with five diaphragms in 1.9 mm., and the walls scarcely crenulated. The species is also represented from the Clinton of Yellow Springs, Ohio, in the Columbia College Cabinet. All of these forms can readily be placed under *F. venustus* if the size of the tubes be made a criterion, but if the possession of spiniform crenulations be considered the chief specific feature, then most of the forms described here, especially those with distant diaphragms, may belong to some new species. We suspect that the spines may not always be preserved in fossil forms even if present originally.

Favosites.

A few specimens of *Favosites* were found at Cumberland Gap, Tennessee, in all of which the individual tubes are seen to be radiating from a common centre. None of the pieces are large enough to determine whether this gave rise to a semi-spherical or spherical body. The largest mass extends 19 mm. from the centre. The single polyp walls are pentagonal or hexagonal in outline, 2.1 mm. in diameter, and occasionally show traces of the original, quite scattered pores.

Small radiated masses of Favosites were also found at Collinsville, Alabama, the corallites extending about 12 mm. from the centre. The tubes are 3 mm. in diameter. In two specimens the walls of the tubes are strongly corrugated transversely.

We have no means of determining whether these specimens are the young form of some large tubed, more massive species, or whether they form an independent species of the type of *Favosites Forbesi*.

At Ludlow Falls, Ohio, are found small specimens not exceeding 30 mm. in diameter, usually somewhat flattened vertically, having a surface of medium convexity. The tubes are very unequal in size, the largest being 2.2 mm. in diameter, among which tubes of much smaller size are abundantly interspersed. The cell walls are distinctly crenulated, but no spiniform processes were noticed in the tubes. They have very much the appearance on top of *Favosites Forbesi* var. *discoidea*, figured by Roemer from Tennessee, but the tubes of our form are smaller, the radiated interior of that species has not been observed, and the epithecal membrane lining the base has also not been discovered, so that the Clinton form is almost certainly distinct.

Alveolites Niagarensis, Rominger.

With all the latitude permitted by Rominger's description of this variable species, one of the forms found at Ludlow Falls may readily be included. They are however larger than the forms he figured from the Niagara of Point Detour and Drummond's Island, Michigan, equalling in width rather those figured by W. J. Davis from the Niagara near Louisville, Kentucky, but the cells are not all so much flattened, being more readily compared in this respect with the types figured by Rominger. The average diameter of the cells laterally is about 1.2 mm. In a transverse direction the diameter varies greatly, from almost the same diameter as the width, to .4 mm. The generally unequal diameter of the tubes readily distinguishes this species, however, from any known Favosites. One side of these flattened tubes is usually more curved than the other, the second side being sometimes irregularly concave; usually, however, the appearance is more like the somewhat flattened cells of Favosites. The walls of the tubes are crenulated, none of the crenulations in our specimens being very marked in size. Horizontal diaphragms occur at the rate of five in 2 mm.

Striatopora (Cladopora?) proboscidialis, sp. nov.

This species occurs in considerable abundance at Fair Haven and in small quantities at Ludlow Falls, Ohio. The stems have an average diameter of 3 mm. tapering thence, often within an inch, to 2.2 mm.; usually however the rate of tapering is less. The stems branch at very unequal distances, usually more frequently where the diameter of the stem is greater. The more slender branches may be unbranched for 15 mm. or more. The polyp calyces are directed obliquely forwards and outward, usually forming irregularly polygonal outlines at the surface. The size of these calyces varies apparently a little with age, or at least with the diameter of the stems, from five calyces in the larger stems to almost six calyces in the smaller branches, in a length of 6 mm. In the larger calyces of some specimens the radiating striæ which give name to the genus can be detected. In the smaller calyces these are often obsolete. In some specimens also a moderate number of very distinct pores connecting adjacent polyp calyces can be detected. In others we have failed to see them. The branches of this species are often moderately curved and bent, but to our knowledge are never known to anastomose. Branching seems to be usually dichotomous, the branches forming angles from 45° to almost 90° with each other. Our specimens usually have the form and appearance of the figure on Plate 97 of Davis's Fossil Corals of Kentucky, taken from a specimen from the Niagara of Louisville, Kentucky.

Halysites catenulatus, Linnæus.

This polymorphous species is abundantly represented in the Clinton Group. The smaller form found occurs not infrequently at

Ludlow Falls, Ohio. In it ten tubes occupy a length of 7 mm., the vertical height of the entire zoarium being 17 mm., the width about the same, while the contortion of the walls is such as to enclose from fifteen to twenty very irregular spaces. The next largest form is from the same locality, five tubes occupying a length of 5 mm. The form next in size and of more general occurrence is found frequently at Fair Haven, Ohio. In it five tubes occupy a length of 8 mm. Horizontal diaphragms frequently cross these tubes in a proportion of ten diaphragms in a length of 6 mm. This form not infrequently has a vertical height of 100 mm. It is also found at Soldiers' Home, Ohio.

Halysites catenulatus nexus var. nov.

At Collinsville, Alabama, a form occurs which can readily be distinguished from the normal types of the species by the large size of the tubes compared with the generally short size of the corallum. There are usually four tubes in a length of 9 mm., the zoarium usually not exceeding 45 mm. in height. Owing to the large size of the cells and the small height of the zoarium as a whole, the tubes spread out very rapidly from the base as a centre, all the tubes tapering more or less rapidly towards the base, and giving a side view of the wall a very different aspect from those forms where the tubes are more nearly parallel. In all other respects it seems to be identical with the species.

Syringopora (Drymopora) fascicularis.

This species is fairly common at Ludlow Falls, Ohio, and at Fair Haven, Ohio. The tubes vary from .7 mm. in the Ludlow Falls specimens and .8 mm. in the Fair Haven specimens as the most frequent diameters to 1.1 mm. as a maximum. The tubules branch and again become connected with each other by approximation, without the intervention of narrower transverse channels. No septæ, or septal spicules were noticed in the tubes. Diaphragms of any sort were also not seen, but this is a less important observation since careful search for the same was not made. The exterior of the tubes is finely wrinkled transversely. This species may be readily distinguished from *S. fibrata*, Rominger, by the larger size of the tubes and the absence of radial crests, and from *Romingeria vannula*, W. J. Davis, by its smaller tubes and far less pronounced fasciculate branching, even three branches from the same part of the parent stem not being a common occurrence in the Ohio Clinton specimen.

Aulopora precius, Hall, compressus, var. nov.

Corallum found at Ludlow Falls, Ohio, in the Clinton, parasitic, consisting of elongate tubular cells attached to some species of *Clathrodictyon*. The cells begin with a diameter of .8 mm., gradually enlarge to about 1.7 or 2 mm. at the aperture, at the same time becoming more or less vertically elevated above the object to which the corallum is attached, to the extent of about 2 mm. at the apertural end. The cells are usually strongly flattened or compressed on the sides, and wrinkled transversely. The distance between the budding averages 6.5 mm. After budding the parent turns upward and ceases to grow, the aperture being oblong-oval, the greater diameter 1 mm., the transverse diameter .3 mm. Owing to the wearing away of the specimen the aperture usually appears more nearly circular having a greater diameter of 1.3 mm. and a transverse diameter of 1 mm. Budding takes place beneath and slightly to one side of the parent cell in a direct line, or more to one side dichotomously, the two new cells forming angles of about 45° with each other in the particular specimen here described.

The species was described from the Niagara at Waldron, Indiana. The Clinton form from Ohio differs in the lateral compression of the cells, the greater length is between the budding, and normally there is a smaller, less flaring and less rotund mouth. *Aulopora precius*, as figured by W. J. Davis from the Niagara of Louisville, Kentucky, presents a vertical view precisely like the Ohio form with cell apertures slightly worn.

Cyathophyllum celator, Hall, Daytonensis, var. nov.

(plate ix, figs. 9-11.)

The type specimen figured is from my own collection. The other specimens here figured and described are from the collections at the Ohio State University under charge of Prof. Edward Orton. The polyp corallum is simple, subturbinate, rapidly expanding below, the rate of expanding decreasing above, especially in the more elongate polyps. The base of the corallum is always decidedly curved, or bent towards one side, the curvature continuing more or less with the growth of the polyp, but becoming moderate near the top of the more elongate specimens. The polyp walls are always more or less strongly wrinkled transversely, the wrinkles being chiefly formed by a contraction of the rim of the calyx at some point after which the expansion of the polyp walls is again resumed. The indications of the septa within are occasionally well marked though usually very faint at the surface, or even obsolete, but where the specimens are partially weather-worn the septa can be readily detected. Their number is usually five in a width of from 3.2 mm. to 4 mm. The number of septa varies from seventy-five to ninety in the specimens examined. Vertical sections show that the walls of the calyx descend abruptly, and that the calyx is from 10 to 12 mm. deep. Horizontal sections show that half of the septa disappear within half the distance from the exterior to the centre of the corallum ; the remaining lamellæ are twisted towards the centre. On the side toward the apertural gap there seems to be an apertural fovea quite distinct toward the centre but filled nearer the margin with two or three septa which do not reach the centre, at least at the same level with the rest. Longitudinal sections also show but very few horizontal diaphragms, at least near the upper portion of the corallum. On the other hand, numerous striations are seen which are perpendicular to the walls of the corallum or run inwards at a more elevated angle than this would indicate. In the horizontal sections, these are seen to be dissepiments in part at least. Weather-worn portions of the exterior seem to indicate that these structures in great part are crenulations on the septa, extending laterally into the spaces between the septa. These crenulations occur at quite regular intervals, usually ten or eleven in a length of 5 mm. The sections also seem to indicate that the septal lamella are elevated about the fovea. In a specimen from Todd's Fork believed to belong to this species, they are elevated laterally and anteriorly about this apertural fovea.

This variety may readily be distinguished from the typical form in the Niagara at Waldron, Indiana, by its smaller size, a somewhat less rapid increase of growth, and a less flaring calycular border. It is fairly represented at the Soldiers' Home quarries near Dayton, Ohio. The variety is also represented in the cabinet of Columbia College from the Clinton conglomerate at Belfast, Highland Co., Ohio, where it occurs among the cementing material.

Cyathophyllum facetus, sp. nov.

(plate ix, fig. 8.)

At the roadside quarry north of the Soldiers' Home grounds near Dayton, Ohio, are found numerous small specimens of a species of *Cyathophyllum* similar in type to the form just described, but differing from the same in the fact that at the same period of growth the variety *Daytonensis* has a much greater diameter, while the rate of increase in size is, of course, also much greater. Most of the specimens found do not exceed 25 mm. in length. The polyp increases quite regularly in size, a few transverse wrinkles or annulations being occasionally found near the upper extremity. The apertural side is always convex in outline, and the opposite side, concave, excepting occasionally near the top where transverse wrinkles or annulations are present. The rate of curvature is about that of the more elongate forms of *C. celator* var. *Daytonensis* although much less than the more turbinate and more typical forms of that species.

Exteriorly the position of septa is indicated by longitudinal ribs, which may be quite distinct or even obsolete. Transverse striæ are also sometimes present, though in none of our specimens very conspicuous. The mouth of the calyx is more or less oblique. The number of septa varies from fifty to sixty-five, five septa occupying a width of about 2.8 to 3 mm. The calyx walls descend abruptly, the calyx having a depth of about 4 or 5 mm. On the apertural side is a septal fovea towards the border of which two or three septa are intercalated. Half the septa are of small size, not even reaching the base of the calyx as a rule. On each side the septa are crenulated; of these crenulations five come in a length of 1.8 mm. At the centre the septa are somewhat twisted. Excepting for the much more rapid increase of growth in *C. celator*, this species might be associated with that form. Specimens of this type are also found at Todd's Fork, near Wilmington, Ohio.

Cyathophyllum.

Two casts found at Cumberland Gap, Tennessee, present the characters of this genus. One of these is 10 mm. long, 10 mm. wide at the mouth of the calyx, has twenty-six large septa and twenty-six smaller ones extending two-thirds of the distance down the cast. The other specimen is 9 mm. long and 9 mm. broad;

there are nineteen large and nineteen smaller septa, the latter extending slightly more than half way down the cast. The dissepiments between these septa average five to six in a length of 2 mm. The specimens which these casts represent were originally perhaps 15 and 12 mm. long.

There is found at Collinsville a species of *Cyathophyllum*, which is erect, the outlines of the sides forming an angle of about 15° at the base. It has twenty-seven prominent vertical septa, alternating with twenty-seven very narrow septa, from which prominent spines project into the calyx. The species is about 20 mm. long and the diameter at the mouth of the calyx 12.5 mm.

At Collinsville, Alabama, are also found small specimens curved after the fashion of *C. facetus*, and larger specimens resembling *C. celator*. An undoubted specimen of *Streptelasma* allied to *Zaphrentis? bilateralis*, Hall, is also at hand. All these forms are scarcely worth describing, excepting for the fact that they show the existence of a certain type of corals in considerable numbers in the Clinton rocks of Alabama and Tennessee. They are all casts and not always of the best character.

Ptychophyllum ipomea sp. nov.

The specimens here described are from the upper layers of the Clinton Group at Allen's Quarry, east of Centreville, Ohio. The calyx of the best preserved specimen has a diameter of 56 mm. and is composed of ninety-seven septa, which have an average width of 2 mm. near the border of the calyx, where they are contiguous ; they gradually narrow towards the centre of the calyx, becoming separated ; at a distance of 6 mm. from the centre they are separated to the extent of about .5 to .8 mm. At the centre the lamellar septa of our specimens are not visible but are presumed to be more or less twisted as is common in the genus. At the border of the calyx the tops of the septa are broad and flattish, very moderately convex, and maintain this character for a greater or less degree for about 10 or 12 mm. where they gradually assume the lamellar form. The calyx is broad and flat or but moderately concave for about three-fifths the distance from the border to the centre of the calyx, after which the septa rapidly descend forming a central cup about two-fifths of the width of the calyx in diameter, and *at least* 5 mm. deep, although on account of the partial filling up of this central depression exact measurements cannot be given. Towards the border the margin of the calyx is usually slightly elevated, thus adding to the suggestiveness of the specific name. The septa as a rule are almost straight in the flattened portion of the calyx, although sometimes slightly curved, yet never as much so as in the Niagara specimen figured from Louisville, Kentucky. The vertical height of the specimen is about 33 mm. The external surface of the specimen is vertically marked by the septal furrows, which are in many places rather indistinct, and by concentric quite strong wrinkles with very few concentric striæ; the preservation of the exterior of the specimen is such as to suggest that fine striæ, even if originally present, have probably not been preserved. Various pits and markings on one side of the specimen may indicate the bases of former rootlets, but of this no certainty is felt. A section at the base of the specimen shows transverse dissepiments when the septa are not contiguous.

DIPHYPHYLLUM CÆSPITOSUM, Hall.

This species is common at Brown's Quarry west of New Carlisle Ohio, and at Ludlow Falls, Ohio. The specimen here described came from Brown's Quarry. The calyces have not been found well preserved, and beyond the fact that they are concave towards the centre, nothing can be said. The average diameter of the stems is 7.5 mm. The branches bud from the sides of the parent stem, have a diameter of about 3 mm. at their point of origin and gradually increase in size until again equalling the parent stem. The stems are cylindrical, abundantly striated transversely, the striæ sometimes assuming the proportions of stronger wrinkles, but never to the extent assumed in *Diphyphyllum rugosum*, Milne-Edwards. The form of that species figured by Rominger from the Niagara Group of Louisville occupies an intermediate position between the more typically rugose form figured by W. J. Davis from the Upper Niagara of Louisville, Kentucky (Pl. 109, fig. 1) and our Ohio Clinton form. The stems average about forty-five or fifty vertical septa of which one-half usually do not extend for more than 1.8 mm. towards the centre of the stems, the other half in large part terminating within 3 mm. from the border of the stem, while frequently a few twisted ends of the septa extend to the very centre of the stem. The septa are crossed towards the centre by horizontal diaphragms, which may occur at the rate of five or even more in a length of 3 mm. Near the ends of the smaller septa, within 1.8 mm. of the border of the periphery, these diaphragms bend upward and then outward to the periphery of the stem, the various diaphragms here either interfering or becoming increased by the addition of short dissepiments so that the peripheral portion of the stem is somewhat vesciculose.

This species is rare at Soldiers' Home, near Dayton, Ohio, and at Allen's Quarry, west of Centreville, Ohio. It is represented, together with *Illœnus Daytonensis*, from the Clinton of Yellow Springs, Ohio, in the Cabinet of Columbia College.

Our specimens more closely resemble the types and other specimens gathered from the locality where they were found than they do the published figures from the Niagara of New York.

Some of the specimens at Ludlow Falls are more rugosely wrinkled and mark an advance toward the *Diphyphyllum rugosum* type.

Streptelasma Hoskinsoni, sp. nov.

(plate ix, figs. 1-4; perhaps 5-6.)

This species is quite common at Brown's Quarry, west of New Carlisle, Ohio. The type specimen belongs to my own collection; all the other forms here described to that of Prof. W. S. Hoskinson. Its form is simple, inversely conical, tapering in the more typical forms quite regularly, with a few transverse annulations. The annulations are formed by a more or less sudden constriction of the mouth of the calyx, the continuation of the coral then beginning again at a slightly decreased diameter. In one specimen there are no annulations present and the coral tapers gradually throughout. In other specimens these constrictions occur frequently and irregularly. The last form figured under this species on our plate probably does not belong to this series, but it is impossible to distinguish it from an exterior view alone, from the shorter, less annulated forms.

The polyp is always slightly curved towards the base, the greater convexity being on the side of the apertural gap. The other side may be either gently concave or almost straight, except near the base. In some specimens the base of the polyp only is curved, the polyp soon after becoming erect. The exterior surface of the polyp walls is very regularly ribbed longitudinally, the ribs being usually gently convex, but sharply defined, and corresponding in number to the septa within. The septa vary from forty to fifty-five in number, and on the exterior five ribs occur in a width of 5 mm. at 25 mm. above the base. The surface is also finely striated transversely. Longitudinal sections indicate that the calyces have a depth of at least 8 mm., the sides of the calyces descending rapidly.

Diaphragms certainly occur in the regions below the calyx, but our sections did not reveal any dissepiments in the calyx. The rock in which they occur is almost a pure, white lime, and the structure was difficult to determine in our specimens. It was impossible with the collections at hand to distinguish from this species certain forms often irregularly bent, or unusually elongated which show similar vertical ribs, although the transverse wrinkles and striæ are usually more developed.

Streptelasma calicula, var. geometricus, var. nov.

(Plate IX, figs. 7, 13, 12.)

Of this form, the two smaller specimens figured belong to my own collection, the larger specimen to that of Mr. B. B. Thresher. The specimens are simple, usually slightly curved at the base, the greater convexity being on the side of the apertural gap. Above the base the polyp is perfectly erect and symmetrical. In some specimens the base itself is erect. The polyps taper regularly to the base, such constrictions as are found not exceeding in size the form of well-marked wrinkles and being of no structural value. The angle formed is usually about 45° or 50°. The surface of the specimen is ribbed longitudinally, the ribs corresponding to the number of septa within. Most of the specimens found do not exceed 20 mm. in height. The number of ribs on the exterior of these varies from fifty-two to seventy-two.

There are usually five ribs in a width of from 3 to 3.3 mm. The ribs are moderately convex, very distinctly differentiated and are crossed by fine striæ. A longitudinal section shows that the calyx has abruptly descending walls and is 7 or 8 mm. deep. The diaphragms are arched between the centre of the polyp and its walls, descending at the centre and apparently forming an invaginated tube there, also crossed by diaphragms. We have not enough sections to determine the matter definitely ; the same is true as to the existence of dissepiments between the septa of the calyx, none having been discovered, although striations perpendicular to the wall were seen, of what structural value could not be determined. Horizontal sections show a septal fovea on the apertural side, and that half the lamellæ do not extend more than 2 mm., sometimes 3 mm. from the walls of the polyp.

The much larger specimen from the cabinet of Mr. B. B. Thresher seems to be only an unusually large form of this species, the septa becoming more distant with age, so that near the top of the specimen five ribs occur on the exterior in a width of 5 mm. A careful examination of these ribs, however, will show a faint median groove, showing that a small additional septum is here intercalated in each case. This form can readily be distinguished from *Streptelasma Hoskinsoni* by its being more erect and having a more regular outline and a greater angle of growth. From *S. calycula* it may be distinguished by its generally more erect form and perfectly symmetrical development. The smaller typical specimens occur at the Soldier's Home Quarry, near Dayton, Ohio, and at Todd's Fork, near Wilmington, Ohio.

The larger specimen just described was found at the Soldiers' Home.

STREPTELASMA OBLIQUIOR, sp. nov.

(PLATE IX, FIGS. 14, 15.)

There is found, not infrequently, in the collection from Hanover, Ind., a small, simple, cup-shaped coral, of which it was impossible to determine accurately the genus, although the failure to find dissepiments in the calycular portion of the corallum makes it probable that it is some species of *Streptelasma* or *Zaphrentis*. The mouth of the calyx in all our forms is very oblique, the highest portion of the mouth being at the apertural gap, the lowest, on the opposite side. The corallum itself expands regularly and is convex on the apertural side and slightly concave in outline, on the opposite side. Most of the specimens show no external indications of septa, but in one much longer specimen there are external indications of the same in the customary longitudinal ribs, which are plain only along the upper half and chiefly on the apertural side. There are about thirty-five septa in the ordinary sized specimens 17 mm. long.

Comparison of the Clinton fossils of the eastern border of North America with those of the Cincinnati anticlinal.

It may seem at first thought that the strata of the Clinton group could be scarcely compared in the manner here suggested, and yet there are features at least of a negative sort in the Clinton of the Cincinnati anticlinal which will distinguish it from that of the Alleghany axis on the east.

Perhaps the most striking of these is the entire absence of *Leptocœlia hemispherica* from the anticlinal, while in the east this species is found throughout the entire range from Anticosti, through New York, Pennsylvania and Tennessee to Alabama.

Another is the absence of *Pentamerus ovalis* from the anticlinal, while it occurs in New York, Tennessee and Alabama.

Strophomena corrugata, the elongate form, occurs in the Clinton of New York, Pennsylvania and Tennessee, but not on the anticlinal. The variety *pluristriata* is also found in New York and Tennessee, but not in the Clinton of the anticlinal.

Strophomena obscura is found in the Clinton of New York and Tennessee, but not in the Clinton of the anticlinal.

Encrinurus punctatus is found rather frequently in the Clinton of Anticosti, New York, Tennessee and Alabama; it is exceedingly rare in the Clinton of the anticlinal and occurs rarely in a modified form from the Niagara of Ohio.

Cornulites Clintoni occurs in the Clinton of New York, Tennessee and Alabama; does not occur in the Clinton of the anticlinal, although a rather distantly related form, *Cornulites proprius*, occurs in the Niagara of Indiana.

A more interesting series of observations is that certain species, more or less common in the Clinton of the east, do not occur in the Clinton of the anticlinal, but appear at a later date in the Niagara.

Illænus Ioxus is found in the Clinton of New York and is doubtfully identified in the Clinton of Alabama; it does not occur on the anticlinal, but is known from the Niagara of Indiana and Wisconsin.

Ceraurus insignis is found in the Clinton of New York; not in the Clinton of the anticlinal, but in the Niagara of Indiana and Wisconsin.

Homalonotus delphinocephalus is found in the Clinton of New York and Pennsylvania, not in the Clinton of the anticlinal, but in the Niagara of Indiana.

Dalmanites limuluris is found in the Clinton of New York and Pennsylvania, not in that of the anticlinal, but in the Niagara of Ohio.

Pleurotomaria labrosa var. *occidens* is found in the Clinton of Tennessee and Alabama, not in the Clinton of the anticlinal, but in the Niagara of Wisconsin and Ohio.

Holopea obsoleta is known only from the Clinton of New York. The variety *elevata* occurs in Tennessee and Alabama, not in the Clinton of the anticlinal, but as a somewhat larger form from the Niagara of Wisconsin.

Streptorhyncus subplana is identified by G. B. Simpson from the Clinton of Mifflin and Blair counties, Pennsylvania, is not known from the Clinton of the anticlinal but is common in the Niagara of Indiana and according to Prof. James Hall is represented by *S. hemiaster*, Winchell and Marcy, in Illinois.

Spirifera radiata is found in the Clinton of Anticosti, New York and Tennessee, not in the Clinton of the anticlinal, but in the Niagara of Indiana and Illinois.

Spirifera rostellum occurs in the Clinton of Alabama, not in that of the anticlinal, but in the Niagara of Kentucky, near Louisville.

Atrypa reticularis is found in the Clinton of Anticosti, New York, Pennsylvania, Tennessee and Alabama, not in the Clinton of the anticlinal, but in the Niagara of Ohio, Indiana, Illinois and Wisconsin.

Rhynchonella Stricklandi is identified by G. B. Simpson from the Clinton of Huntingdon and Mifflin counties, Pennsylvania. It does not occur in the Clinton of Ohio, but is known in the Niagara of Indiana and is probably identical with *Rhynchonella Tennesseensis*, Roemer in the anticlinal region of western Tennessee.

Rhynchonella neglecta is identified by G. B. Simpson from the Clinton of Mifflin and Huntingdon counties, Pennsylvania. It has not been seen in the Clinton of Ohio, but seems to occur in the Clinton of Indiana and is certainly known from the Niagara of that state.

Pentamerus oblongus is found in the Clinton of Anticosti and New York, is absent in the Clinton of the anticlinal, but is found in the Niagara of Ohio and Wisconsin.

Calymene rostrata is found in the Clinton of New York and Georgia; it is not found in the Clinton of the anticlinal, but is represented in the Niagara of Indiana by *C. nasuta*.

What adds to the interest of these occurrences is the fact that at the present moment the fossils of the Clinton of Ohio at least are as well known as, if not better known than those of any of the eastern localities.

It will also be noticed that the forms in question are the more common species, having in some cases a wide geographical range, a number of them being transatlantic. They also have often a fair vertical range, so that forms occurring in the Clinton of the east, but only in the Niagara of the west, are also usually found in the Niagara in the east.

At first thought the explanation might seem simple: the Clinton of Ohio represents the earlier sedimentary deposits of the Clinton and hence does not present many fossils found in the later deposits of the east. But continued study does not bear out such an assertion. The Clinton forms of Ohio and Indiana show a more advanced stage of development than do the Clinton forms of New York; the types are decidedly Niagara and in larger percentage than in the Clinton of New York, but certain species are wanting in Ohio and Indiana Clinton which occur in the Clinton of New York, and which are there associated with forms belonging to as early a period in the history of the Clinton as the Clinton of the anticlinal, if not earlier. But in anticlinal regions these forms do not occur until at a later date, namely, the Niagara.

The Clinton as represented in Anticosti is closely linked with the Lower Silurian and the Niagara. The Clinton of Pennsylvania shows but slight advance over the Clinton of New York. The Clinton of Tennessee is about on the same level with that of Pennsylvania. The Clinton of Alabama as here described shows more marked affinities towards the Niagara than do the corresponding formations in Tennessee and Pennsylvania. And yet the solution of the problem, why certain forms are not represented in the Clinton of the anticlinal, does not seem to depend upon facts relating to the greater affinity of some of the eastern Clinton formations with the Niagara, since most of the forms in question appear in the Clinton of New York, believed to be of earlier age than the Clinton of the anticlinal, and also in Pennsylvania, where the Clinton does not differ substantially in age from that of New York.

Two suggestions may be offered as to the peculiar distribution of these forms in the Clinton. The first is that the fossils in question favored certain localities in the sea possibly those nearer the shore, and that these shore conditions did not occur at the anticlinal until at a later period. The extreme variability of shore conditions however implied by the character of the rocks farther eastward and the probability that parts of the anticlinal showed more shore action during the Clinton than did at least Anticosti, leaves, however, scarcely any margin for such a supposition.

The second is that the species in question may have been migrating towards the west at the time in question after the close of the break of the paleontological record, between the Upper and Lower Silurian epochs, and that they did not reach the anticlinal until after the close of the Clinton period of that region. If this could be established by further observations it would be an interesting point in paleontological research. But if they migrated, where did the forms come from originally? As far as may be determined from the character and thickness of the rock deposits now remaining from that time, the land of the Clinton sea seems to have been nearest southeastern Pennsylvania, and thence to have curved around towards the Atlantic, both on the north and the south, perhaps more rapidly towards the north. This land, judging from the contributions it made to sedimentary strata, from the Clinton to the upper Carboniferous periods must have had decidedly continental proportions. To our knowledge the sea deposits along the northwest of this paleozoic continent at present represented in part at least by the deposits of Anticosti was the only place showing comparatively no paleontological break between the Lower Silurian and the Clinton rocks and very likely was one of the sources from which certain of the Clinton fossils of the anticlinal came. The distribution of such forms as *Pleurotomaria* var. *occidens*, *Holopea obsoleta* var. *elevata* and *Spirifera rostellum* make it probable that such continuous breeding places for species existed also along the southwestern side of the paleozoic continent.

No doubt intermediate localities occurred of which we have no record and the position of which we cannot at present reconstruct. The very great range of many of the Clinton fossils, from Anticosti and New York to Alabama, while at a short distance off the line toward the westward they are absent for a time, or even permanently, make it probable that the species migrated north and south, comparatively freely in the shallower waters off the shore of the paleozoic continent, but that they found some physical obstacle in reaching the anticlinal. This obstacle was not land, since the well-borings of Ohio show that the Clinton is continuous between these two regions. Perhaps it was deep water which made the chances for migration over the short distance from the anticlinal to the Alleghany axis less satisfactory than the opportunities for migration for hundreds of miles along the western border of the old paleozoic continent.

That the anticlinal during the Clinton period was near land at least, seems probable from the occurrence of conglomerate in the southern exposures of the Clinton in Ohio. But what formations were then exposed and where, seems not so certain. The pebbles from the Clinton of Ohio near Belfast in Highland county do not present recognizable remains in any of the specimens seen by us, nor is their lithological character such as to present positive evidence of any except their sedimentary origin. The cement binding the pebbles together contains very fresh specimens of *Cyclonema bilix* and well preserved specimens of the so-called corals mentioned by the Ohio Geological Survey, but which are chiefly species of branched forms of *Ptilodictyæ: Ptilodictya famelicus*, *Ptilodictya rudis*, *Stictopora similis*, *Phœnopora fimbriata* and *Phœnopora magna*. *Cyathophyllum celator* var. *Daytonensis* was also found. Single specimens of *Orthis biforata*, with two plications in the mesial sinus, *Orthis elegantula* and a *Rhynchonella* resembling *Rhynchonella acinus* var. *convexa* were seen. All of the forms mentioned are common anticlinal Clinton forms.

The finding of the fossil tree, *Glyptodendron*, in the marine Clinton of Ohio, if authentic, would be only suggestive of the proximity of land, and the fact of its isolated occurrence would make a considerable distance from this land more than probable. Yet even if the existence of shallow water at the anticlinal be conceded, the existence of deep waters off the shore, between the anticlinal and the paleozoic continent on the east, can scarcely be proved at present. Yet for the present we suggest this view as a theory, perhaps to be compelled to withdraw it even ourselves should the proof to the contrary arise. That the anticlinal was of much consequence as a land exposure during the Clinton of Ohio seems rather doubtful, since a careful tracing of the Clinton from exposure to exposure, and its replacement where subsequent erosion is *evident*, leave unaccounted only places, in most of which subsequent erosion *can scarcely be denied*, even if not proven. This subject will receive more detailed consideration in a future paper.

EXPLANATION OF PLATES.

C. T., at the close of each reference, signifies that the fossils figured were collected at Cumberland Gap, Tenn.; C. A., at Collinsville, Alabama; H. I., at Hanover, Indiana; S. O., at Soldier's Home near Dayton, Ohio; B. O., at Brown's Quarry near New Carlisle, Ohio; E. O., at Eaton, O.

PLATE V.

Figs. 1–4. *Stricklandinia lens*, Sowerby. Figs. 1, 3, 4, casts of ventral valves; fig. 2, cast of dorsal valve; fig. 2 *a*, reconstructed interior of the dorsal valve. C. A.

Fig. 5. *Spirifera* (*Cyrtia*) *rostellum*, Hall. Cast of ventral valve and a line indicating its convexity. C. A.

Fig. 6. *Spirifera plicatella* var. *radiata*, Sowerby, dorsal valve. C. T.

Fig. 7. *Cornulites distans*, Hall. C. A.

Fig. 8. *Cornulites serpularius* var. *Clintoni*, Hall. C. A.

Fig. 9. *Leptæna transversalis*, var. *Alabamensis*, Foerste. Cast of ventral valve, and a line indicating its convexity. C. A.

Figs. 10–12. *Euomphalus sinuatus*, Hall. Fig. 10, view of the spire-the spire conjecturally completed from the curvature of the fragment, found; fig. 11, an entirely conjectural figure of a side view based on the slight elevation of the spire indicated by the fragment found, but serving to indicate the actual position of the sinus at *a*; *a* is a view of the sinus, the position of which is indicated in figs. 10 and 11; fig. 12, a view of a part of the fragment found, from the umbilical side. C. A.

Fig. 13. *Leptæna transversalis*, var. *prolongata*, Foerste. Ventral valve and a line indicating the convexity of the same. Wildwood station, Georgia.

Fig. 14. *Pleurotomaria labrosa* var. *occidens*, Hall. C. A.

Fig. 15. *Cyclonema bilix*, Conrad. B. O.

Fig. 16. *Conularia Niagarensis*, Hall. Todd's Fork, Ohio.

Figs. 17, 18. *Pentamerus ovalis*, Hall. Fig. 17, a finely preserved cast of a dorsal valve; fig. 18, a cast of a ventral valve. C. A.

Fig. 19. *Pterinea*. C. A.

Fig. 20. *Illænus*, perhaps *I. Ioxus*, Hall. Fragment of a glabella, possible outlines indicated. C. A.

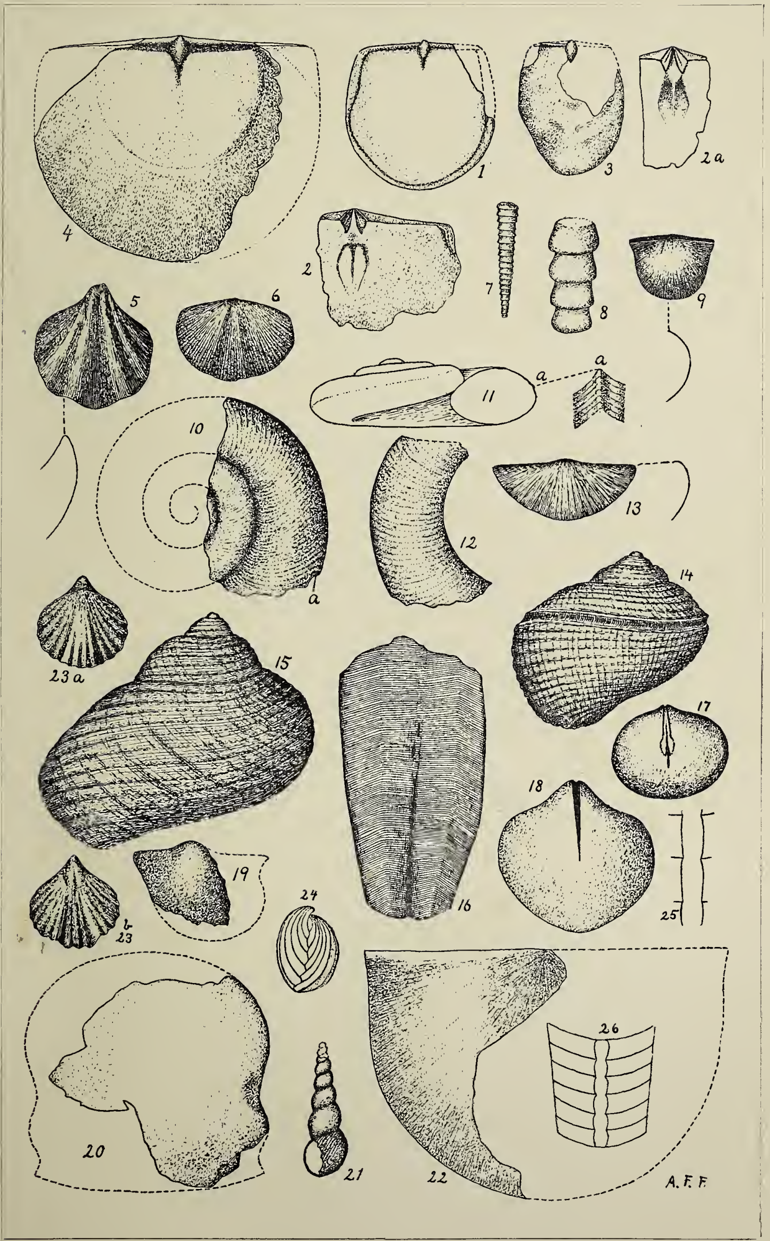
Fig. 21. *Holopella?* cf. *Loxonema subulata*, Conrad. The striæ partly preserved on the last coil. Todd's Fork, Ohio.

Fig. 22. *Strophomena patenta*, Hall. Fragment, dorsal valve, its original outlines restored. C. A.

Figs. 23, 24. *Rhynchonella Janea*, Billings. Fig. 23 *a*, inner cast of a dorsal valve; 23 *b*, inner cast of a ventral valve; fig. 24, side view of an inner cast.

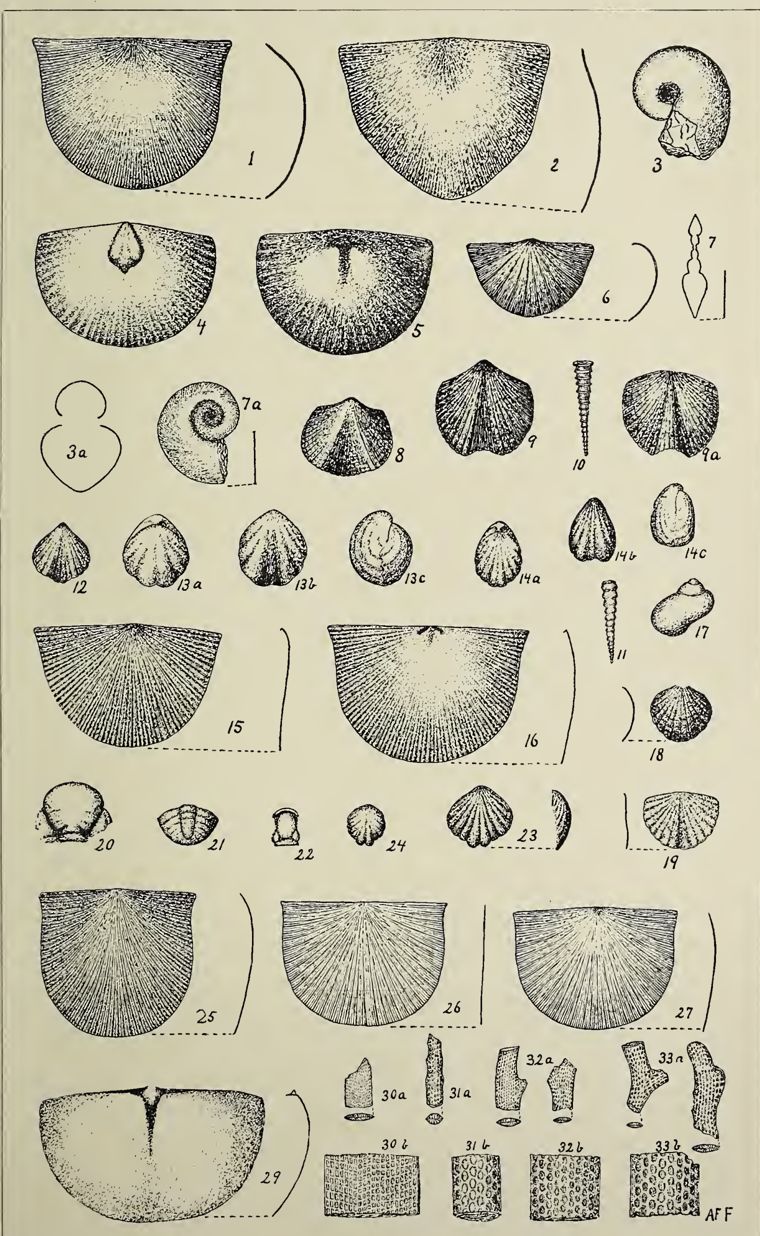
Fig. 25. *Orthoceras Nova Carlislensis*, Foerste. A section of the siphon.

Fig. 26. *Orthoceras Crawfordi*, Foerste. A vertical section showing the siphon.



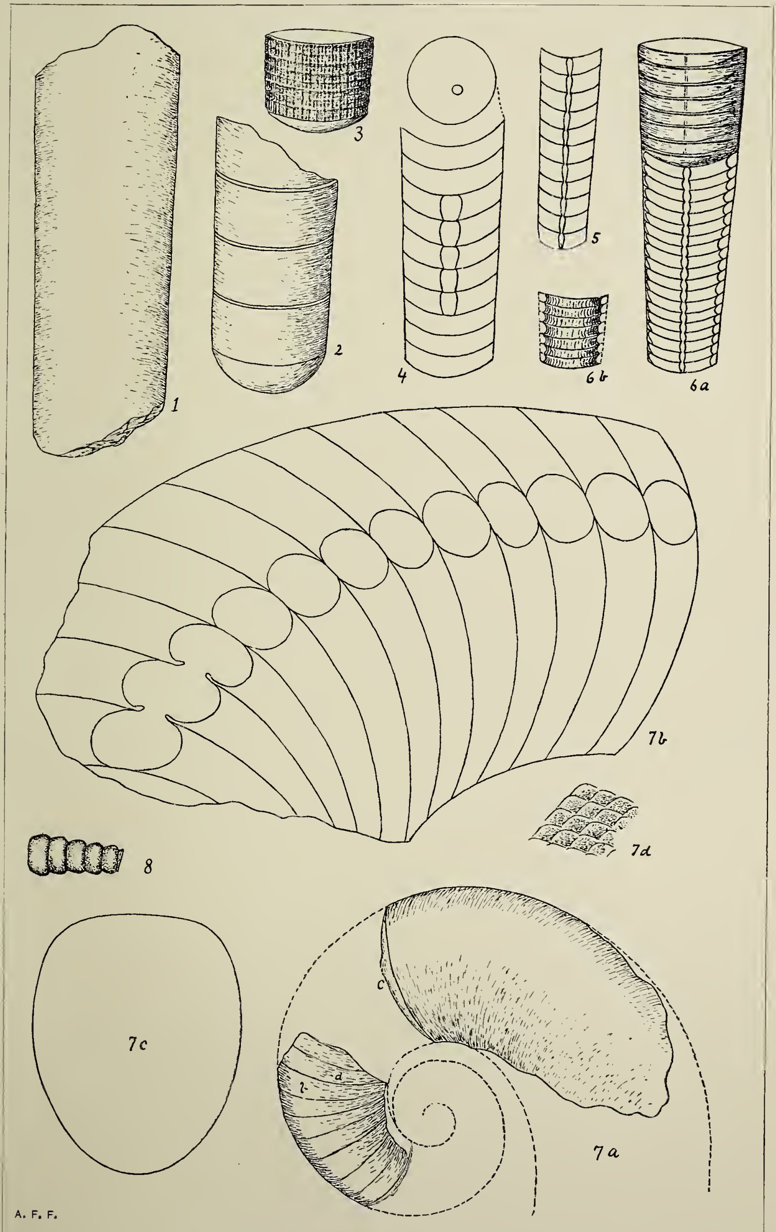
LUX CO., BOSTON.

Fossils of the Clinton Group.



LUX CO., BOSTON.

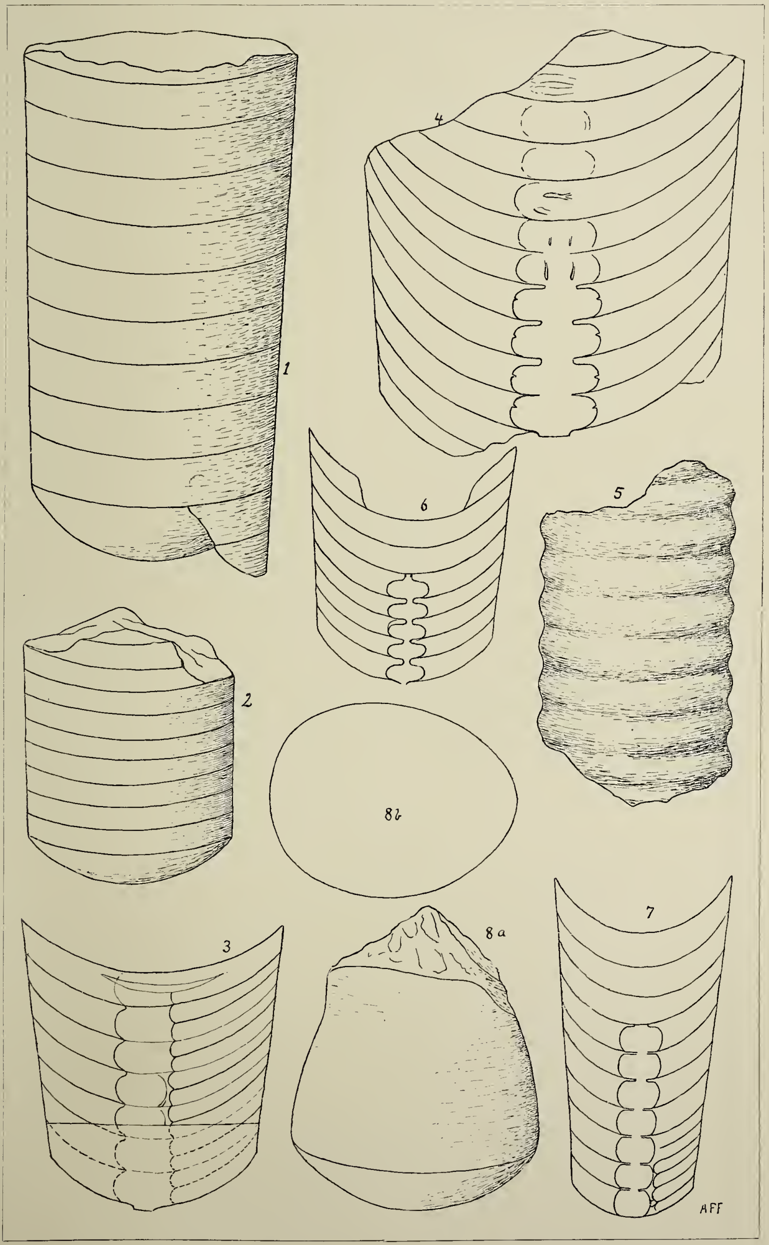
Fossils of the Clinton Group.



LUX CO., BOSTON.

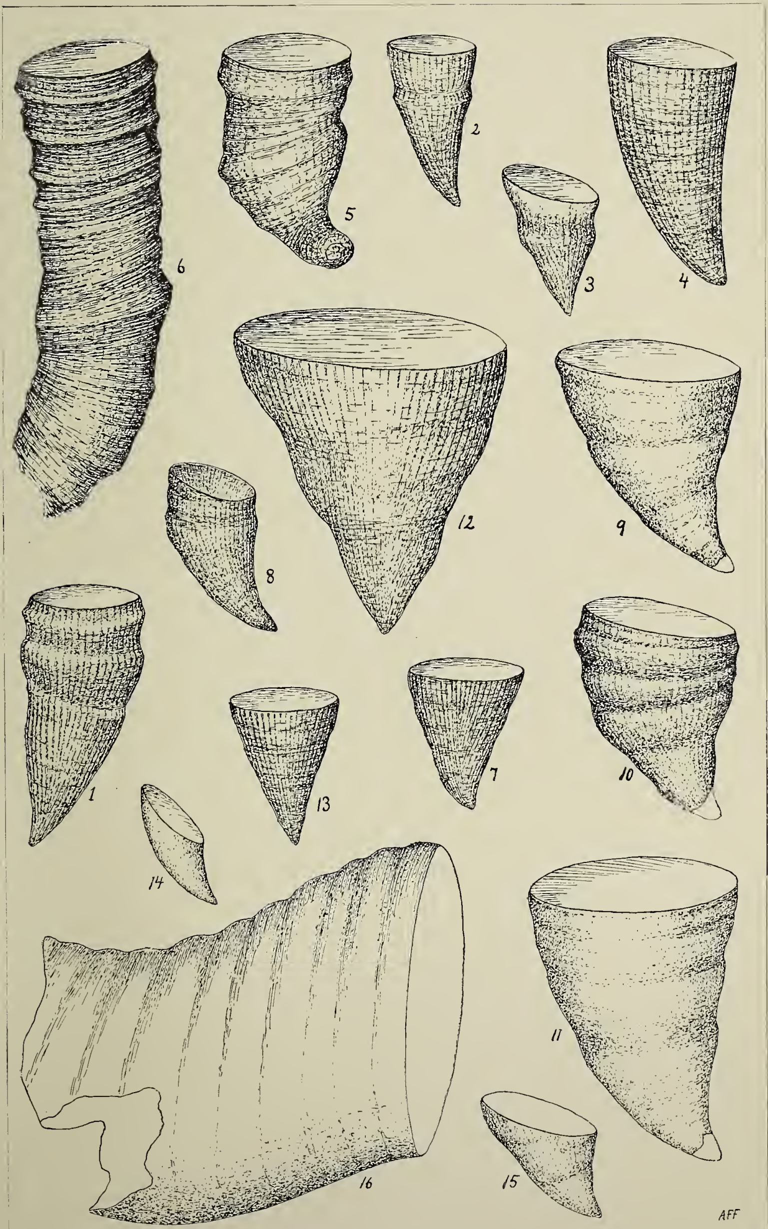
Fossils of the Clinton Group.

 Plate VIII.



LUX CO., BOSTON.

Fossils of the Clinton Group.



LUX CO., BOSTON.

Fossils of the Clinton Group.

PLATE VI.

Fig. 1. *Strophomena Hanoverensis*, Foerste. Ventral valve and a line indicating its convexity. H. I.

Fig. 2. *Strophomena patenta*, Hall? Apparently a sickly form, dorsal valve, and a line indicating its convexity. H. I.

Fig. 3. *Bellerophon* (*Bucania*) *exigua*, Foerste. Fig. 3, side view; 3*a*, lines indicating the character of a section transverse to fig. 3. H. I.

Figs. 4, 5. *Orthis calligramma*, *Dalman* var. *flabellites*. Fig. 4, cast of a ventral valve; fig. 5, cast of a dorsal valve. H. I.

Fig. 6. *Leptæna transversalis*, var. *elegantula*, Hall. Ventral valve, and a line indicating its convexity. H. I.

Fig. 7. *Cyrtolites Youngi*, Foerste. Fig. 7*a*, a magnified side view with a line indicating the real size of the specimen; fig. 7, lines showing the outlines of a section vertical to fig. 7*a*, also magnified. H. I.

Fig. 8. *Atrypa marginalis*, var. *multistriata*, Foerste. Ventral valve. H. I.

Fig. 9. *Atrypa marginalis*, Dalman. Fig. 9, ventral valve; fig. 9*a*, a dorsal valve. B. O.

Figs. 10–11. *Cornulites distans*, Hall. Fig. 10 resembles a species of *Tentaculites*; fig. 11, both in the cast and in the exterior views, is a figure of a true *Cornulites*. C. T.

Fig. 12. *Rhynchonella neglecta*, Hall. Ventral valve. H. I.

Fig. 13. *Rhynchonella acinus*, var. *convexa*, Foerste. Fig. 13*a*, dorsal valve; fig. 13*b*, ventral valve; fig. 13*c*, side-view. H. I.

Fig. 14. *Rhynchonella acinus*, Hall, from the Niagara of Waldron, Indiana, the most distinct form; fig. 14*a*, dorsal valve; fig. 14*b*, ventral valve; fig. 14*c*, side view.

Figs. 15–16. *Leptæna obscura*, Hall? Fig. 15, dorsal valve, and a line indicating its convexity; fig. 16, ventral valve and a line indicating its convexity. C. T.

Fig. 17. *Holopea obsoleta*, var. *elevata*, Foerste. C. T.

Figs. 18–19. *Leptocœlia? hemispherica*, Sowerby. Fig. 18, ventral valve, with a line indicating its convexity; fig. 19, dorsal valve, with a line indicating its convexity. C. T.

Figs. 20–21. *Phacops pulchellus*, Foerste. Fig. 20, a glabella; fig. 21, a pygidium. C. T.

Fig. 22. A glabella of *Cyphaspis Clintoni*, Foerste. C. T.

Figs. 23–24. *Rhynchonella decemplicata*, Sowerby? Fig. 23, a dorsal valve and a side view of the same; fig. 24, perhaps a young form of this species. C. T.

Fig. 25. *Strophomena corrugata*, Conrad. The elongated form figured first by Hall under this species, but not the typical form of Conrad. C. T.

Figs. 26–27. *Strophomena corrugata*, var. *pluri-striata*, Foerste. More like that figured second by Hall under *S. corrugata*. It is not impossible that this may prove to be the typical form of Conrad. Fig. 26, dorsal valve, and a line indicating its lack of convexity; fig. 27, ventral valve, with a line indicating its convexity. C. T.

Fig. 29. *Stricklandinia lens*, Sowerby? ventral valve and a line indicating its convexity. C. T.

Fig. 30. *Ptilodictya emarcescens*, Foerste. Fig. 30*a*, part of a frond, with a section showing its convexity; fig. 30*b*, a part of the same magnified. E. O.

Fig. 31. *Ptilodictya farctus*, Foerste. Fig. 31*a*, part of a frond, with a section showing its convexity; fig. 31*b*, a part of the same enlarged. E. O.

Fig. 32. *Ptilodictya famelicus*, Foerste. Fig. 32*a*, parts of two fronds with section showing their convexity; fig. 32*b*, a part of the left hand specimen enlarged. E. O.

Fig. 33. *Ptilodictya rudis*, Foerste. Fig. 33*a*, parts of two fronds with sections showing their convexity; fig. 33*b*, a part of the left hand specimen enlarged.

PLATE VII.

Figs. 1, 2. *Orthoceras rectum*, Worthen, var. *junior*. Fig. 2, a side view; fig. 1, a specimen with a smooth exterior, perhaps of this species. H. I.

Fig. 3. *Orthoceras Jamesi*, Hall and Whitfield. Side view. Todd's Fork, Ohio.

Fig. 4. *Orthoceras ignotum*, Foerste. A vertical section through the siphon, with a transverse section indicating the position of the same. H. I.

Fig. 5. *Orthoceras virgulatum*, Hall? A vertical section through the siphon. S. O.

Fig. 6. *Orthoceras Hanoverensis*, Foerste. The upper part of the figure (fig. 6*a*) represents a view of the cast of the interior of the shell; the lower part represents a vertical section of the same passing through the siphon; fig. 6*b* represents a part of the other side of fig. 6*a*, where it has been weather-worn. H. I.

Fig. 7. *Cyrtoceras? subcompressum*, Hall. Fig. 7*a* is a side view of two fragments upon which this species is founded; the smaller, the type; the larger, a part of the living chamber, placed in the position they are supposed to have once occupied, while the character of the remainder of the coil is conjecturally indicated. The diameter of the whole is reduced to one-fourth. The coil as here figured is imaginary. It may have been a closed coil but probably was not; fig. 7*b*, a vertical section through the type showing the character of the siphon; fig. 7*c*, a transverse section of the living chamber near the last septum reduced to one-half the diameter; fig. 7*d*, showing the character of the surface marking of the type at *d*, in fig. 7*a*, but representing them far more distinctly than warranted by their actual state of preservation. B. O.

Fig. 8. *Cornulites serpularius* var. *Clintoni*, Hall. C. A.

PLATE VIII.

Fig. 1. *Orthoceras Nova-Carlislensis*, Foerste. View of interior cast. B. O.

Fig. 2. *Orthoceras rhythmoides.* Foerste. View of the interior cast. B. O.

Fig. 3. *Orthoceras* (*Actinoceras*) *Youngi*, Foerste. A vertical section showing the siphon on one side. H. I.

Fig. 4. *Orthoceras* (*Actinoceras*) *lata-nummulatus*, Foerste. A vertical section through the siphon. S. O.

Fig. 5. *Orthoceras annulatum*, Sowerby. A badly preserved exterior. B. O.

Fig. 6. *Orthoceras* (*Actinoceras*) *Daytonensis*, Foerste. A vertical section passing through the siphon. S. O.

Fig. 7. *Orthoceras* (*Actinoceras*) *turgida-nummulatus*, Foerste. A vertical section passing through the siphon. S. O.

Fig. 8. *Gomphoceras.* Fig. 8*a*, a side view of the living chamber; fig. 8*b*, a transverse section of the same near the last septum. B. O.

PLATE IX.

Figs. 1–6. *Streptelasma Hoskinsoni*, Foerste. Figs. 1, 2, 3, 4, various typical forms; fig. 5, a very contorted form doubtfully referred here; fig. 6, a transversely wrinkled form, perhaps an *Amplexus*, provisionally referred here. B. O.

Figs. 7, 12, 13. *Streptelasma calycula*, var. *geometricus*, Foerste. Fig. 7, the type specimen, S. O.; fig. 12, a similar form, Todd's Fork, Ohio; fig. 13, a larger form referred here. S. O.

Fig. 8. *Cyathophyllum facetus*, Foerste, found at the roadside quarry east of S. O.

Figs. 9–11. *Cyathophyllum celator* var. *Daytonensis*, Foerste. Figs. 9, 10, from S. O.; fig. 11, probably from the same place, now in the cabinet at the Ohio State University.

Figs. 14, 15. *Streptelasma? obliquior*, Foerste. Fig. 14, typical form; fig. 15, perhaps larger form of the same. H. I.

Fig. 16. *Lituites?* B. O.

Note.—The following corrections in the references to plates in the text should be made: On p. 268, Plate III should be Plate V, and Plate IV should be Plate VI; Plate IV on page 272 should read Plate VI.

General Meeting, November 6, 1889.

The President, Prof. F. W. Putnam, in the chair.

Prof. Thomas Dwight read a paper on the "Joints and Muscles of Contortionists."

Professor Dwight began by stating that this was essentially a more scientific treatment of the subject of his paper in Scribner's Magazine of April, 1889. He referred to the "forward" and "backward" varieties of contortionists. Occasionally the same man can do work of both kinds, but never in the same perfection as those who become very expert in a single kind of work. These latter usually present peculiarities in their skeletons depending on their work. The lumbar region of the " backward " performer becomes excessively hollowed, while the spinous processes of the same region may become enlarged in the " forward " man owing to the strain of the supra-spinous ligament which is made tense by flexing the spine. Those of moderate proficiency and who practise both kinds of contortion may show neither of these peculiarities. It is necessary that the thorax of the " backward " man should be flexible and able to yield. " Backward " contortion is essentially in the spine. Probably the power of relaxing antagonistic muscles comes into play, but this is more strikingly shown in the forward acts. These involve other joints, for mere forward bending of the spine gives little variety. One of the feats is to put one or both thighs and legs straight upward, either standing on the other in the case of one, or resting on the hands in the case of both. Now every one can flex the hip and straighten the knee, but the trouble is to do both at once, and it seems as if the hamstring muscles must either be longer, more elastic, or that the individual must have the power of relaxing them. The position known as the "stride" in which one leg is thrown straight forward and the other back is essentially the same as the one just mentioned, and we need assume no peculiarity of the joints to account for them unless in rather extreme cases. The " split," however, in which the legs are thrown nearly straight out sidewise with the toes upward is probably a physical impossibility in spite of early training and the power of relaxing muscles, to those who do not have a peculiarity of the joints. Dr. Dwight believed that there was in these cases a partial dislocation. It must be remembered that parts of the ligamentous apparatus of a joint may be lax and others not, and that the latter with the assistance of muscles may be sufficient for the needs of the joint for support and locomotion as it is not in every position that the strong bands of all joints are tense. At the shoulder joint the head of the humerus is retained by muscular action. A joint, the ligaments of which are, at least in part, overlax is not an absurdity. It is evident that this power of partial dislocation will make postures which are possible without it still more remarkable. It is therefore of great assistance to a contortionist though not necessary for most positions. A photograph of the hand of a forward performer was shown to prove that he could dislocate his fingers. A certain amount of contortion can probably be taught to young children by practice, but for eminence certain natural gifts are requisite.

Professor Dwight's paper was illustrated with the stereopticon.

The Secretary then read a communication from Prof. G. Frederick Wright in relation to the Nampa Image found in borings in Nampa, Idaho. He also read letters from Mr. Charles Francis Adams, Mr. M. A. Kurtz and Prof. S. F. Emmons in relation to the discovery of the image, and the geology of the formation from which it was taken. This evidence will be published in the proceedings of a subsequent meeting. Remarks on the antiquity of the image were made by Professors Putnam and Haynes, Messrs. Warren Upham and S. H. Scudder.

The following paper was read by title:

REPLY TO THE QUESTIONS OF MR. SELWYN ON "CANADIAN GEOLOGICAL CLASSIFICATION FOR QUEBEC."

BY JULES MARCOU.

Mr. Alfred R. C. Selwyn, Director of the Geological Survey of Canada, in a paper lately published in these Proceedings, Vol. xxiv, p. 216, July, 1889, says: "It becomes quite evident that his [Mr. Marcou's] statements are simply expressions of his individual opinion and certainly have 'no basis of fact' to support them." "There are, however, one or two pertinent questions to which I think Mr. Marcou might be asked for a reply." He then enumerates several questions numbered 1 to 7 and half a dozen others not numbered, although comprised in what he calls "one or two pertinent questions."

Here is my reply to his questions:

First question: "Does he think Emmons, Logan and myself and many other geologists, who agree with us, do not know gneiss from quartzite? A simple yes or no to this would suffice."

Reply: Yes.[1] Does Mr. Selwyn think Dr. Charles T. Jackson,

[1] Emmons wrote the article: "Geology of Montmorenci" (*Amer. Magazine*, Nov., 1841; reprinted in *Amer. Geologist*, Aug., 1888) after a short and hasty visit, which was never repeated. From my knowledge of Dr. Emmons, I have no doubt that he would have corrected his error; for no one was more ready than he, to accept a correction. But with Logan and Mr. Selwyn, it is very different. After the publication of my joint

Delesse, Daubrée, Barrande, Capillini and myself and many other geologists who agree with us, do not know quartzite from gneiss?

Now that I have answered as briefly as Mr. Selwyn wished me to do, I shall leave it to the geologists to judge of the merits of the question of the so-called "Laurentian gneiss" of the Fall of Montmorency.

In 1861, on my second visit to Montmorency, wishing to see why Logan continued to call the beautiful quartzite which forms the bed of the Montmorency river, the chasm of the precipice and the foot of the fall "Laurentian gneiss," I took special care to observe very closely the rocks and brought away with me specimens taken *in situ* at different places, choosing specimens to illustrate the average structure and composition of the rocks, in order to submit them to other practical geologists well informed on lithology, being unwilling to rely entirely upon myself. I first showed my specimens to Dr. Charles T. Jackson of Boston, who declared that they were quartzites. When in Paris in 1866, I showed them to Delesse who called them quartzites, and afterwards to Barrande and Daubrée who said, "pure quartzites." Prof. G. Capellini of Bologna also visited the Montmorency fall in 1863 and published a description with a section of the fall (see *Ricordi di un viaggio scientifico nell' America settentrionale*, p. 55, Bologna, 1867), in which he refers the rocks of the fall and river bed near the precipice to the quartzites.

Mr. Selwyn, in his correspondence with me, insisted that the rocks were gneiss. I asked him to collect *in situ* at different places of the fall several specimens and to send them to Mr. M. E. Wadsworth, Director of the Michigan School of Mines, the best expert in lithology in America, adding that I would accept his determination. Mr. Selwyn has made no answer to my proposal.

If Mr. Selwyn is truly desirous of settling the lithological question of the composition of the rocks forming the Fall of Montmorency, I hope he will be induced to send specimens to Prof. H. S.

note with Barrande ("The primordial fauna and the Taconic system" in *Proceed. Boston Soc. Nat. Hist.*, 1860), in which I call the rock forming the fall, *quartzite*, from notes taken in Sept., 1849, when visiting Montmorency, Logan chose to disregard my determination of the rocks and continued in all his numerous publications on the fall of Montmorency, to call the rocks *gneiss*. Mr. Selwyn has done the same, publishing a section of Montmorency fall as late as 1884, in which he refers the rocks forming the fall to gneiss. So with Logan and Mr. Selwyn: the determination of the quartzite of Montmorency fall, as "Laurentian gneiss," is made with the full knowledge of the different opinions of other practical geologists.

Rosenbuch of Heidelberg, to Messrs. T. H. Bonney, J. J. H. Teall of London, or to M. Michel Lévy of Paris, all excellent lithologists who are trusted by everybody. I hope Mr. Selwyn will not content himself with saying that "it seems almost idle to attempt any discussion or explanation about the geology of Quebec with Mr. Marcou, because when he has the boldness to assert that the Fall of the Montmorency is not over gneiss, in spite of the dictum of every other geologist who has visited and examined it and when . ."

The value of the section of the Fall of the Montmorency, made by Prof. Capellini is far greater than the three sections published by Logan and Mr. Selwyn; and I do not hesitate to say that my own knowledge of the Fall is supported by a "basis of fact" well observed; while, on the contrary, the sections of Logan and Mr. Selwyn with their folded "Laurentian gneiss" are fanciful to the last degree and contrary to what exists there and, according to my observations, "certainly have 'no basis of fact' to support them."

The use of the adjective "Laurentian" with gneiss has not the power to change a quartzite into a gneiss.

Second question: "What are the sandstones of the Strait of Belle Isle if not Potsdam?"

Reply: The sandstones designated by Logan, Billings and Richardson as A, B, C of their section of the rocks of the Strait of Belle Isle "have nineteen species of fossils, none of which are found in the Potsdam sandstone of Canada. In that part of the group which is usually known in the State of Vermont under the designation of the Georgia slates" (*Palæozoic fossils* by Billings, Vol. I, p. 371), the following fossils occur: *Obolella* (*Kutorgina*) *cingulata*, *Olenellus Thompsoni*, *O. Vermontana* and *Conocephalites Teucer*, all most characteristic species of the Georgia formation of the upper part of the Middle Taconic, which is far below the Potsdam. I do not go so far as Mr. Walcott who, in his last paper ("Stratigraphic position of the Olenellus fauna in North America and in Europe," *Amer. J. Sc.*, 1889), places the Georgia formation, which has the fossil *Olenellus Thompsoni*, in the Lower Taconic. He puts it below the shales with *Paradoxides* of St. John, New Brunswick, and those of St. Mary's bay, Newfoundland, and those of Braintree, Mass. He places the Georgia group in parallelism and regards it as the equivalent of the lower part of Manuel's brook section with *Holmia* (called by mistake *Paradoxides* and *Olenellus*) *Bröggeri* Walcott. In Mr. Walcott's judgment the

Olenellus Thompsoni sandstone of Lance au Loup, Strait of Belle Isle, are so far below the Potsdam that he places them at the base of the Taconic, while the Potsdam sandstone is placed at the top. The thickness of strata between them is at least twenty thousand feet. But I think this is another great mistake of the adversaries of the Taconic who cannot agree among themselves as to the exact position of a single group of the system named by them Cambrian. A Cambrian of their own making, as far as possible of the original Cambrian system of Sedgwick.

It, therefore seems, that, according to Billings and Mr. Walcott, the sandstones of the Strait of Belle Isle are not Potsdam, but belong to the Georgia formation.

Third question: " If the Pointe Lévis beds are older than the Potsdam, why have they never yet been discovered underlying the latter?"

Reply: Because in the part of the province of Quebec where the Pointe Lévis beds exist, the Potsdam was not deposited.

Fourth question: " Page 69 (*op. cit.*), we are told ' we have there [vicinity of Quebec], two distinct formations, one of very small extent [? thickness] belonging probably to the Trenton and another extremely thick, forming the hill of the City of Quebec, Pointe Lévis and La Chaudière Falls [here are three very distinct series lumped together, Selwyn], strongly upheaved and broken before the deposit of the Trenton limestone.' Why, if this impression is correct, is the Trenton limestone, nowhere in its entire course of hundreds of miles, seen resting on anything resembling this supposed older formation?"

Reply: "Very small extent" for the Trenton means thickness as well as ground covered by the formation. "The hill of the city of Quebec, Pointe Lévis and La Chaudière Falls" are mentioned as geographical places only; and instead of having committed the mistake of "three very distinct series lumped together," as Mr. Selwyn accuses me; on the contrary, as far back as 1862, many years before Mr. Selwyn came to Canada, I had divided tne series of strata into three distinct formations, called then by me Quebec group (City of Quebec and not the Quebec group of Logan for the whole province), Pointe Lévis group and Chaudière and Sillery group (see *letter to M. Joachim Barrande, on the Taconic rocks of Vermont and Canada*, p. 9 and following, Cambridge, 1862). The statement that I have embraced in one formation "three very distinct series lumped together" is an assertion contrary to plain fact and an error of Mr. Selwyn.

"The Trenton limestone is nowhere, in its entire course of hundreds of miles, seen resting on anything resembling this supposed older formation." I have given, close by the city of Quebec, the section from Charles river to Charlebourg, showing that the Trenton limestone at the Trèsplat, rests upon older slates of the Citadel Hill and Quebec city formation (see *Memoirs Boston Soc. Nat. Hist.*, vol. IV, pl. 13, 1887). It is very easy at that place to see on what rocks the horizontal Trenton limestones lie; and I have asked Mr. Selwyn to have an excavation or two made just at the foot of the little plateau formed by the beds of the Trenton limestone overlooking the church and the village of Charlebourg, but he has not answered my request up to the present time. I have explained in my paper (*Canadian geological classification for the province of Quebec*, p. 71) how it came about that erosion and denudation have reduced to extremely limited dimensions the Trenton limestone, and I shall not repeat it.

Fifth question: "If there is no fault, as indicated by me between Lévis and the citadel, why do the Lévis beds not reappear with their characteristic fossils on the Quebec side directly towards which they are striking?"

Reply: At Pointe Lévis where the lenticular masses of limestone with their characteristic fossils exist, the beds do not strike directly toward the Quebec side; on the contrary they strike in the opposite direction or east-east-south. That a fault exists, as indicated by Mr. Selwyn, between Lévis and the citadel in the bed of the St. Lawrence river, is a supposition which nobody can prove, and has "no basis of fact" to support it. If Mr. Selwyn is "able to discern the evidence of a fault" as he claims, he will have to point it out somewhere else than in the middle of the bed of the river St. Lawrence.

Sixth question: "Would Mr. Marcou state where I have ever called the break synclinal?"

Reply: On page 3 of *The stratigraphy of the Quebec group*, by A. R. C. Selwyn, 1879, Mr. Selwyn says, "a broad cramped and folded synclinal."

Seventh question: "When did I say, or even imply that I could 'almost point out what part of the northern coast of the St. Lawrence and Labrador they came from as boulders?' "

Reply: I have no time for researches among the twelve or fifteen bulky volumes of the Reports of the Geological Survey of Canada; therefore Mr. Selwyn will excuse me if I quote his letter to me, dated November 6, 1884. He says, "I have, I think, also determined the *source* of the very peculiar limestone pebbles in the Lévis and Bic Harbor conglomerates which hold characteristic ancient forms of trilobites. It is far to the north around the shores of Lake Mistassini and along the east coast of Hudson Bay."

I have now replied to the seven (not one or two) pertinent questions asked by Mr. Selwyn. It is useless to answer the half-dozen others, not numbered, and his statement that "there are in Mr. Marcou's papers a great many more inaccuracies, misstatements." I have long ago given up all hopes and recognized the impossibility of convincing Mr. Selwyn. During many years I have patiently answered all his long letters and endless inquiries, but without making the smallest impression on him. Further discussion is useless and cannot give any result.

I shall only refer, to end the discussion on my part, to his saying: "Had Mr. Marcou investigated the facts on the ground over the whole area as closely and carefully as I and my colleagues have done during the past twenty years, he would at least have some right to criticise our work . . . but to criticise as Mr. Marcou does after very partial observations, and consequently in ignorance of many most important facts, and entirely regardless of others, is, I think, misplaced."

Mr. Selwyn, according to his last report of 1887, had under his orders fifty assistants and an annual appropriation of $115,000; while I am entirely without any help, having to pay all my expenses and to do all the work without the assistance of a single colleague. However, I have "closely and carefully" "investigated the facts" at Pointe Lévis, and published in 1864 (Bulletin Soc. géol. France, vol. XXI, p. 236, Paris), a detailed paper with a map and a section, very different from those of the Canadian Geological Survey papers, published on the same locality in 1861 and 1865. Hitherto, not a word has been said against the exactness of my observations at Pointe Lévis, notwithstanding the "last twenty years of careful and close investigation of Mr. Selwyn and his colleagues."

On the contrary, I have received several favorable opinions as to their value. The last one which was received is from Capt. A. W. Vogdes and is dated Fort Hamilton, New York Harbor, Oct. 15,

1889. It reads as follows: "I am under obligations to you for the valuable aid your excellent article, *Sur les gisements des lentilles taconiques de la Pointe Lévis*, gave me during my investigations on the 'Quebec group,' so that I feel called upon to address you a letter of thanks."

My observations on some other portions of the vicinity of Quebec, although not so thorough as at Pointe Lévis, instead of being, as Mr. Selwyn says, only partial and in "ignorance of many most important facts," were made and checked most carefully. In fact I saw enough to be able to deal with the strata and their great divisions, as they exist around Quebec city, Pointe Lévis and La Chaudière.

Mr. Selwyn has the advantage over me of time, money and assistants; and it is his duty, as Director of the Survey, to make a complete and detailed map and report of the district of the city of Quebec, which he says "will soon be ready for publication;" but is far from being yet complete enough to be issued. This work ought to have been published many years ago; for it is an absolute necessity to have represented on a good geological map, prepared by the Geological Survey of Canada, the fault in the rear of the Quebec citadel, the one under the river in front of the fortress, the one from Pointe Pizeau to St. Foix, and the geographical distribution and description of the four thousand feet of the Hudson river group, called Citadel Hill slates, and placed above the Trenton and Utica as the equivalent and homotaxis of the four hundred feet of the Lorraine shales of the vicinity of Ottawa and the state of NewYork.

Mr. Selwyn is dissatisfied with my criticism of his geological maps and with my conclusions on the singular classifications made by his predecessors. He calls them "rash and incorrect" and also speaks of "inaccuracies, misstatements, and partial references," and announces that he "will give the final conclusions reached by the Survey." I have criticised Logan and Mr. Selwyn's works on the area of the vicinity of Quebec, for the sake only, of the progress of geology and knowledge of truth; at the special request of Barrande, Billings, Jewett and L. Agassiz, who asked me repeatedly in 1860, '61 and '62 to explore Pointe Lévis and Montmorency Fall. My motives are as honorable as it is possible to imagine. No pay, no help, no reward of any sort to expect; great distances to travel before reaching Quebec, and hard work at hand when there; and I have only to sustain me, my love of geology and my consciousness of doing work, which nobody else was willing to undertake.

Happily in geology a Director of a geological survey backed by large appropriations, and a staff of fifty assistants or colleagues, cannot make erroneous observations and have "his individual opinion" accepted as correct for any length of time; and whatever Mr. Selwyn may think of my researches about the city of Quebec, I have full confidence in the long run in the value of my observations made in conformity with all the principles of practical stratigraphy and in accord with lithology as well as palæontology. For we are now already very far from my starting point of 1849, when I first made a hasty survey of the vicinity of Quebec, in company with my friend Francois Xavier Garneau, the historian of Canada. The "thick development of slates" of Quebec, Pointe Lévis and La Chaudière cannot now be referred to the Hudson river group, the Oneida and Medina formation, and the primordial fauna of Pointe Lévis cannot be transferred above the second fauna. Mr. Selwyn is making the last effort to save what he can of that singularly incorrect classification used by the Geological Survey of Canada, and his remarks on my last paper "certainly afford no assistance in elucidating the geological structure of such a complicated region as we have to deal with in the Province of Quebec" (*op. cit.*, p. 218). All his efforts cannot suppress my five papers[1] on the geology of the area of Quebec, my tables of the "stratigraphy of the Province of Quebec," published in the Proc. Bost. Soc. Nat. Hist. vol. xxiv, p. 79, or my paper "Canadian geological classification for the Province of Quebec." These, as well as my "Abstract Section of the vicinity of Pointe Lévis, Chaudière falls and Quebec" of 1862, can stand the wear and tear of time, for they are constituted on a "basis of fact" in the field of the vicinity of the city of Quebec.

[1] On the primordial fauna and the Taconic system, by Joachim Barrande, with additional notes by Jules Marcou. Boston, 1860.

The Taconic and Lower Silurian rocks of Vermont and Canada. Boston. 1861.

Letter to M. Joachim Barrande, on the Taconic rocks of Vermont and Canada. Cambridge, 1862.

Notice sur les gisements des lentilles trilobitifères taconiques de la Pointe Lévis au Canada. Paris, 1864.

Canadian Classification for the Province of Quebec. Salem, 1889.

General Meeting, Nov. 20, 1889.

Vice-President, Prof. Geo. L. Goodale, in the chair.

Mr. S. H. Scudder made a few remarks on the "Distribution of Insects in the Rocky Mountain Tertiaries, and the Discovery of New Localities for collecting Fossils of this Group."

Prof. W. M. Davis then read the following paper:

THE GEOGRAPHIC DEVELOPMENT OF NORTHERN NEW JERSEY.

BY WILLIAM MORRIS DAVIS AND J. WALTER WOOD, JR.

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Preface.

1. The following essay had its beginning in work by the authors as teacher and student in a second course in physical geography at Harvard College in 1887–88. The home of the student being in New Jersey, the physical geography of that state was taken as our theme; and with the reports and admirable contoured maps published by the State Geological Survey in hand, the subject was investigated with such methods as could be devised. An excursion across northern New Jersey in the spring of 1888 gave us a brief view of the typical areas described below. At about the same time the publication of the first number of Mr. McGee's essay on "Three Formations of the Middle Atlantic Slope" gave us the results of his observations over an extended area, with which we were already in substantial accord as far as the topography of New Jersey is concerned. The investigation proved instructive and entertaining beyond our expectations, and foreshadowed the impulse that will be given to geographical study when all our states shall be well surveyed.

The completion of our manuscript having been much delayed, it has been extended from time to time by the senior author beyond its original form. Use has thus been made of the five-mile relief map of New Jersey, published in the summer of 1888; of the later articles by Mr. McGee; of his account of the fall-line displacement, as presented in the "Geology of the Head of Chesapeake Bay" in the Seventh Annual Report of the U. S. Geological Survey; and of the account of the Topography of New Jersey by C. C. Vermeule lately published in the first volume of the Final Report of the State Geologist, Prof. George H. Cook. In the untimely death of Professor Cook we have lost the leader under whose direction nearly all of the published data on which our work rested was prepared.

Introduction.

2. *General scheme of geographic classification.* The surface of the land may be regarded as composed of a number of individual forms, whose general character depends on the rock-structure which the processes of land-sculpture have worked upon, and whose more particular expression depends on the degree of advance in the degradation of the surface from its initial, constructional form to the smooth, low, baselevel plain to which it is finally reduced. Thus regarded, any geographic individual may be associated with certain others, to which it is related by similarity of structure, and the whole group of similar individuals, thus related, may be idealized in a type, which presents all the essential, but none of the accidental features of the group that it represents. The type is therefore an elastic conception, not limited in the way of size, nor in the number of its features, nor in any variable element; but always holding fast to those characteristics that distinguish it from the types of other groups. Moreover, in order that individuals of different age may be properly represented by a single type, every type must be conceived to vary systematically in passing through the cycle of changes that its individuals suffer from the time when the first attack is made upon them by the destructive forces of the weather, to the time when they are worn down to baselevel, the level of the standing water into which their drainage flows, below which land erosion cannot reduce them; and, if they front on the sea, their type will include a coast-line with its varying expression from the early time when the waves make their first attack upon it to the distant end when the whole is planed down to a flat submarine platform at an undetermined depth. Individuals under a type may then be regarded in natural relationship; they are not final results of processes, but are stages in a cycle of systematic change, and are therefore to be regarded not only

as related by similarity of structure, but also as comparable in regard to age. Moreover, some individuals raised to a considerable elevation in their youth, attain an intense development of all their features in maturity, and weaken only in old age; others that have never gained much elevation have but a mild expression even at the strongest.

3. *Conception of systematic geography and geographic development.* This conception of geography differs from that generally adopted in giving more attention than is commonly allowed to the development of geographic form, and in basing a classification on the sequence of forms assumed in the successive stages of the development of the type, as well as on the different structures of the types of various groups. It seems to be a rational extension of the study; for nothing is better established than that the surface of the earth was not made in a final form as we see it, but has come to its present form through the action of natural processes, still in operation, such as are discussed in geology; that the form resulting from these natural processes depends on the structure that the processes work upon, on the time that the processes have been at work, and on the rate and opportunity for work as determined by altitude, climate, and other factors. It is certainly advisable to extend our conception of geography as fast as the various branches of knowledge applicable to it are extended; meteorology has advanced into a field of mathematical physics; zoölogy turns on embryology; chemistry follows physics in utilizing atomic and molecular hypothesis to an extraordinary degree; and if geography is to advance beyond narration and numeration, it must take all that it can gather from geology, and search for natural and genetic systems of classification and description. Geography comprehends a description of the surface of the earth; and in order to carry the study out to its fullest use, it must draw on any source of information that aids and completes its descriptions. Physical geography includes discussion and explanation besides description, and must employ every method that increases the rational understanding of its data.

When one attempts the physical description of a political area, such as one of our states, it is like the work of a botanist in describing the flora of a limited region. Plants of many kinds will be found there naturally associated in an order quite unlike that given to them in a treatise on systematic botany; but if good work is to be done, the systematic order embodying the concentrated experience of earlier students must be familiar before an examination of the order in the state of nature is undertaken. Otherwise the observer will fail to apprehend the significant features discovered by previous investigators, and will be too much influenced by individual and temporary characteristics. Trees might be classified according to their height; growing trees would be separated from dead and leafless trunks of the same kind; small plants would be overlooked.

In the same way there should be some general scheme of geographical classification in mind before attempting to describe the topographical features of any given region: we shall therefore follow the scheme based on structure and age, outlined above[1]. Besides this, there is need of some systematic order of arrangement of the members of the scheme, but geographers are not yet agreed about the order that shall be followed; it has therefore been our purpose not only to present a systematic description of New Jersey, but also to illustrate one—the historic—of the many possible systems of arrangement that might be followed, in the hope that by trial of various systems, a satisfactory one may be at last adopted for general use.

4. *The geographic divisions of New Jersey.* New Jersey may be conveniently divided into three main districts, according to the broader features of its structure and topography roughly outlined in fig. 1. The crystalline Highlands lie in the north, a region of rugged uplands, broken by deep and steep-sided valleys; associated with Kittatinny valley and mountain on the northwest. The sandy Lowlands occupy the south, with monotonous surface of faint relief; and between these two there is an intermediate Central plain of Cretaceous and Triassic beds, traversed by long, narrow ridges of trap. All of these divisions extend beyond the political limits of New Jersey. In describing them we shall begin with the oldest land surface of which there is any trace still remaining, and take up after it as many others as may be found in the order of their development.

[1]A fuller discussion of this plan of classification is presented in a paper by the senior author on "Geographic methods in geologic investigation," National Geographic Magazine, I, 1888, 11.

THE HIGHLANDS.

5. *Genearl account of the Highlands.* When standing on one of the Highland plateaus, the observer must be struck with the nearly uniform elevation reached by all the surrounding uplands. The profile of one mass after another rises close to the common standard of height and there maintains an even outline with much constancy. The flat-bottomed valleys sink deep below the general upland surface, but there are no corresponding elevations above it. Schooley's mountain may be taken as a good example of one of

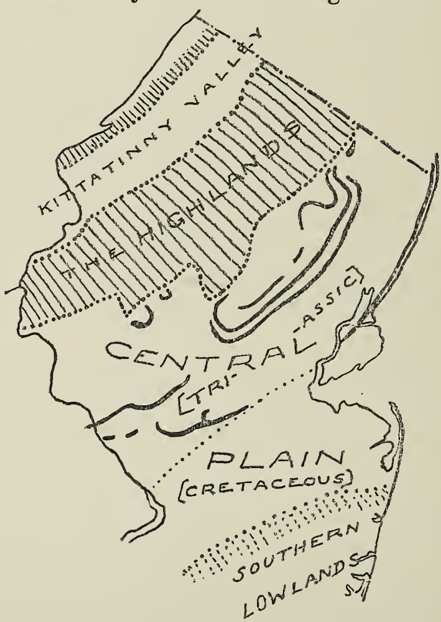

Fig. 1.

these Highland plateaus. In the neighborhood of Budd's lake, its surface rises to ten or eleven hundred feet above the sea level and maintains this elevation with moderate inequality over broad stretches; on the southeast, the broad German valley is drained by the south branch of the Raritan at a height of about six hundred feet; on the northwest the Musconetcong flows in a wide-open valley about a hundred feet lower. A walk over the mountain from one valley-railroad to another can easily be accomplished in a few hours and can be made within a day, even if one has to start from New York by train in the morning and return there in the evening. A fine round-trip excursion can be made by taking a morning train on the Morris and Essex division of the Delaware, Lackawanna and Western railroad to Waterloo station in the Musconetcong valley, walking over the mountain past Budd's lake, and on the way passing from the glaciated to the non-glaciated area, and descending in the afternoon to the German valley at Bartley station, whence the return to New York is made by an interesting ride on the Central railroad of New Jersey. The justice of the following description by Professor Cook will then be appreciated.

"The Highland mountain range consists of many ridges which are in part separated by deep valleys and in part coalesce, forming plateaus or table-lands of small extent. Some of the included valleys are quite as deep as the red sandstone plain on the south and the Kittatinny valley on the north and west . . . . . . A characteristic feature is the absence of what might be called alpine structure or scenery. There are no prominent peaks or cones. The ridges are even-topped for long distances and the average elevation is uniform over wide areas. Looking at the crests alone and imagining the valleys and depressions filled, the surface would approximate to a plane gently inclined toward the southeast and toward the southwest . . . . . The new atlas of the state will show how remarkably even-topped these ridges of the highlands are and enable the reader to construct for himself the plateau indicated here by these crest lines . . . . . The more prominent and larger of these high levels are the country south of Dover and east of the German valley, Schooley's mountain range, Scott's mountain and the country from lake Hopatcong, extending northeast . . . . . They are not to be understood as level, but as diversified by the ridges which rise from 100 to 300 feet above the deepest depressions, the latter being 400 to 600 feet above the adjacent valleys and plain country. Once upon them, the so-called mountains disappear and sink into hills, whereas, when viewed from the valleys, the plateau or table-land rises up as a mountain . . . . Near the valley, the apparently lofty ridges are designated as mountains; in the ridges, away from the valleys and outside plain country, names are often wanting for even the highest crests, as they are called hills[1] . . . ."

[1] Geol. Survey of New Jersey, Annual Report, 1883, 27–29.

After describing the great distortion and folding of the highland rocks, Professor Cook continues: "It is to be remarked that there is a great degree of uniformity in the altitudes of the mountain ranges of the Highlands. A large area south of Dover and Rockaway and west of Morristown has an average elevation of 800 to 900 feet. And the traveller attaining the summit of this plateau, as it were, recognizes the general level as characteristic of it. The broad Schooley's mountain range, extending southwest to where the Central railroad crosses it, is another example of this uniformity of height, having an average elevation from 1000 to 1200 feet. Scott's mountain has about the same average height. Another remarkable table-land is in the northeastern part of Sussex and the western part of Passaic counties. Its mean height is probably over 1200 feet, as there are many summits over 1400 feet, and scarcely any depressions less than 1000 feet. The surface is by no means level or even an approximation to a plane; but there are no very prominent peaks or ridges, nor any deep hollows or valleys. This uniform feature of the surface is not accidental, but must have had its origin in some way related to the original uplifting and folding of the strata, modified greatly by the subsequent erosion due to the drainage and glacial action in part."[1]

6. *Development of the Highlands.* It may now be asked what was the antecedent land-form from which the present Highlands have been developed; and if any trace of this antecedent form still remains, the geographer may legitimately extend his inquiry to include its examination.

We know from the general principles of valley-making and land-sculpture that any surface exposed to denudation is worn fastest along the stream lines, until they approach base-level, and is wasted slower on the interstream surfaces. Given a plateau, for exam-

Fig. 2.

ple, whose base-level is *B–L*, its profile in successive stages of development might be roughly illustrated in fig. 2. The heavy line may be taken as the average present form of the Highlands. Then

[1] *Id.*, 60, 61.

the antecedent form may be restored, with sufficient accuracy for our purpose, by filling up the valleys nearly to the height of the uplands between them, as Professor Cook suggested; and it is manifest from an examination of the maps or from a view of the country, that the restoration would be a broad surface of very gentle undulation, so smooth that we may call it almost a plain, that is, a *peneplain*.[1] It is then from such an old peneplain surface that the present rugged Highlands have been carved. The old peneplain remains but slightly attacked on the interstream plateaus, such as the broad summit of Schooley's mountain; its destruction has been carried farthest on the softer rocks, where the valleys have been deepened and widened.

7. *Origin of the old Highland peneplain.* How could the old plain surface of the uplands originate? It was not a constructional plain, like that of the Red river of the north, between Minnesota and Dakota, for there is no reason to suppose that it was ever by any means perfectly level. The rocks of the Highlands are chiefly crystalline gneisses and schists, with slates and limestones, all greatly disturbed;[2] if there be any truth in the prevailing theories that account for the present condition of such rocks, both the formation of most of them and the deformation of all must be ascribed to processes working at depths of thousands of feet below the surface of the earth. Moreover, the folia of the gneisses and schists and the strata of the bedded rocks northwest of them are commonly seen standing at steep angles, and their present outcropping edges manifestly do not mark their original extension. It must, therefore, be surely concluded that the old upland peneplain was not the original constructional surface of the underlying rocks, but was a surface produced by the action of destructive forces on a once much larger mass. It remains to be seen why a tolerably even surface was produced by these destructive forces.

Examples may be quoted in plenty from the region of the western plateaus to show that destructive forces produce even surfaces when they denude a cover of softer rocks and encounter a hard stratum; but, in such case, the hard stratum must be horizontal. The peneplain of the Highlands cannot be explained in this way, for its rocks are strongly tilted, as has been stated above. The peneplain had

[1] This term was used by the senior author in describing the restored forms of the uplands in Connecticut, which are believed to be of the same age as those here considered. Amer. Journ. Science, XXXVII, 1889, 430.

[2] Ann. Rep. Geol. Surv., N. J., 1884, 44; 1886, 89, 119.

no sympathy with the underlying rock-structure and must have been produced independently of it.

The only way in which an even surface, that is discordant with the rock-structure, can be explained is to regard it as the form to which all land-masses are ultimately reduced by denudation, from whatever initial form they may have had, provided only that the denuding forces have had time enough to act; and this is true whether the ultimate form is the subaërial baselevel plain of land denudation, or the subaqueous platform of marine denudation. Given sufficient time, the wasting away of the land under the air or at the edge of the sea will result in a low, even surface; and in one or the other or both of these ways, we may hope to explain the peneplain of the Highlands.

It is worth while to recognize clearly that this explanation rests on the principle of exclusion; a principle that must be employed cautiously. Some process adequate for the production of a certain old plain is searched for; several processes are suggested; some of them are manifestly insufficient; then the true explanation must be sought among the remaining processes. The postulate of this argument is that all the processes by which plains can be produced have been considered; otherwise the true explanation might escape us. But it may also be recognized that nearly all geological argument is of this character, and that it becomes safer as the progress of the science makes it unlikely that any adequate process has been omitted from the discussion. The reader must judge whether it is safe, in the present state of geology, to conclude absolutely that plains can be formed only in the four ways above named; if he can suggest other ways, the conclusion of the preceding paragraph is invalid.

But if it may be safely concluded, as we think it may, that the old peneplain of the Highlands was either a subaërial baselevel plain or a submarine platform, it follows that the land must have stood lower than it now does when the lost material was worn away. The baselevel of that time must have been B′ L′, fig. 2. The present upland must then have been a lowland, and the opportunity for cutting the present valleys must be ascribed to a general elevation at a later date. This will be returned to farther on.

8. *Difference between plains of subaërial and submarine origin.* It remains for us to inquire whether the old Highland peneplain was the product of subaërial or submarine processes. Thirty years

ago, the latter explanation would probably have been accepted without a question. At present, many students would almost as unhesitatingly accept the former. But it must be admitted that, as far as our inquiry has progressed, both are adequate, and some better method of discriminating between them than the fashion of the time must be devised. We find no established guides in this inquiry, but the following considerations may be suggested.

A subaërial baselevel plain is gradually completed by the action of ordinary forces on all parts of its surface. Reduction to baselevel is slowest along the divides on the harder rocks, and quickest along the streams on the softer rocks. The valley bottoms therefore approach and practically reach baselevel long before the interstream areas are reduced so low.

A submarine platform is essentially completed strip by strip, once for all, as far as it goes; its advance is rapid at first, very slow at last. Its landward margin is surmounted by a sinuous cliff or slope with a level base, facing the sea and separating an interior of greater or less relief from a smooth sea-bottom, unconformably veneered over with the deposits from the land. If the transgression of the sea over the land be aided by a depression of the land, many inequalities of the surface might be preserved beneath the unconformable cover of marine deposits. Such a surface, when again lifted and somewhat denuded, might be indistinguishable from one that had not been submerged. The occurrence of unconformable deposits on an even foundation cannot alone be taken as evidence that the foundation is a surface of marine denudation; it may be a subaërial baselevel plain depressed below sea-level and covered with sediments from an adjacent portion of the same that was not submerged.

The ultimate forms of the two kinds of plains are probably much alike, and it may be hopeless to seek to distinguish them after they have been elevated and roughened by subsequent erosion. But the penultimate forms of the two might be separated; one would be gently rolling, its residual inequalities being of the hill and valley type; the other would be smoother, and might be very smooth if its veneer be regarded as its surface, but it would have a definite margin, beyond which the penultimate subaërial plain would be found. The two forms are of course often associated.

9. *Value of contoured maps in geographic study.* We have tried to detect on the restored surface of the old Highland pene-

plain some indications of its origin according to the above criteria, and in such work contoured maps are essential. They have a quantitative accuracy, while shaded or hachured maps give only a qualitative idea of form. It would be quite impossible to carry on careful geographic study without the knowledge of height, such as contours give, as well as of length and breadth; for the study of the form of the land is a study of three dimensions. The contoured map of New Jersey is invaluable in this regard.

10. *A restoration of part of the old Highland peneplain* was made by copying from the contoured maps on a sheet of tracing paper the heights of all the broad, topmost elevations of the plateau divides between the streams. The principle has already been stated that the valleys, which have been deepened quickly in a geographic sense, were once almost as high as the interstream plateaus, which must have wasted away much slower; and this warrants our believing that the interstream elevations may be taken as giving some indication of the form of the surface before the valleys were made. Contours are drawn on the tracing paper in accordance with these elevations, and a fair map of the old Highland peneplain is thus constructed. It should be noted that the restoration thus secured may have somewhat less relief than the old plain possessed; for it is only a generalization, on which much detail is lost. The old plain is at once seen to be broadly undulating, and the undulations seem to be too strong to be considered as belonging to an ancient submarine platform. The plain is therefore best regarded as an area of subaërial denudation, not entirely worn down to the ultimate form of an absolute plain, but reduced from a mountainous maturity to very mild relief in its old age.

The penultimate stage of subaërial denudation would give essentially such a surface as has been discovered in our restoration. It may, however, be suggested that the old surface was a true submarine platform, subsequently somewhat deformed, perhaps at the time of general elevation. To this it can hardly be answered that no traces of the platform sediments have been found on the plateau, for they might easily have been swept away during the excavation of the deep and wide valleys that now traverse the Highlands; but it may be fairly argued that a final subaërial baselevel plain could be similarly distorted; and it may be strongly urged that, since the higher parts of the restored surface coincide with the areas of harder rocks, as the penultimate elevations of an old baselevelled area must, it is not likely that distortion is accountable for the gentle undulations of the ancient plain.

11. *Conclusions as to the origin of the Highland peneplain.* We may therefore conclude that, whatever was the earlier history and form of the Highland region, it once stood with its present upland surface but little above sea-level for a period long enough to be worn down to a lowland of moderate relief, and that it was subsequently lifted bodily to its present elevation.

This may on first reading seem out of place in a geographic essay; but just so much of the past as is needed to explain surface forms still in existence is fairly within the province of systematic geography. Certain it is that no sufficient comprehension of the geography of the New Jersey Highlands can be gained without thus turning to the past for an explanation of their broad uplands. Geology need not grudge what seems at first like a trespass on its province; it has enough to do with the still earlier history of the Highlands, the discussion of their rocks and of their ancient dislocations that have left no mark on the present surface; indeed the trespass, if it be such, may be to the advantage of geology in suggesting points of view before unnoticed.

12. *The Schooley baselevel.* The general altitude of the surface of the sea with respect to the land during the development of the present upland surface of the Highlands constitutes an important plane of reference, which will be named the "Schooley baselevel;" and as we have concluded that the greater part of the denuded area was reduced to a surface of gentle relief by subaërial forces, the surface itself as then worn down, although by no means perfectly flat, will be called the "Schooley baselevel peneplain," or more locally "the Highland peneplain." We shall also speak of the "Schooley cycle," meaning thereby the time spent in the development of the old plain.

Geographic inquiry hardly leads us further in the past than to the time when the Highlands were lowlands. There is no longer any remnant of earlier surfaces in the topography of New Jersey—though there may possibly be inheritances from them in the position of certain water courses, as Mr. McGee has suggested to us. If the reader should, however, desire to reconstruct the still earlier antecedent form of the region, from which the Highland peneplain was developed, we believe good reasons could be given for arguing that it was probably a faulted mountainous region of parallel ridges, with Appalachian trend, having bold bluffs to the east, and gentler slopes to the west; these slopes themselves being nearly baselevelled surfaces of a still earlier Triassic date; in many ways like the present form of the Sierra Nevada of California,[1] although of not so great relief.

13. *Extent of the Schooley baselevel peneplain.* The ancient baselevel peneplain of the Highlands cannot have been limited to northern New Jersey; it was the product of far extending as well as of long existing conditions; it must have stretched beyond arbitrary political boundaries of which even the present natural lines are in good part of a date subsequent to its production. It is believed that the same ancient peneplain determines the general community of height and the prevailing level crest-line of Kittatinny mountain on the northwest border of New Jersey and of the associated ridge lines and upland surfaces of the Alleghanies and of the plateau farther west in Pennsylvania;[2] but on this, final decision can hardly be reached till the Keystone state follows the example of its smaller neighbor and prepares a contoured map of its surface, than which that of no state in the country offers more interesting problems. We can say less of the extension of the northern part of the plain into New York; but its southeastern extension across New Jersey is open to our investigation.

14. *The Watchung mountains.* Standing on one of the front members of the Highlands, such as Sheep Hill, north of Boonton, one sees the long, even, parallel crest-lines of the Watchung mountains rising over the Triassic area to the southeast. These are the bevelled edges of two broad sheets of trap, intercalated in the beds of sandstone and shale of the Triassic formation; their steep outcrop faces look to the east, and on the west their slopes descend gently at an angle somewhat less than the dip of the accompanying beds; they are trenched at several points by water gaps, through which streams carry back-country drainage across them, and by notches or wind-gaps; but between the gaps their crests extend in unbroken levels for long distances.[3] The question arises here as in the Highlands, under what circumstances could crest-lines as even

[1] J. LeConte, Amer. Journ. Sci., xxxii, 1886, 167; J. S. Diller, Bulletin 33, U. S. Geol. Survey, p. 12, 1, *et seq.*

[2] Compare an essay by the senior author on the Rivers and Valleys of Pennsylvania, Nat. Geog. Mag., I, 1889, 197.

[3] A view of the Watchung ridges back of Plainfield, as seen from the east, is given in Ann. Rep., N. J. Geol. Survey, 1882, pl. 1.

as these be developed? A geological examination of the district leads to the conviction that the trap-sheets, like the sedimentary beds between them, have formerly had a great extension upward along the plane of their dip into the air, just as they still have an undetermined extension downward into the ground; their present edges simply mark the lines back to which the sheets have been consumed by denuding forces of one kind or another. If the land had stood at its present altitude during the long time needed for the consumption of the lost portion of the sheets, the long, level crest-lines between the transverse gaps could find no explanation in accordance with the general laws of land-sculpture, as they are at present understood; they might in such case be rounded, as in fig. 3*a*, but could not be even, as they are shown in fig. 3*b*. The

FIG. 3*a*.

FIG. 3*b*.

only satisfactory explanation of their evenness is to be found in the supposition that their crests are remnants of a plain of baselevel denudation, formed when the land stood lower than now. The valleys between and alongside of the parallel ridges, and the transverse gaps that cross them, have been worn out since this plain was elevated to about the height of the present crest-lines.

Several other trap ridges of similar form call for a similar explanation. Sourland and other ridges in the southwest, Rocky Hill on the south, and the Palisades on the east all have tolerably even crest-lines, and are presumably remnants of extinct plains that once stretched away to either side of the ridges at the level of their tops.

It may be reasonably inquired whether these extinct plains were not, at the time of their fullest development, parts of one and the same surface with the Highland peneplain ; and the best answer that can be made is in the affirmative. A long period of lower continental stand is needed for both ; this period was closed by a massive uplifting at a time far enough back in the past to allow the subsequent erosion of deep and steep-sided valleys in the hard rocks of the Highlands and to permit the excavation of broad lowlands on the softer sandstones and shales between the hard trap-sheets of the Triassic area, leaving the trap projecting as even-topped ridges. Moreover, when the restoration of the Schooley baselevel peneplain is extended southeastward by the process already described, the highest crests of the various trap-ridges being taken as indices of the former surface of the Triassic area, a tolerably consistent series of contours can be drawn, showing a broad eastward extension of the baselevelled area. We conclude therefore that the Schooley peneplain stretched southeastward, as well as westward ; it was a geographic feature of great importance in the earlier history of our country. But although the broad plain of faint relief thus restored must have been a nearly level lowland before it was elevated, its remnants do not indicate that it was uniformly elevated into a level highland ; for while it falls slowly below sea-level about New Brunswick, where the Palisade-Rocky Hill crest-line dips underground for a distance of twenty miles, it rises gently to the north, northwest and southwest as a faintly warped and inclined surface. This unequal elevation is natural enough. Nothing can be more likely than that the elevation of the extinct plain should have been uneven and greater at one place than another. Irregular upheavals of every degree are clearly seen in the deformation of bedded rocks that once lay horizontal, and it is natural enough that similar irregularity of upheaval should appear in the elevation of our old, once nearly horizontal peneplain.

15. *Extension of the Schooley peneplain over the Triassic area.* Let the observer now visit some of the more commanding points of view on the crests of the long Watchung trap-ridges and attempt to reconstruct the extinct geography, of which the remnants are so suggestive.

Westward there is the broad valley of the Passaic, worn out on the sandstones that overlie the trap-sheets ; this must in imagination be filled up to the surface that is defined by the summit of the Watchung ridges on the southeast, and by the front of the Highland plateau on the northwest. Washington valley is hollowed out on the shales between the parallel trap-ridges. Eastward and southeastward, the broad lowlands from north of Paterson to Newark and Elizabeth and thence westward beyond Bound Brook, must also be refilled; the chief defining lines here being the Watchung ridges on the west, the Palisades on the east and Rocky Hill on the south. It may be confidently believed that the last two ridges are parts of a single trap-ridge—the edge of a single trap sheet—depressed and buried under Cretaceous deposits at its middle about New Brunswick, and rising thence northward and southwestward in accordance with the deformation that the ancient peneplain has suffered. No statement can be made as to the extension of the old peneplain beneath the cretaceous deposits above referred to; but the geological structure of the region clearly demonstrates that, after this part of the plain had been made, it was submerged by a transgression of the Atlantic, and buried under detritus from some adjacent land. This is considered further in section 19.

To one who is unaccustomed to the magnitude of the work of erosion in fashioning the surface of the earth, it may seem almost incredible that so great an amount of material as is indicated by the amount of filling just called for should have been worn away; but the more the surface of the world is examined, the more necessary it is to admit that the land as we see it is carved deep in the land as it has been. If evidence is asked for in confirmation of this, we need only turn to the vast beds of stratified rocks, twenty to forty thousand feet thick in the central Appalachians and as much in parts of the Cordilleran region, to discover some of the depositories of ancient destructive work of this kind. There may again be doubt when one is asked to accept the fact of heavy erosion in New Jersey on what may seem at first like imperfect and insufficient evidence, as presented above; but we are persuaded that the more the matter is studied, the fuller confidence will be gained that the evidence of the crest lines is susceptible of no other interpretation than that here adopted. We may later ask what has become of the waste carried from the land, first in making the Schooley peneplain, and later in roughening it again.

The reader must guard against making too artificial a conception of the smoothness of the Schooley peneplain at the time of its elevation. The harder rocks, such as the gneisses and the traps, undoubtedly resisted the destructive forces successfully enough to maintain rolling elevations above the general surface in the late maturity of the region, and they may not have been quite smoothed down even at their latest stage; but the weaker rocks, such as the limestones of the Highlands and the red shales of the Triassic belt were probably worn down very flat, for they are so easily weathered that they must have been reduced close to a baselevel surface at a relatively early date; just as at present they have been cut deep in valleys and widely opened in lowlands before the gneisses and traps have lost all indications of the extinct plain from which the valleys and lowlands have been eroded.

16. *General conception of baselevels and baselevel plains.* The definition of baselevel may be purely geometrical, and the ultimate form of the surface developed on it might theoretically be a flat plain; but such conceptions are too rigid for application in geology and geography. The Schooley baselevel that we have been considering must not be regarded as a definite surface, absolutely fixed with reference to the Highland mass; it was more likely the average position of many small oscillations of sea-level down towards which the ancient land mass was gradually reduced; and the Schooley baselevel peneplain was rather a general approach to a smooth surface, prevailingly low and nearly featureless, but by no means a surface of geometrical uniformity, absolutely coincident with its controlling baselevel. While it might be possible that endless time and stationary attitude would result in geometrical simplicity of land form, we need not expect to find such a result in natural occurrence, for the land is too unsteady to allow it.

When Powell first introduced the term "base level," he employed it in two senses. He said " we may consider the level of the sea to be a grand base level, below which the dry lands cannot be eroded:" this is the general and persistent baselevel of a region so long as the relative level of the land and sea does not change. He then adds, "but we may also have, for local and temporary purposes other base levels of erosion, which are the levels of the beds of the principal streams which carry away the products of erosion."[1] The context shows clearly that these two uses of the term are employed. These "local baselevels of erosion" are described, in ascending the Colorado and Green rivers,[2] each one being determined by the passage of the stream for a distance over par-

[1] Colorado River of the West, 1875, 203. [2] *l. c.*, 207.

ticularly resistant rock ; the softer rocks next up stream being widely opened while only cañons are eroded on the harder ones. We have in New Jersey similar local and temporary baselevels, whose general recognition will greatly improve the popular conception of our topographic features. The hard sandstones of Kittatinny mountain form such a baselevel for the up-stream country of the Delaware river; and the trap sheets of the Watchung mountains exert similar control over the upper basin of the Passaic. Powell on another page speaking of the Appalachians, says "the base level of erosion of the entire area would have been the level of the sea:"[1] this is the general and ultimate sense of the term; to this final baselevel must all temporary and local baselevels be reduced, if time be allowed.

Other American geologists have also used the term in two senses. Dutton uses it in the plural when he refers to the base levels of a river system, thus indicating the recognition of local controls in different parts;[2] and he also says: "all regions are tending to base-levels of erosion, and if the time be long enough each region will, in its turn, approach nearer and nearer, and at last sensibly reach it. The approach, however, consists in an infinite series of approximations like the approach of an hyperbola to tangency with its asymptote."[3]

Several European writers have suggested terms closely allied to the one under discussion. La Noë and Margerie[4] use "niveau de base" in the same general and local senses as attach with us to baselevel; but it seems to me that they have misapprehended Powell's definition of the term, for they quote from him only that part of his statement that refers to the temporary baselevel. Heim at an earlier date wrote of the mouth of a river basin as the "basis" for valley making in the whole area concerned.[5] But the conception of the relation of denudation to its fundamental controlling datum plane does not yet appear to be general or definite enough to call for the introduction of a special term, such as baselevel, with which to name it in text books of geology. It is still customary to illustrate the work of erosion with examples of its

[1] *l. c.*, 209. [2] High Plateaus of Utah, 1880, 23, 45.
[3] Tertiary history of the Grand Cañon District. U. S. G. S., Monogr. II, 1882, 76.
[4] Les Formes du Terrain, Paris, 1888, 54, 57.
[5] Mechanismus der Gebirgsbildung, 1878, I, 296.

smaller accomplishments, such as valleys or even cañons, instead of with baselevelled plains.

A conception related to the one here considered under the name of baselevel has been introduced by Dausse,[1] Philippson,[2] La Noë and Margerie.[3] When a river has deepened its channel so far as materially to reduce its slope and therewith its carrying power also, and at the same time opened extended valley walls whence it receives an increasing load of detritus, it reaches a condition of quasi equilibrium, in which the further deepening of its valley is slow; but deepening is only retarded and delayed, not stopped, and the entrance of a river into this stage of its history is by gradual transition, not by abrupt change. While thus slowly deepening the valley, it represents in a general way the local baselevel of its region; but this must not be confounded with the absolute and ultimate baselevel.

The more frequent employment of the conception of baselevel has been accompanied by a natural evolution of its terminology. Powell said "base level of erosion." Later writers omitted the last half of the phrase and said more briefly "base level" or "base-level," the fully expanded expression being too cumbersome for frequent use. In this essay, we have omitted the hyphen, and write "baselevel" as a single word, a necessary scientific term. At the same time, the word has become a verb, for we often hear such an expression as "given time enough, and a river will baselevel its basin;" and an adjective, as in saying "a baselevelled region;" and even a noun applied to the form produced by the baselevelling process, as "the upper Wisconsin baselevel," "the old Appalachian baselevels," meaning here the plains or peneplains of denudation by which these districts are characterized. This is quite as it should be, and illustrates the practical value of the idea expressed in the term.

17. *Correlation of geographic development and geologic time.* The deformation of the old Schooley peneplain has left part of its east-

[1] "Profil d'équilibre." Etudes relatives à l'endiguement des rivières et aux inondations. Mém. sav. étrangers Acad. des Sciences, XX, 1872. Here quoted from La Noë et Margerie, as below.

[2] "Erosions terminant;" Ein Beitrag zur Erosionstheorie, Petermann's Mittheilungen, 1886, 67.

[3] État de stabilité ou d'équilibre; Les Formes du Terrain, Paris, 1888, 55, 56. Hilber has lately made a review of this question. Zeitschr. f. wiss. Geogr., VI, 1888, 201.

ern extension below sea-level, where certain stratified deposits of later date conceal the depressed middle portion of the Palisades-Rocky Hill trap sheet about New Brunswick; the same deformation has lifted the western part to a height that allows the excavation of deep valleys below the old baselevel surface.

Several questions now arise. We may ask the geologic date of the completion of the Schooley baselevelling, in order to associate it properly with other topographic features of the same age. We may inquire into the geographic conditions of the origin of the stratified .deposits that now bury the Palisades-Rocky Hill trap sheet, and ask if they give indication that the eastern part of the Schooley peneplain is a platform of submarine origin. The further original extension of the same deposits to the northwest must be considered, in so far as they may have had geographic consequences in controlling the development of our existing stream-courses. Finally, the date of the elevation of the Schooley peneplain must be discovered, in order to gain some comprehension of the rate of subsequent geographic growth, measured in geologic units.

18. *Date of the Schooley baselevelling.* The general sequence of events by which the geological date of the Schooley baselevelling is determined is as follows. The great Appalachian revolution culminating in Permian time produced a mountain range of strong constructional relief, and presumably of strong actual relief for a certain period after the disturbances. But in the area occupied by the Triassic belt, the topography seems to have been reduced to a moderate relief before Triassic deposition began; this we know because the southeastern margin of the Triassic formation, where it joins with older rocks, is a rather even line across the Triassic-Cretaceous peneplain of to-day. From this it must be concluded that the foundation on which the Triassic beds lie is also a peneplain, the product of pre-Triassic erosion on a mass of mountainous structure. The great mass of sediments accumulated in the Triassic cycle has suffered tilting and probably faulting also, and there is good reason to think that this disturbance extended over a considerable area on either side of the present Triassic belt: this produced a new mountainous topography, of less elevation and of much less structural distortion than that of Permian time, but still of considerable strength, as suggested in paragraph 12; and it is the old age of the forms of this cycle of development that we have de-

scribed under the name of the Schooley baselevel peneplain. This peneplain, with the unconformable cover of Cretaceous beds that subsequently transgressed over its eastern margin, was at some later time elevated in the interior, and in the declining surface of the plateau thus formed the valleys of the Highlands and the lowlands of the softer Triassic beds have been cut out, at times and to an amount that will be considered farther on. The Appalachian chain, as we now see it, is therefore not to be regarded as the residual relief of an elevation given once for all at the time of the great Permian folding. The first and probably the greatest Appalachians were worn down low before and during Triassic time; they were regenerated to a considerable strength by the post-Triassic faulting, tilting and elevation, and again worn down low and faint to the Schooley baselevel peneplain; and the ridges that we now see are simply the parts of this old peneplain that have as yet withstood the erosion consequent on a still later uplift. The first elevation was accompanied by tremendous crushing and folding; the second was accompanied by little more than monoclinal tilting and faulting; the third, as well as other minor oscillations of later date, were chiefly massive uplifts of moderate amount and gentle inequality.[1]

It appears then that the period of the Schooley baselevel was of later date than the post-Triassic tilting, that it was of earlier date than the oldest of the strata that lie upon it in the New Brunswick district, and according to recent determinations these are of low Cretaceous or perhaps late Jurassic time. From this it may be concluded that the Schooley baselevel attitude was taken and maintained during Jurassic time; and that the baselevelling of the older Highland mountains into the old Highland peneplain was well advanced in the same period.

19. *Character of deposits overlying the Schooley peneplain.* The southeastward extension of the Schooley peneplain may be followed beneath the unconformably overlying Cretaceous beds;[2] and from this we must conclude that at least this portion of the plain suffered some depression after its baselevelling and before its elevation to its present altitude. This forms a subdivision of the Schooley cycle. The depression occurred after the deep denudation of the Triassic shaly area, for the northwestern margin of the overlying

[1]Compare Willis, Nat. Geogr. Mag., I, 1889, 299.

[2]McGee's Potomac formation is here included with the Cretaceous.

beds appears as an essentially straight line on the peneplain of to-day, and hence their foundation must have been a peneplain. But it is very probable that the area of the Highland crystalline rocks was not so soon worn down ; these rocks are much harder than the shales and most of the sandstones of the Newark belt, and when the latter were reduced to their lowest topographic terms, the former may still have shown hills of considerable height. But the denudation of the Highlands continued during all the time of Cretaceous deposition, and this great interval following on the previous one appears to have been sufficient for the production of the Schooley peneplain even over the area of the hard crystalline rocks.

If the southeastern part of the Schooley peneplain were a platform of marine denudation, the lowest of the superposed beds would be made of fragments derived from the closely adjacent landward part of the plain ; but numerous exposures in the clay pits about Amboy have demonstrated that the lowest members of the Cretaceous series, even where lying directly on the red shales of the Triassic formation, contain very few fragments of red shale, and are in great part derived from some other source. Its sands and white quartz pebbles might certainly have come from the Highlands. This confirms the idea that the Highland plain was of subaërial origin. Its Atlantic shore-line must have stood southeast of New Brunswick and Amboy at least until the relatively soft Triassic beds were baselevelled ; then a small submergence would cause so rapid a transgression of the sea over the land to the northwestward that the shore waves would not remain long enough at any point to accomplish much work at the bottom ; after the submergence, the shore line would probably be found west of the Triassic area on the edge of the hard crystalline rocks, whose reduction to baselevel was slower. The fine waste from the shore might supply the sands and marls of the Cretaceous beds with little admixture from the red shales on which the beds were deposited.[1]

All this accords better with the subaërial origin of the Highland plain, above adopted, than with its submarine origin.

[1]The absence of the fragments of shale in the Cretaceous beds is so nearly complete that it has been suggested that the land from which they were derived lay to the southeast of the present coast, and has since then sunk out of sight (Geol. N. J., Report on Clay Deposits, 1878, 30). But the bottom clay beds do contain some fragments of red shale (*id.*, 40, 41, 43, 162, 168), and the explanation given above seems to us more in accordance with the geographic development of New Jersey and with the general geologic history of the Atlantic slope.

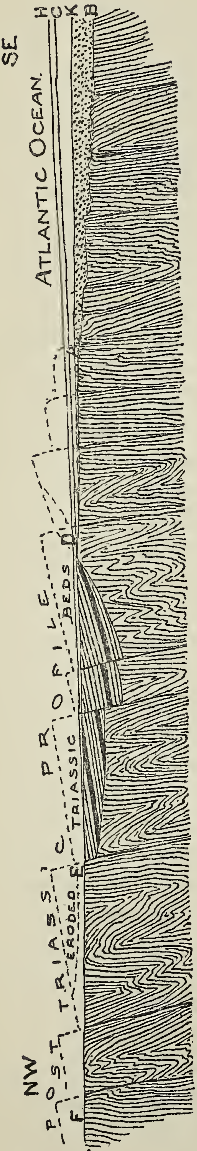

Fig. 4.

This may be made plainer by reference to fig. 4,[1] which gives a general northwest-southeast section of the region. The profile that would have resulted from the post-Triassic monoclinal faulting and tilting without erosion may be typified by the uppermost dotted outline. The ocean then stood at the Schooley baselevel, AC, with the shore at A. Long continued erosion during a stand of the land at about this position reduced the surface to the Schooley baselevel plain, FED, the shore waves having in the meantime eaten into the land from A to D; the land waste is transferred to the ocean bottom A B K. The soft Triassic portion, DE, of the old plain was worn down sooner and smoother than the hard crystalline portion EF. At about the end of Jurassic time, the old plain was somewhat depressed, especially to the southeast; the ocean level rose from C to H, and the shore line was thereby carried inland from D to E. The rapid transgression of the sea over the smooth plain, DE, did not allow the waves time to gather much Triassic material for the sediments that were formed; but when the advance of the shore line was checked by reaching the higher ground at E, marls and sands were supplied in moderate quantity from the low hilly country of slowly disintegrating crystalline rocks. These form the relatively thin Cretaceous deposits that were spread over the new sea-bottom, EDK, thin towards their shoreward margin, but thicker in deeper water. It is likely that there were minor oscillations of sea

[1] The location of this section and of several other diagrams is given in fig. 8.

level and of shore line during Cretaceous time, but the changes do not appear to affect the present topography of the country. During all this time, the more resistant crystalline rocks were worn lower and lower, and so the almost completion of the old Schooley base-level plain in Cretaceous time followed the good beginning made in Jurassic time.

Since first reaching the above conclusion, McGee's articles already referred to[1] have given us information of an oscillation of level that took place after the early wearing down of the Highlands had been well advanced. It was in the sense of an elevation during which narrow valleys of moderate depth, from one to two hundred feet, were cut to be filled again when depression allowed the accumulation of the lowest member of the superposed series, the Potomac formation of this author. Another elevation is recorded by the unconformity between these first deposits and the superposed members of the Cretaceous series. This was followed by a second depression. These facts were discovered by observation on the ground and are of manifest geologic importance ; but they do not appear to be recorded in the present topography of the country, and were not discovered in our study of the maps. If of more recent date, they would be visibly recorded in the form of the surface ; and it will be seen that as we take up the later chapters of the history of New Jersey, brief subdivisions of time marking slight oscillations of level attain importance. Similar subdivisions of ancient time would be called for by a full knowledge of past history ; and the Schooley cycle must be regarded as containing many sub-cycles, not traceable in our method of study. In the general sequence of geographic development, our conclusions agree substantially with those reached by McGee.

20. *General drainage system in the Schooley cycle.* The introduction to our essay has explained what is meant by a geographic cycle. We must now consider the conditions of drainage during the cycle of development when the land stood at the Schooley baselevel, and the sub-cycle at the end of this division of time, when the land was somewhat depressed, allowing the transgression of the Cretaceous ocean. It does not appear practicable at present to inquire closely into the early stages of Highland drainage, for this would carry us into questions of geological structure on which there is not yet reached any general agreement. Our own feeling is that the early

[1]Amer. Journ. Sci., XXXV, 1888, 134, 135, 141.

stage of most of the Highland streams was in general of consequent arrangement, the stream courses being taken in accordance with the deformations that had in early Jurassic time tilted and faulted the Triassic beds and the subjacent and adjacent crystallines, briefly outlined in paragraph 13. The reasons for this belief are drawn as much from the history of the Triassic in the Connecticut valley[1] as from New Jersey, and will not be considered here. Whatever the early stages were, it is very probable that in late Schooley time, when the land was worn low, the streams had lost many of their original courses in the process of mutual adjustment as explained by Löwl, and were thus more dependent on internal structure than on original deformation. The streams in their old age must have flowed along the strike of the soft beds for the greater part of their course, escaping to the sea by not infrequent transverse streams, some of which, like the Pequannock,[2] may have been located on ancient fault lines ; and to streams thus well established a special name should be applied, inasmuch as no one of the names now current is fairly applicable. They may be called streams of mature adjustment.[3] The old streams of the Schooley plain surely were of this kind. Most of them must have finally settled down on the softer beds, and therefore then as now there must have been streams in the Kittatinny and Musconetcong valleys ; and these must have found outlet to the sea by transverse master streams, such as the Delaware. Thus many of our present streams may have had their antecedents in the Schooley cycle, from which they have descended by what we shall call "revival," caused by massive elevation of the country, as will be further considered below.

Whatever may have been the drainage of the Triassic portion of the old baselevel plain in the Schooley cycle does not now appear, for as has been indicated in the section on the geological date of the Schooley cycle, after this portion of the plain had been baselevelled, it was moderately depressed beneath the sea of Cretaceous time and buried in Cretaceous sediments. The stream courses of the Schooley cycle on the Triassic area were thus extinguished. This will be seen to be of importance when the development of the central plain in the next cycle is considered.

[1] Amer. Journ. Sci., XXXVII, 1889, 432. [2] Geol. N. J., 1886, 122.
[3] Nat. Geogr. Mag., I, 1889, 206.

THE CENTRAL PLAIN AND THE HIGHLAND VALLEYS.

21. *Elevation of the Schooley peneplain and its consequences.* We now enter a later cycle in the development of the state. The lowlands, which were so broadly worn in Jurassic and Cretaceous time on the Schooley baselevel and partly sealed over along their coastward margin with Cretaceous sediments, are now no longer lowlands, but have at sometime in the past been elevated; and wide valleys and lowlands of a second order have been opened in their formerly uniform surface. The geographic cycle in which these newer valleys and lowlands have been produced is now to be investigated. Certain general considerations may precede the special study of the case. We know that while the old Schooley baselevel peneplain has been elevated, it was not necessarily raised at once from its original to its present position; it may have, for a time, resided at some other altitude, perhaps at an intermediate height between its former and its present stand; and the present position of the land may have been assumed only after a second or third change of elevation. Again, if the land has stood at any altitude intermediate between the Schooley baselevel and the present for a considerable time, there should be topographic indication of it in the occurrence of topographic forms developed with respect to the position referred to. Finally, forms of this kind will be most apparent in the region of the softest rocks, for there the rate of development is most rapid.

We therefore now take the area of the weak Triassic and Cretaceous formations as the region for first examination. It is as proper to select this district in the present case while we are looking for the signs of relatively recent geographic development, as it was to take the area of the hard crystalline rocks of the Highlands in searching for records of a long past time.

22. *The Central Triassic and Cretaceous plain on the Somerville baselevel.* The interstream surface of the Triassic lowlands where traversed by the railroads west and southwest of Bound Brook are, clearly enough, dissected portions of a once continuous plain of moderate elevation, but high enough for the streams to sink distinct channels below it. The same process of reasoning as that employed in studying the old Highland peneplain leads to the conclu sion that this Triassic plain marks an old baselevel; it is not a constructional surface, in sympathy with the rocks below, for the red

shales all dip at a moderate angle northwestward or thereabouts. It is, indeed, a more recent and more evident baselevel plain than that of the Highland plateaus. We have given it the name of the Central plain from its position in the state. The baselevel, with references to which it was denuded, may be called the Somerville baselevel, from the excellent development of the plain in the neighborhood of that town.

The Central plain is developed with considerable distinctness over most of the Triassic formation, where the soft shales have been quickly degraded from the Schooley baselevel. On crossing the Delaware to Pennsylvania at Yardley by the Bound Brook railroad, the broad fields that stretch far and wide at corresponding heights on either side of the Delaware are conspicuous illustrations of the surface of this extensive plain, showing that it is not limited to New Jersey. Thence northeastward, it forms the general surface of the lowlands between the trap ridges, until its smoothness is concealed by the addition of the morainic hills between Plainfield and Elizabeth. Along the Pennsylvania railroad it is almost unbroken from Princeton nearly to New Brunswick, being developed here on the lower strata of the Cretaceous formation. Farther southeastward, it is continuous for some distance, as along the railroad from Monmouth Junction, for example, almost to Jamesburg; but there it is much broken, and further on it is difficult to trace; southwestward, along the Delaware, it is trenched by streams, and its higher parts are much broken.

The northern extension of the plain into the glaciated area has not been closely examined.

The production of the Central plain on the Somerville baselevel illustrates to a nicety the different rates of development of a plain on rocks of different hardness. In the region of the crystalline rocks, the Somerville plain is not perceptible, unless in the limestone valleys; and even there it is altogether subordinate to the great mass of the little broken plateaus on either side. In the Triassic region, the greater part of the rocks are soft enough to allow the Central plain to take on good form; but there are portions of the Triassic mass that are hard enough to retain in good preservation remnants of the Schooley peneplain, namely, the trap ridges and the Hunterdon plateau of hard sandstone; the former are so hard as to form long, continuous ridges of even height, whose value in restoring the Schooley plain has been recognized. In the Cretaceous portion of the Central plain, even a greater share of the beds are soft enough to have been worn down to baselevel; and the only parts that have withstood this reduction are certain loosely cemented conglomerates and sandstones, associated with the green sands, which still seem to stand above the general level of the plain that surrounds them. They appear in a range of disconnected hills from Navesink southwestward; Pine Hill near Perrineville, at the head of the Millstone river, is of this class. It is in a country of remnants like these, especially when the region is complicated by the erosion of a later cycle still, that we find the greatest difficulty in tracing out ancient plains of denudation, and hence the restoration of the Somerville plain in the southeastern part of the state is at present uncertain.

Inasmuch as the above mentioned Cretaceous hills remain on the seaward part of this plain, and as it extends with about as much distinctness back of Rocky Hill and Sourland mountain as in front of them, we have concluded that it is a product of subaërial and not of submarine erosion.

23. *Date of the Somerville cycle.* The Central plain is manifestly of younger date than the Schooley plain, for the former is excavated below the surface of the latter. Baselevelling has been accomplished at the Somerville level only on the softest rocks. The Highlands were subjected to erosion during the same period and yet were only channelled by deep valleys with strong sloping sides; but the soft Cretaceous and Triassic beds were less successful in resisting erosion and hence were reduced so low as to form broad-open lowlands, broken chiefly by the trap ridges, whose crests retain something of the Highland altitude, as already described. The Somerville attitude was therefore maintained for a considerable period, but for by no means so long a time as the Schooley cycle endured. Finally, since the Central plain was lifted, the streams have accomplished only a small share of the new work offered them; post-Somerville time has not been nearly so long as Somerville time. The moraine on the northeastern part of the plain has not been nearly as much eroded as the plain itself. These statements may be summarized as follows: the Somerville baselevel was maintained for a considerable part of post-Cretaceous, that is of Tertiary time; the elevation that put an end to the development of the plain with reference to this baselevel took place in late

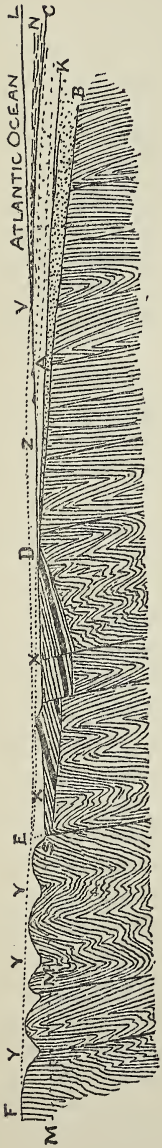

FIG. 5.

Tertiary time, and the valleys excavated in it were well advanced toward their present stage by the time of the glacial period.[1]

These changes from the Schooley peneplain may be more clearly conceived by comparing fig. 4 with fig. 5. The restored Schooley peneplain is *FED*. The soft limestones of the crystalline region *FE* are worn down to valleys *YY;* the weak Cretaceous beds *EDV* are stripped off for many miles from their ancient western edge *E* and are worn down low, except where a few harder beds hold out a little way against the forces of destruction ; and the soft Triassic shales thus laid bare are opened out into lowlands, *XX*, between the hard trap sheets which still hold their crest lines near the surface of the Schooley plain. The material eroded below the surface of the Schooley peneplain, *FED*, and its partial cover, *EDV*, has been transferred to the ocean floor, *VCN*, where it probably forms those Tertiary beds which are not represented within New Jersey.

24. *Somerville cycle of drainage in the Highlands and on the Central Plain.* A deductive consideration of the origin of valleys gives reason for suspecting that the valleys by which the drainage of the Somerville cycle was carried on were of two kinds : one originating on that part of the Schooley peneplain that was never transgressed by Cretaceous beds ; the other originating on the Cretaceous cover that overlapped the southeastern part of the peneplain.

[1] In this connection, the reader should consult McGee's study of the Columbia formation, in which the production and the elevation of this and other baselevelled areas are correlated with the first glacial epoch, *l. c.*, 376, 465.

Consider first the valleys formed on that part of the peneplain that was never covered by Cretaceous beds. Even the smoothest part of the uncovered crystalline rocks of the Highlands cannot have been reduced to absolute flatness at the end of the Schooley cycle; the restoration of their surface that we have attempted has shown that a residual relief of some distinctness probably remained before the present valleys were begun. The harder rocks resisted weathering more stubbornly while the softer ones were worn down to the lowest level, and this difference must have been maintained, though with decreasing distinctness, to the end. Just before the elevation of the Highlands that we are about to consider, the streams must have wandered sluggishly with almost imperceptible slope along broad lowlands of northeast and southwest trend, between faint dividing swells of land of the same direction. Many such longitudinal streams would find escape southeastward in a single transverse master stream, after the fashion of old mountain drainage in general. When the whole area was lifted and tilted to the southeast, the sluggish streams were revived and entered a new cycle of their long life. The smaller streams followed the lead of their masters, but without changing their position, although the tilting of the old plain might in some cases reverse their direction of flow. All would be in accord with the slope of the country that they drained, but as the slope was in most cases the residual of the relief of the old plain and not necessarily in accord with any ancient constructional slope, the streams should not be called "consequent" in the meaning of that word, as it was first employed by Powell. Whatever their origin on the ancient plain, they are now simply "revived."

The case would be different with that part of the old Schooley plain that had been submerged under the shallow Cretaceous sea and that now rose with the Cretaceous cover on its back. Here the land, as it rose from beneath the waters, would appear as a smooth surface, with gentle seaward slope; and the streams that ran out across it from the crystalline area, or that headed upon it, would follow its slope to the retreating ocean in the southeast. Then after a moderate amount of channel cutting, the unconformable underlying rocks would be discovered, and the streams persisting in the courses taken on the smooth Cretaceous surface, would of necessity traverse the under rocks with little reference to their structure. Valleys cut by such streams have been called "superimposed" by

Powell, "epigenetic" by Richthofen, and "inherited" by Shaler; and they may be recognized even after the cover from whose slope they inherited their epigenetic courses, has been entirely consumed. Their discrimination from the simpler revived valleys is a mat-

Fig. 6.

ter of interesting study, and is of manifest geologic as well as of geographic importance. Two special examples may be considered, in illustration of revived and superimposed streams.[1]

[1] Figure 6 presents an outline of the drainage areas of northern and central New Jersey, that may serve as an index to locate the various streams referred to here and in later pages. The abbreviations are as follows:

A. Assanpink.	P. Paulinskill.	Rn. Raritan, north branch.
F. Flat.	Pc. Passaic.	Rs. Raritan, south branch.
H. Hackensack.	Pg. Pohatcong.	Rk. Rockaway.
L. Lopatcong.	Pp. Pompton.	Ro. Ramapo.
M. Musconetcong.	Pq. Pequannock.	Ry. Rahway.
Ml. Millstone.	Pt. Pequest.	W. Wallkill.
Mn. Manalapan.	R. Raritan.	Wy. Whippany.

The rectangular course of the Delaware on the west and the fjorded channel of the Hudson on the east are too well known to require naming. The shading of lines in various directions indicates the several drainage basins, the linear forms of the Highland

25. *Revived Streams.* The Musconetcong, fig. 7,[1] follows a remarkably straight southwesterly course for forty miles, from its head in the centre of the Highland plateau to the Delaware a little below Easton. The branch that carries the overflow of Lake Hopatcong to the main stream is very likely a post-glacial tributary, and is omitted from the figure; with this exception the Musconetcong basin is hardly over five miles wide; all of its side streams are short, and nearly all of them have a direct course down the slopes of the enclosing mountains to the main stream. These mountains are of resistant gneisses and schists, while the longitudinal valley is excavated along a synclinal band of limestone. This example is the very ideal of a valley cut out by a revived stream whose course had been finally adjusted in a previous cycle to the structure of the old land that it channelled. Its relation to the long lost constructional form of the land cannot now be deciphered.

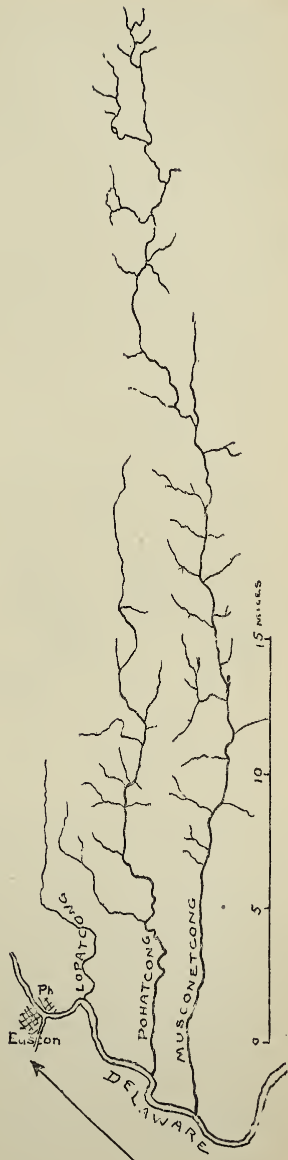

Fig. 7.

valleys being clearly apparent. The great area drained by the Raritan and the Passaic, with the little Rahway between them, is left unshaded.

The line of heavy dots from the Ramapo to the Musconetcong marks the southeastern border of the Highlands; a lighter dotted line from the Assanpink to the mouth of the Raritan is the approximate position of the fall-line; and a dotted line running southwest from the Atlantic coast indicates the vague northern border of the southern lowlands.

[1] Fig. 8 (see p. 398) is a guide to show the locations of fig. 7 and several others in their appropriate parts of the state.

The branches of such streams may sometimes be independent of any streams in the previous cycle and owe their existence simply to the backward gnawing of lateral gulleys and ravines ; such would be called "subsequent" branches of revived streams.[1]

The control exerted on the form of the Highland valleys by the (apparent) synclinals of limestone that lie between (apparent) anticlinals of gneisses, etc., is finely illustrated at several points, perhaps nowhere better than in German valley, where the South Branch of the Raritan has its source. This valley is deep and wide as far as it is cut on limestone, but at its southern end the bottom of the limestone trough appears to have risen above the Somerville baselevel, and consequently the stream has here sunk a narrow gorge about five miles long in the gneiss. The exit from the constricted gorge to the broadly rolling Triassic plain at High Ridge is highly suggestive, when it is remembered that the difference of form between the gorge and the plain is not due to difference of age, but to difference in hardness and consequent difference in rate of wasting of their rocks.

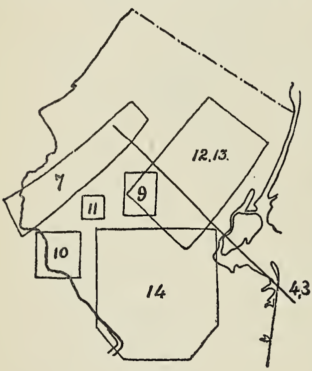

Fig. 8.

The Musconetcong in its lower course, about six miles from its junction with the Delaware, cuts into a longitudinal saddle of gneiss that separates the limestone troughs of its upper and lower course : this is also probably a disclosure made by the river in the Somerville cycle. The same may be said of the transverse escape of the Pequest from one longitudinal limestone valley to another, seven miles east of Belvidere ; the location of the cross-cut was probably determined by a sag in the intervening anticlinal of gneiss which allowed the limestone here to wrap over the gneiss from one synclinal valley to the other. All these examples where the streams have cut down from limestone to a much harder rock, that would not otherwise be chosen for stream courses, may be regarded as "locally superimposed." The relative length of the Musconetcong and the Pohatcong, fig. 7, is

[1] Nat. Geogr. Mag., I, 1889, 207.

determined in the same way: the former is sunk on a long limestone belt; the latter on a much shorter one.

26. *Superimposed streams; the North Branch of the Raritan.* The course of this stream, figure 9,[1] appears to be as distinctly inherited from rock structures that have now disappeared as that of the Musconetcong is consequent on structures that still exist. The North Branch rises on one of the front masses of the Highlands and flows southerly through a deep oblique valley between Mendham and Peapack to the Triassic lowlands. On the way at Roxiticus, it crosses a belt of limestone that trends south-southwest, reaching the border of the Highlands north of Peapack. Now if the North Branch had been revived from a course dependent on the slope and structure of the elevated old Highland peneplain, it must surely have followed the relatively soft limestone out to the lowlands; but its indifference to this line of easy valley-cutting can be explained by the hypothesis of inheritance of its course from the slope of some now extinct overlying beds; and these must have been the Cretaceous. The Cretaceous beds must therefore be regarded as having once extended across the Triassic area and a little way over the margin of the crystalline rocks of the Highlands, from which they were derived.

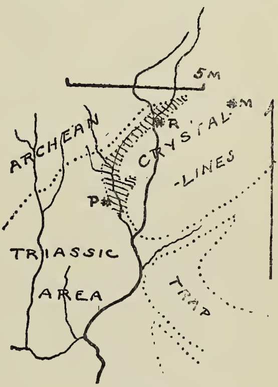

Fig. 9.

It might be suggested that the present course of the North Branch results from the backward gnawing of a "subsequent" stream that began as a ravine on the front of the Highland plateau and at last captured a back country stream and led it away from the limestone valley by the present deep gorge. There are two objections to this suggestion. In the first place, streams that are undoubtedly of subsequent origin, such as those that flow into the Ramapo from the front bluff of the Highlands near the northern border of the state, are much shorter than that part of the North Branch from

[1] Fig. 9 represents a portion of the North Branch of the Raritan, where it leaves the Highlands, near the southwestern hook of the Watchung crescent. The limestone belt that it traverses is shaded by transverse lines. The neighboring towns are P, Peapack; R, Roxiticus; M, Mendham.

the front of the Highlands to the limestone belt; therefore, it cannot be admitted that the North Branch has yet had time to cut its valley back as far as the limestone by the very slow process of headwater gnawing. In the second place, if there had been time enough for the suggested process, it would be the stream on the soft rock that would capture the headwaters of the other one whose outlet was on the harder rocks, and not *vice versa;* and indeed there is some possibility that this capture may yet be made. The divide on the limestone belt is at a height of 470 feet between the North Branch and the little tributary of the Peapack which follows the limestone out to the lowlands, and there joins the North Branch below the gorge. The North Branch is at an elevation of 360 feet on the limestone just below Roxiticus; and from here to the divide above mentioned is a distance of a mile. Where the Peacock joins the Raritan, the river is only 140 feet above the tide-level.

Some observers see evidence of a fracture in the gorge of the North Branch rather than an inheritance from an unconformably overlying formation;[1] and it cannot be absolutely denied that such may be the case. But the fault cannot be of large throw, for the transverse limestone valley is not dislocated on the line of the gorge; indeed there has not as yet been presented any complete evidence of the existence of fractures in this district of sufficient importance to outrank the limestone belts in giving location to matured river courses, in cases where either course was open to natural selection. If any fault exist in this neighborhood, it is more likely along the Archæan-Triassic boundary than in the line of the river. In general it appears that the more closely rivers are studied, the less attention they seem to pay to fault-lines; and the most probable conclusion in the present case does not appear to be in favor of accepting a fracture as a guide.

27. *Distribution of revived and inherited valleys in and near the Highlands.* Most of the streams of the Highlands are parallel to the general structure of the region and follows its softer rocks; and of the several transverse streams, none can give so clear indication of an inherited course as the North Branch of the Raritan. The Delaware needs no such explanation; it is essentially a revival of the master-stream that gave outlet to a large area of back

[1] Nason, Geol. Survey N. J., Ann. Rept., 1888, 43. Britton states that the Pequannock is located on a transverse fault. Ann. Rep., 1886, 122.

country drainage on the old peneplain. The Rockaway and the Pequannock are much smaller than the Delaware, but are sufficiently explained in a similar way; they flow southeast from the highest part of the Highlands and carry the waters of a few longitudinal streams with them. All of these are probably revivals of the Schooley cycle of drainage. Faults may have had in that or some still earlier cycle some share in locating these transverse streams; but this question has not been definitely settled. The irregular course of the Rockaway by Boonton is the result of drift obstructions in its simpler preglacial course, and need not be referred to an inheritance from the Cretaceous cover. But the Lockatong, fig. 10, a small branch of the Delaware, flowing across the sandstone plateau of West Hunterdon between Flemington and Frenchtown, can hardly be regarded as a simple revived stream; if such had been its history its headwaters must have escaped by Warford creek (*a*, fig. 10), on a short course along the strike of the beds to the neighboring master river, instead of crossing the beds for twice this distance. Indeed, this adjustment cannot be much longer delayed. The upper Lockatong runs over the plateau in a very shallow valley, and near the flat divide between it and Warford creek, the stream is at an elevation of 470 feet. The head of Warford creek is only a quarter of a mile away, and this stream falls 300 feet in its course of two miles and a quarter along the strike of a relatively weak stratum, while the Lockatong makes the same descent in about seven miles across the strike of harder strata.

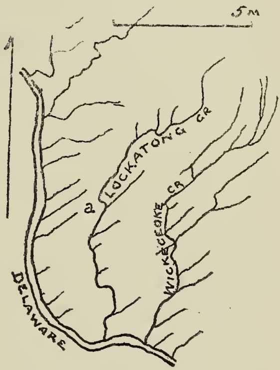

FIG. 10.

FIG. 11.

The notch, x, fig. 11, in the curve of Cushetunk mountain, one of the smaller trap ridges near the Highlands, where the wagon road finds entrance to Round Valley from the southeast, is probably the abandoned site of a superimposed stream, whose beheaded remnant is Holland brook and whose headwaters have been led off westward to the Raritan by Prescott brook; the change that is in store for the Lockatong being here already accomplished.

On the other hand, the Ramapo, joining the Passaic near Pompton, is a good illustration of a stream whose course shows no dependence whatever on the Cretaceous cover; it follows the line between the Triassic and the Crystallines, gathering small branches from either side, and not only giving no sign of inheritance from some extinct structure, such as the North Branch of the Raritan showed so clearly, but flowing in as close accord with the present structure as the Musconetcong.

Taking these streams as guides, it may be concluded that the overlapping of the Cretaceous that resulted from the transgression of the Atlantic over the Schooley peneplain at the time of its slight depression, reached all across the Triassic formation in the middle and southwest side of the state, but not quite so far in the northeast. It undoubtedly oscillated back and forth many times about this line. The occurrence of inherited streams above the head of Chesapeake bay at some distance inland from the present margin of the Cretaceous cover,[1] and the general correlations allowed by the suppositions here brought forward, lend support to a conclusion that might otherwise be more easily questioned.

28. *Drainage of the Triassic area of the Central Plain.* The streams of the Triassic area generally do not give unequivocal evidence of inherited courses. They are on the one hand susceptible of explanation as the revived successors of old streams whose position was determined during the long development of the old Schooley peneplain; and on the other hand they might be regarded as superimposed from the drainage of the extinct Cretaceous cover. They are therefore not like the Lockatong and the Raritan in demanding the former inland extension of the Cretaceous formation over the Triassic area; but as that extension seems to be well proved, the best understanding of the Triassic drainage can be gained by regarding it as inherited. This conclusion seems to be more accordant than any other with the conditions of drainage farther south along our Atlantic slope.

[1] McGee, *l. c.* 133, 134. It is the Potomac formation that McGee regards as having here stretched over the peneplain.

Let us consider, therefore, the transverse streams which rose on the crystalline lowland peneplain in the latest part of Schooley time; they flowed across the strike of the rocks, that is, in a general way, to the southeast and entered the shallow Cretaceous sea somewhere near the line above indicated as marking the limit of its northwestward transgression; but later, as the whole region was elevated and the even sea-bottom became a land area of smooth surface and gentle southeastward slope, the transverse streams from the Highlands must have prolonged their courses in the same direction.

The examination of the present altitude of the remnants of the Schooley peneplain, in paragraphs 15 and 21, gave us reason to think that when this plain and its cover were lifted, the slope of the cover was not uniformly to the southeast; for the crest of the Palisades-Rocky Hill trap ridge is not now a level line, as it must very nearly have been on the Schooley peneplain; it is lowest from Amboy to New Brunswick, where the Cretaceous cover still buries it; and it rises northward and southwestward from these points. The unequal lifting of the Cretaceous sea-bottom, thus indicated, gives reason for the convergence of the Passaic and the Raritan from the north and west and explains the location of their passage across the Palisades-Rocky Hill sheet where it is still buried.

We cannot say how much additional length the streams from the Highlands gained as they crossed the newly lifted Cretaceous plain, but the process by which it was gained has a modern homologue in the growth of the streams that flow southeastward across the lowlands of southern New Jersey, where the uplift from the sea is so recent and so slight that the streams have not trenched their channels through the beds on which they took their birth. But in the Triassic portion of the Central plain under consideration, the elevation by which the rivers grew longer was long ago and the uplift was of considerable measure at the margin of the crystalline area, whence the surface of the Cretaceous beds sloped with distinct fall to the coast of that time, perhaps not far from the present coast line. Time, elevation and slope all being allowed, the lengthening streams from the Highlands have been able to trench their channels deep below the Cretaceous beds on which they took their birth and to reveal the unconformable underlying Triassic formation, which they traverse in superimposed courses. How far can we find evidence in favor of this sketch of their history? A peculiar portion of the Central plain may now be examined in this connection.

29. *Drainage of the Watchung Crescent.* Many of the streams that took courses across the Cretaceous cover of the submerged portion of the Schooley peneplain soon encountered the buried edges of hard trap ridges beneath the soft Cretaceous beds and from this time forward there was frequent opportunity for one stream to rob another and to become confirmed in this habit of robbery as time went on. To illustrate this, suppose the land were raised some two hundred feet higher than it now is. The Raritan would then soon encounter the Palisades-Rocky Hill trap sheet, fig. 1, under the Cretaceous beds below New Brunswick; being a large river, it would with relative quickness cut a deep gorge or gap through the resistant sheet. But the smaller Rahway river, encountering the same obstruction a little farther north, would be so slow in cutting down its gap that, before it was safely trenched close to base-level, some side branch of the Raritan, such as Bound Brook, would eat its way back and tap the headwaters of the Rahway and lead them away by the deeper passage prepared by the larger river. Thus strengthened, the Raritan would be still better enabled to perform the same piratic act on other rivers, and hence the number of streams that cross the trap sheet would be lessened and at last reduced to a small number at the time of mature adjustment. Is it not likely that some such process as this is to be considered in explaining the present course of the streams in the region of the curved Watchung mountains? In the discussion of this problem, we must refer to fig. 12, which is reduced from a tracing of the region from the relief map of the state.[1]

We have concluded that the Cretaceous cover once stretched over the Watchung ridges when they made but faint relief on the old Schooley peneplain. The streams born on the newly elevated and gently sloping Cretaceous cover cannot be thought to have taken courses as circuitous as these that now lead the drainage out from the Highlands. It is true that part of the present complexity is certainly due to obstructions by glacial drift: for example, the round-about outlet of Great Swamp is pretty surely determined by the great morainic barrier, stretching from Morristown to Chatham and traversing the Triassic lowland that had in Somerville time

[1] The Highland plateau in fig. 12 is separated from the Triassic lowland by a line of heavy dots. The fine dotted line is the contour of three hundred feet; the heavier broken line of five hundred feet. The several parts of the three trap ridges composing the Watchung mountains are marked I, II and III. Several cities and towns are abbreviated thus; B. Br., Bound Brook; Bn., Boonton; Mn., Morristown; N. Br., New Brunswick; Pat., Paterson.

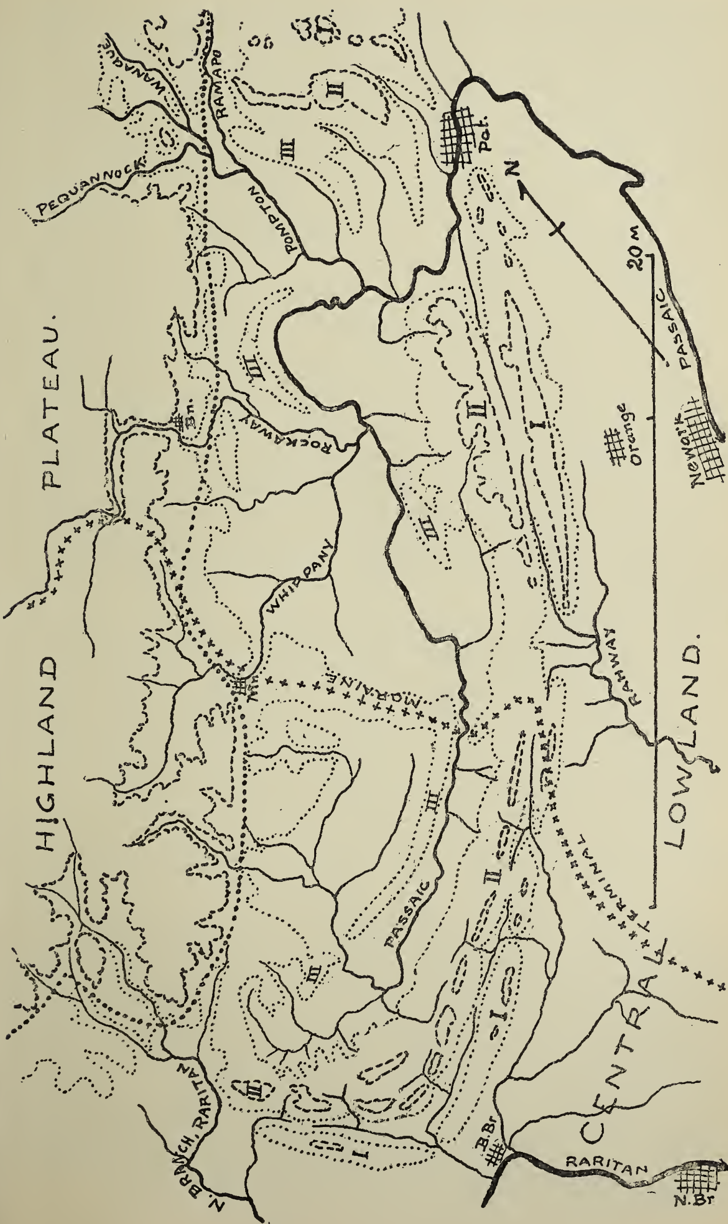
HIGHLAND PLATEAU.
CENTRAL LOWLAND.
PEQUANNOCK
WANAQUE
RAMAPO
POMPTON
ROCKAWAY
WHIPPANY
MORAINE
TERMINAL
PASSAIC
PASSAIC
RAHWAY
RARITAN
N. BRANCH, RARITAN
Pat.
Orange
Newark
N
20 M
B.Br
N.Br
I
II
III

FIG. 12.

been opened behind the Watchung ridges. But the general concentration of all the back country drainage at Paterson is not what would be expected of a system of rivers still persisting in courses taken on the Cretaceous surface sloping gently to the southeast. It might truly be suggested that the trap ridges were not entirely buried or that their residual relief on the Schooley peneplain was not entirely concealed by the Cretaceous cover; and, in that case, the passage of the Passaic at Paterson might mark the passage of some old stream of the Schooley cycle, where the drainage from the back country would naturally pass when the Cretaceous plain rose from the sea. Between this suggestion and the explanation by mature adjustment following superimposition as already indicated, we must choose by means of the accordance of one or the other hypothesis with such details of drainage as a careful examination of the country may disclose. The best test that can be applied in choosing between the two hypotheses is found in the location of water and wind gaps in the Watchung mountains. If they are not distributed at random, but manifest an arrangement that seems to be in accord with a systematic development of many superimposed streams, more confidence may be felt in one hypothesis than in the other.

The essential peculiarities of a drainage system that would be developed by the adjustments of superimposed streams would be the occurrence of wind gaps near the water gaps of the master streams, and the persistence of water gaps followed by small streams at a greater distance from the masters. This seems to be actually the case to a certain extent, as appears in fig. 13.[1]

The interpretation that we would give to the rivers of this area is as follows. The northern part was drained by a large transverse stream rising in the Highlands, *AA*, and composed of what are now

[1] Fig. 13 gives an hypothetical interpretation of the actual drainage arrangement indicated in fig. 12. The initial courses of several superimposed streams, chosen on the sloping surface of the elevated Cretaceous cover, are marked by waving lines, *AA*, *BB*, *CC*, *DD*, corresponding with parts of existing streams whose names are given in Fig. 12. The most important diverting stream is marked by a heavy, broken line, *EFG*. Wind gaps and a few divides in stable positions are marked *O*. Inverted streams have dots along side of their lines. Divides not yet pushed by the inverted streams to a stable position are marked □, and these are all in the south. The moraine is indicated by *XXX*, heavy where it acts most effectively as a divide. Streams whose courses have been much changed by a glacial drift are cross-lined, as the Passaic, *GKR*, and the Rockaway at Boonton, *M*, and below. Divides, where capture may yet be made, are marked △, as on the north branch of the Raritan, *H* (see paragraph 26) and on the old drift-filled course of the Rockaway, *L*. The terminology of diverting, diverted, inverted and beheaded streams is explained in Nat. Geogr. Mag., I, 1889, 210.

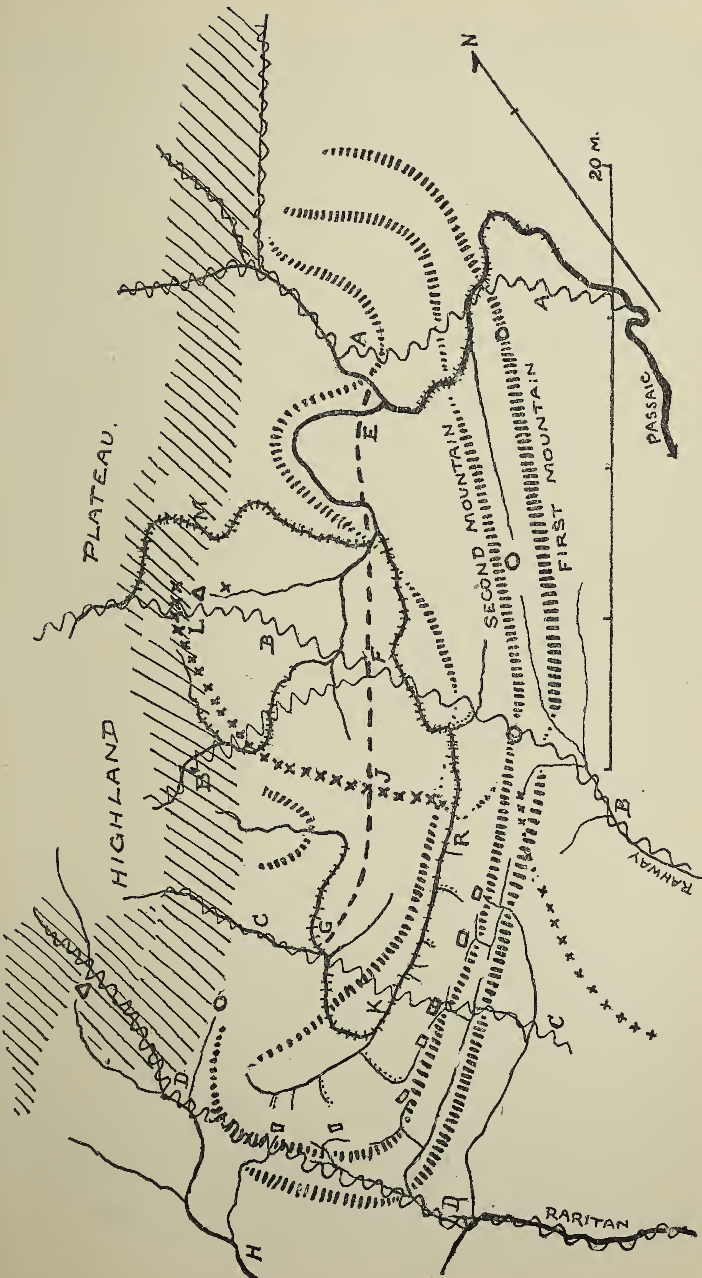
PLATEAU.
HIGHLAND
SECOND MOUNTAIN
FIRST MOUNTAIN
PASSAIC
RAHWAY
RARITAN
20 M.
N

Fig. 13.

called the Pequannock, Pompton and lower Passaic, with the Wanaque and Ramapo as branches, of revived origin in and near the Highlands, but superimposed farther east. The Rockaway-Rahway, *BB*, was another stream of the same kind, draining across the middle of the Watchung crescent. The headwaters of the present Passaic perhaps constituted the upper portion of a third stream, *CC*, that found its lower part somewhere about Plainfield. All these streams flowed across the buried Triassic area upon its Cretaceous cover. Of the three named, the first has certainly now and probably then had the largest drainage basin, and the last had the smallest. The first would therefore, other things being equal, excel the other two in the rate of channel cutting, and thus would find opportunity to capture their headwaters at some point above any hard reef that they might encounter. The record of an early capture of this kind is seen in the Notch in the First mountain, just south of Paterson, now followed by the New York and Greenwood lake railroad. We cannot say what were the headwaters of the stream that once flowed here, but it is tolerably evident that after it had accomplished a good beginning towards cutting down a water gap, its headwaters were led away by the more successful river, which thereby became all the more able to compete with the remaining streams. Every time that the river thus captures the headwaters of its neighbor, it gains strength to acquire other headwaters; and we must therefore regard river capture of this kind as one of the normal lines of progress in river development. Possibly the Pequannock and Wanaque at first had independent courses across the trap ridges, and joined forces by one capturing the other, thus forming the Pompton; the Pompton then still further deepened the gap at Paterson; its side streams pushed away the lateral divides more rapidly than before, and thus the Rockaway was caught and led to the larger stream at *E*. It must be noticed that at this time the original Rockaway, *BB*, did not leave the Highlands at Boonton, *M*, but by the now drift-filled valley, *L*, farther south, whence we supposed it crossed the sandstone basin towards Summit, where its gaps were cut across the two trap ridges; thence forward it continued as the Rahway. It was probably tapped midway on its course, as at *F*, by a branch of the Pompton; the divide between the diverted and beheaded parts of the once continuous river slowly migrated eastward, until it took a stable position on the trap sheet of Second mountain; the water gap in this ridge thus became a wind gap and is marked *O*, like several other stable divides that appear to have been adopted after the ancient capture of one stream by another; while the diminished lower part of the stream continued to the sea as the Rahway. The Passaic-Plainfield river, *CC*, was next captured at *G*, its divide between the lower beheaded and the upper diverted portions also at last migrating towards the Second mountain. But as the distance from the gap of the master stream at Paterson increases, its diverting branch, *EFJG*, has less favorable conditions for capture of the other streams; hence in the southern part of the Watchung crescent, there are still several small streams draining outward across both trap mountains, whose divides have not yet been driven to a stable position on Second mountain, as has happened in every case farther north. It is correspondence of this kind that lends color to the hypothesis of superimposition and adjustment that we offer; but whether it is the color of truth or not can hardly be decided at present. The diverted course of the upper Passaic was not in the valley, *KR*, that it now follows between the second and third trap ridges, but along the then open basin from Great Swamp, *G*, northeastward, past *J* to *F;* the present course of the river being determined by the heavy morainic barrier, *XXX*, stretching from Morristown to Chatham. This compelled the stream, *GJF*, to turn back and flow over the courses of several streams, *GKR*, that were presumably independent of one another in preglacial time. So with the middle course of the actual Passaic, *RE;* it is certainly much affected by drift, flowing through swamps for long distances, and it cannot be taken as a close indicator of the maturely adjusted stream by which the crescent was drained to the northeast in the Somerville cycle.

When the trap ridges were disclosed by the wearing away of the Cretaceous cover, it may be that some inequality in their thickness or some fractures may have exercised a control in locating some of the streams. For the two main sheets we have no indication of this, unless it be at the gap in First mountain, where the Rockaway-Rahway river, *BB*, is supposed to have crossed it. When standing on the south end of Orange mountain, as the outer ridge north of the gap is locally called, one may look to the south and see that there appears to be an imperfect alignment with the southern member, suggesting some dislocation or irregularity in the sheet; but the conclusion is not definite. At the same place, the greater depth of the gap in First than in Second mountain is also apparent and calls for explanation; for it is not easy to see how the beheaded remnant of the former river could have cut so deep a gap in the front ridge. It is possible, however, that the inequality of depth is only apparent, and is really due to a heavy drift filling in the wind gap of the second ridge, where the moraine crosses it. This seems very likely.

Inequality of thickness in the lava sheets does not appear clearly in First and Second mountains, but it is probably characteristic of the third sheet, which is thinner than the others, and is worn down low in part of its length, so low as to suggest structural weakness rather than concentration of destructive processes. Its several parts have different local names; Long hill, Rikers' hill and Hook mountain.

The conception of the Highland plateau, as an old baselevel plain, elevated and partly cut away again, may now be recalled once more. Returning to one of the high points of view on the front of the Highlands, and in imagination filling up again the Highland valleys and the Triassic lowlands to the general level of the crystalline plateaus and trap ridges as described in paragraph 15, we must now stretch the Cretaceous cover over the Triassic area to the margin of the crystalline Highland plain, a cover formed of materials washed from the inner non-submerged portion of the Highlands. From this as the initial condition of the Somerville cycle, the greater part of our existing geography appears to be developed.

30. *Drainage of the Uinta Mountains of Utah.* It thus appears that while the present Watchung drainage is in greatest part accordant with the structure of the district, it is also in a small way characterized by such significant discordances that its origin is best referred to superimposition. As a corollary of this, it follows that superimposed drainage is to be recognized by its full discordance with structure only during its youth, and that in its more mature age it may come to be almost or fully accordant, thus simulating consequent drainage. Antecedent drainage may in the same way lose its initial discordances. With this in mind, we have looked over Powell's account of the drainage of the Uinta mountains, where he first proposed the terms antecedent, consequent and superimposed,[1] the idea embraced in the latter term having been previously stated by Marvine.[2] The drainage of the Uinta mountains is concluded to be chiefly antecedent; not only the Green river being thus regarded,

[1] Expl. Colorado River of the West, 1875, 163, 166. Geology of the Uinta mountains, 1876. 12.

[2] Hayden's Surveys, Report for 1873 (1874), 144.

but also a number of smaller streams which join it. The reasons given for this conclusion are that the location of the streams is not accordant with the initial structural surface of the range, for a number of the branches of the river join it by monoclinal instead of synclinal valleys. But inasmuch as the region is one of enormous denudation, it does not seem unlikely that such monoclinal side valleys may be adjusted courses of consequent or superimposed streams, instead of persistent courses of antecedent streams ; for the process of adjustment by which hard courses are deserted for easier ones was not then considered. But this indoor correction of an outdoor conclusion is suggested only in a tentative way.

31. *The Kittatinny Valley.* While the Central plain was developed on the soft Triassic and Cretaceous beds, and the valleys of the Highlands were opened by their revived streams, the broad area of limestones and slates between the Highlands and the heavy outcrop of Medina sandstone near the northwestern line of the state was denuded into a broad lowland known as Kittatinny valley : all this being the work of the Somerville cycle. If the observer climb to the commanding summit of Jenny Jump mountain, one of the outlying masses on the northwest side of the Highlands, near the Delaware, he may see a great length of the Kittatinny valley lowland in New Jersey and Pennsylvania, bounded on the west by Kittatinny mountain. The slates, that are associated with the limestones on the northwestern side of the valley, are more resistant and form hills not yet reduced to the Somerville baselevel ; they are thus homologues of the hills formed on the harder Cretaceous beds on the southeastern part of the Central plain. In the same way, the even crest of Kittatinny mountain corresponds with the even crests of the Watchung ridges, still preserving the general elevation of the Schooley peneplain. The extension of this peneplain into Pennsylvania and its relation to the development of valleys in that state have been elsewhere discussed by the senior author.[1]

The Millstone Deformation of the Central Plain.

32. *Present attitude of Central Plain.* The Central plain has been unevenly lifted from the position that it held during its development, for it is not now so low or so level as it was then. Its present altitude is naturally the result of the summation of all the small

[1]The rivers and valleys of Pennsylvania. Nat. Geogr. Mag., I, 183-253.

movements it has suffered since it was formed; but we shall not now attempt to detect the individual elevations and depressions of which the total is composed; the geological evidence by which they may be proved is not yet all worked out, and with exceptions that will be mentioned in later paragraphs, the minor oscillations that have probably occurred have been without geographic consequences recognizable on the maps.[1]

The plain is lowest about Bound Brook, where its interstream surface averages only about seventy feet over present sea-level; it rises thence to the south, and along the back of Rocky Hill reaches one hundred and twenty to one hundred and thirty feet; from Somerville towards Flemington and White House, it rises from one hundred to two hundred feet; the latter altitude is maintained near the Delaware by Lambertville and above Trenton. From Trenton across the country to New Brunswick, there is another low strip ranging from eighty to a hundred feet; farther south about Hightstown, the surface rises to one hundred and thirty or one hundred and forty feet; near the Atlantic-Delaware divide, the plain is two hundred feet above the sea. It appears from this that the Central plain is no longer a level or continuous surface. It has been tilted and dislocated, its two parts dipping at a gentle angle to the north or northwest; and the step by which they are separated marks the location of the fall-line dislocation, as described most fully recently by McGee, of which more below. It seems to be necessary to regard the two parts into which the Central plain is thus divided as formerly joining in a continuous surface; for they are both baselevelled plains of post-Cretaceous erosion, and they have both been channelled by comparable amounts in later time. If the two parts of the country had held their present relative positions while the lower part was baselevelled, as it is so perfectly about Monmouth Junction, it is impossible that the upper portion could have retained as much of its interstream surface unworn as appears around Princeton. The two parts have been baselevelled together; their unequal heights now indicate subsequent unequal elevation. As the fall-line dislocation follows close along the boundary between the Triassic and Cretaceous formations, the two parts into which the Central plain is now divided may be named after these geological areas.

[1]The deltas and shore line deposits of the Columbia formation described by McGee, not being represented by special colors on the geological map of New Jersey, are not here considered.

Although the dislocation may at first sight seem somewhat surprising, it does not appear to differ from many well known facts. The forces of dislocation know nothing about baselevelled regions: they act where the resistance of the whole mass subject to them is least, and it is indifferent to them whether the plane of action outcrops on the surface of the constructionally level lava plains of southern Oregon or on the once baselevelled plains of central New Jersey. The result in either case is dislocation and tilting of what was before level and continuous.

Other portions of the lowlands produced in the Somerville cycle also give evidence of change of level. The Kittatinny valley-lowland has suffered elevation since it was reduced to a peneplain, for its interstream surfaces now stand at an altitude of four hundred or more feet. This is decidedly greater than the height of the corresponding surface of denudation in the Central plain about Bound Brook, but it has not yet been possible to determine whether the inequality is due to warping or to faulting. The Highland valleys are not broad enough to give definite record of the position of the Somerville baselevel on the contoured maps, but a brief sight of them from a railroad excursion gave encouragement to think that deliberate examination on the ground might solve the problem ; the streams appear to have sunk young trenches below the general valley bottom.

33. *Valleys of the Millstone cycle.* The elevation of the country from its Somerville attitude has revived the streams and carried them into a new cycle of work. The streams in well marked valleys, such as those of the Highlands, where Somerville time was not nearly sufficient to accomplish baselevelling, give no indication of any change from their Somerville courses ; but, as suggested above, they seem in some cases to have trenched new channels in the flat-bottomed valleys of earlier (Somerville) date. This is much more apparent in the Kittatinny valley, where the Delaware flows in a steep-sided valley a hundred or more feet below the general valley-lowland, and its side streams trench the lowland as it has given them opportunity. The Lehigh from Easton to Bethlehem in Pennsylvania exhibits this relation with great clearness, and many other examples might be named.

The same thing appears in the Central plain : the traveller on the Pennsylvania railroad cannot fail to be impressed by the narrow cut of the Raritan at New Brunswick ; or, if crossing the state by the "new route," he must notice the little-stream valleys that interrupt the general interstream plain between Trenton and Bound Brook. These are all the product of the Millstone cycle. The valleys are of moderate width, and hence this cycle is not far advanced.

The depth to which a stream may cut its channel depends on the altitude of its drainage area above its baselevel. Lowlands can therefore never acquire the intensity of topographic relief that characterizes the maturer stage of highlands. It is for this reason that the valleys that have been cut in different parts of the Central plain are of different depths. The valleys of the Delaware and Lehigh, above mentioned, are much deeper than the valley of the Raritan at New Brunswick; not because the former are older, but because they have had a higher mass in which their trenches were to be cut. So again with the Raritan at New Brunswick and at Bound Brook; the stream has insignificant fall from one place to the other, but its trench deepens from fifty feet below the Central plain at Bound Brook to a hundred and thirty feet below it at New Brunswick, because the surface that it trenches rises in that direction. The Millstone river, fig. 14,[1] after which the cycle under discussion is named, is even more interesting in this respect. Its various head branches rise in the Cretaceous plain, where their trenches are sunk from twenty to forty feet below the general interstream surface; the streams thus cross the depressed portion of the plain south of Princeton, and then uniting into a single river they enter the higher part of the plain northwest of the fall-line, here cutting a valley a hundred feet deeper than before, because the plain is now a hundred feet higher; but the depth decreases as the river crosses the Triassic plain to its northwestern lower side, and in the neighborhood of the town of Millstone, the stream is about fifty feet below the plain, like the Raritan which the Millstone there joins. The headwaters of the Millstone have not yet had time to sink their channels close to baselevel; for their discharge to the sea is by a long roundabout course by which their slope is decreased; and on the way their outlet stream crosses the hard trap sheet of Rocky Hill, where the deepening of the channel is retarded. In contrast with the delayed deepening of these head-

[1]Fig. 14 includes the drainage of the Millstone river: BB, Bound Brook; C, Clarkesburg; J, Jamesburg; N. Br., New Brunswick; Pr., Princeton; S, Somerville. The fall line is dotted from Trenton to Lawrence Brook.

waters, we see the strong channelling of neighboring streams like Lawrence brook, that reach the sea by short courses over soft, rock, of which more will be said below.

34. *Persistent and reversed streams of the Millstone cycle.* Most

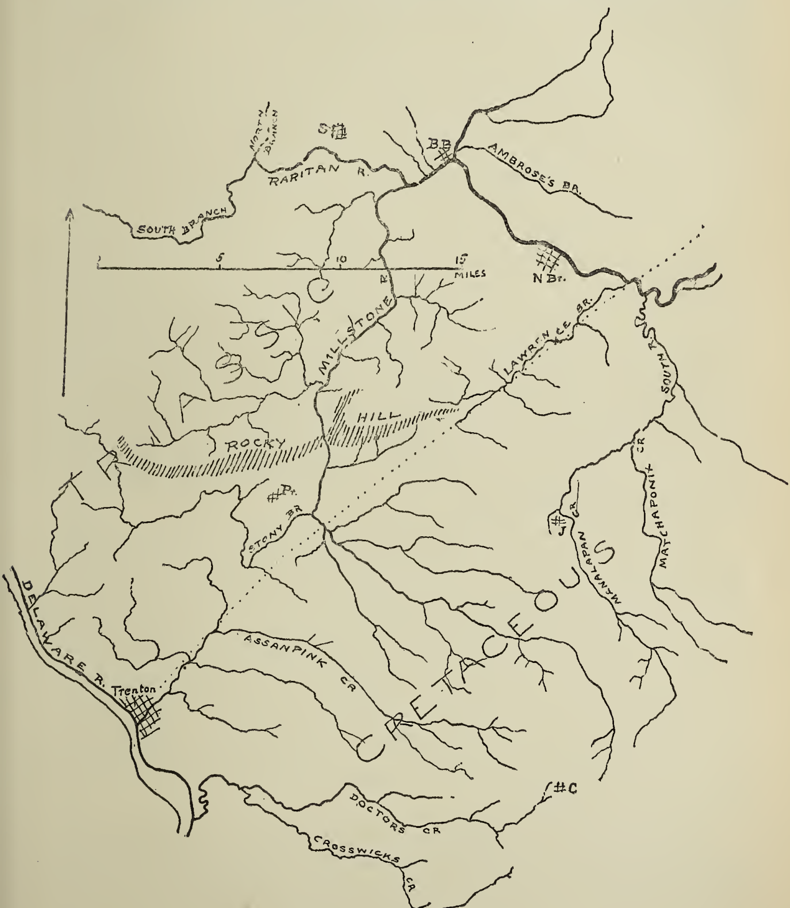

FIG. 14.

of the streams that have trenched the Central plain, the Highland valleys or the Kittatinny valley-lowland in the Millstone cycle exhibit no peculiarity of location or direction that cannot be satisfactorily referred to the Somerville or even to the Schooley cycle.

The streams in the Highland valleys are well hemmed in, and their present trenches are simply the product of Millstone revival on the Somerville valley bottoms, just as the Somerville valleys resulted from the revival of the streams on the Schooley peneplain. The same appears to be true of the Delaware and its side streams in the Kittatinny valley-lowland. The Raritan also seems to retain in good measure its Somerville course, for it runs against the slope of the plain from Bound Brook to New Brunswick after the fashion of antecedent streams; but its traverse of the lower part of the plain near Bound Brook suggests that the Millstone tilting of the plain may have turned it somewhat to this special location.

On the other hand, several smaller streams manifest in their directions so distinct an accordance with the slope that has been given to the Central plain since its formation, that they must be regarded as consequent upon the slope. Ambrose's brook, fig. 14, is an excellent example of this kind: it lies two or three miles northeast of the Raritan where the latter runs from Bound Brook to New Brunswick; but while the larger stream flows southeast against the slope of the plain, the smaller one flows northwest with the slope. A number of streams to the west of the Raritan are probably of similar origin.

But the most remarkable case of this kind is that of the Millstone. Here we have a river of some length, with a number of head branches, all flowing northwestward, as if they had been given that direction by the tilting of the Central plain. The same course is seen in the Rancocas, and in other smaller streams farther southwest, on the same Cretaceous portion of the Central plain. But the Millstone has not only this reversed course; it crosses the fall-line dislocation against its uplift; and in this it has no fellow as far as the fall-line has been traced.[1] The history of the case appears to be as follows.

35. *Reversal of the Millstone river.* All that is known of the processes of the Somerville cycle indicates that central New Jersey must then have acquired a drainage directed in general to the

[1] In McGee's maps of the fall-line displacement, Seventh Ann. Rep. U. S. Geol. Survey, Pls. LVII and LXVII, South river is also drawn as if crossing the fall-line against the heave before joining the Raritan; but it appears more probable that the prolongation of the main line of displacement runs as here drawn though perhaps with diminishing throw; and that the northeast–southwest course of South river is due to another, parallel and subordinate displacement. Farther south in Pennsylvania, Delaware, Maryland and Virginia, all the streams that cross the fall-line run from the northwest to the southeast.

southeast. The Cretaceous beds on which the drainage was first established have a southeastward dip in all cases ; and indeed Professor Cook has shown that the dip of these beds is about equal to the present slope of the reconstructed Schooley peneplain in the Highland area.[1] The southeastward drainage is a general feature of our whole Atlantic coastal slope, and was probably thus introduced over its entire extent. There are two ways in which the streams of a region might be reversed from this prevailing direction. They might be reversed by capture, an inverted northwest course then being taken as the divide is pushed from the point of capture to its final stable position, and we have examples of such inversions on the inner slopes of Watchung mountains ; or they might be reversed by a tilting of their drainage area, as appears to be the case in Ambrose's brook above named.

It is impossible to explain the northwestward course of the Millstone by regarding it as the inverted middle portion of a southeastward river, whose northern head-waters were captured by the Raritan. In that case, the inverted stream must have had its head on the north side of the gap in Rocky Hill, near Princeton ; the rest of the original southeastward river would continue from the south side of the gap in its normal direction as a beheaded stream : the gap would be a wind gap, not a water gap.

The other explanation seems more acceptable. Conceive the Millstone as one of many southeastward streams, born on the Cretaceous cover at the beginning of the Somerville cycle. It was unfortunate enough to sink on the Rocky Hill trap sheet, by which the down-cutting of its head-waters was retarded ; some of its head streams may then have been captured by the more fortunate Raritan, which happened to choose a soft course on its way to the sea. But we must suppose that enough drainage area was left to the Millstone north of Rocky Hill for it to cut down its gap in this ridge close to baselevel before the end of the Somerville cycle. This is not unreasonable ; for the perfection of the baselevelling of the Central Plain could not have been attained before a good sized stream would have cut a deep channel even across a hard stratum. Now it is precisely in the old age of a stream, when its gradient is small, that a moderate tilting may suffice to reverse its slope and change its course. Hence the fully baselevelled channel

[1]Ann. Rep., 1883, 28. The Artesian water supply along the coast depends on this general southeastward dip . Ann. Rep., 1885, 109, 123.

of the Millstone river at the close of the Somerville cycle must have been very liable to reversal of slope if an active change of level then took place. There is no measure of the activity of such a change of level, save in its effects. The Millstone now flows in a direction that clearly indicates an active uplift and tilting at the close of the Somerville cycle, and hence the active uplift may be accepted. The highest elevation reached by the Central Plain and still retained by it is in its Cretaceous portion, in the neighborhood of Clarkesburg: here it is about two hundred feet above sea level. The change suffered by the plain still farther southeast will be briefly considered in a later paragraph. The question here before us is whether such an uplift, perhaps coupled with slight actual depression toward Bound Brook, might not reverse the hypothetical southeastward course that the Millstone river is supposed to have had before. If the Central plain had not been dislocated, the reversal of the river would not be so difficult to believe; but when it is remembered that the river in its hypothetically reversed course had to cross the fall-line dislocation against the uplift, that is, from the thrown to the heaved side of the fault, one may still hesitate to accept an explanation so peculiar. Still, as far as can be seen, there is no other solution than this. The reversal probably occurred before the dislocation; and the dislocation at this point appears to have been slow and of moderate amount, for otherwise the Millstone headwaters would have found exit along the thrown margin of the fault, either southwest to the Delaware at Trenton or northeast to the Raritan below New Brunswick. Indeed, if the dislocation continue in the future, one or the other lateral escape of the Millstone headwaters is highly probable.

The case is interesting as an apparent example of a rare occurrence in the history of rivers. Few cases of the kind have been described.

36. *Deflection of the Delaware along the Fall-line Displacement.* The Delaware, like some other streams of great age that have been revived from the Schooley to the Somerville and from the Somerville to the Millstone cycle, follows an ancient course across the Kittatinny valley and the Highlands,[1] and a superimposed course inherited from the Cretaceous cover of the Triassic belt from about the edge of the Highlands to Trenton; but here it turns abruptly to the southwest. McGee has found explanation of this singular

[1] *Cf.* McGee, *l. c.*, 135.

deflection in the depression that accompanied the fall-line dislocation, and has shown that similar deflections characterize other rivers when they reach this important structural line.[1] This large river might easily have overcome the difficulties presented by the elevation of the southeastern part of the Central plain and have persevered against them, as the Raritan did; but it was led astray by the temptation offered in the depressed belt along the southwest, and thus New Jersey gained greatly in area if not in wealth. The deformation by which the Delaware and other large rivers were deflected was presumably greater and more rapid than that which the Millstone overcame.

Many streams of moderate size that enter the Delaware below Trenton from the southeast seem to have gained their present courses at the same time with the deflection of the Delaware, and with the reversal of the Millstone. The divide between many of these and the Atlantic streams is at present southeast of the outcrop of the more resistant Cretaceous beds; most of the Delaware streams have relatively short courses in sharply cut valleys to the Delaware, while the Atlantic streams have long gentle slopes in flat swampy valleys to the sea. The Rancocas is the chief exception to this statement. In such cases of headwater opposition of streams, there is practically no record of any migration of the divide that may have taken place toward the flatter slope.

37. *Shifting of divides in the Millstone cycle.* The adjustment of stream courses, and particularly the establishment of stable divides that was undertaken within the Watchung areas during the Somerville cycle, is still continued in the Millstone cycle. There is still possibility of the diversion of the upper North Branch of the Raritan to the limestone valley that it now traverses, or of the upper Lockatong to the little stream that may lead its headwaters to the Delaware along the strike of the beds that it now crosses. In addition to these, there are certain adjustments of drainage lines dependent on the conditions of the Millstone cycle alone. The most distinct of these are in the debatable area between the eastern branches of the upper Millstone and the branches of the Manalapan near and above Jamesburg. It is highly probable that some captures have been already made here; for there are several depressions in the prolonged lines of streams that have no explanation either in the structure or in the present drainage of the coun-

[1] Seventh Ann. Rep., U. S. Geol. Survey, 1888, 616.

try. For example, the low pass from Jamesburg northwestward to Pigeon swamp, and from Monmouth Junction northwest by the railroad to the gap in Rocky Hill. It may be supposed that the Manalapan once flowed along these depressions, and that it was captured at Jamesburg by South river and in Pigeon swamp by Lawrence brook; but much more work on the ground is needed before such suppositions need be accepted. No other place in the state offers so good an opportunity for investigations of this kind. The example of river piracy recently described by the senior author in eastern Pennsylvania[1] belongs with these cases in the Millstone cycle.

38. *Marine erosion of the Central Plain in the Millstone cycle.* The altitude given to the Cretaceous portion of the Central plain by the uplift that closed the Somerville cycle has been described as a gentle ascent southeastward from the fall-line: but the ascent ceases about the headwaters of the Millstone and Manalapan, and the surface continues with fairly uniform height for some distance further. Here the streams flow eastward; they have trenched the plain rather strongly and at places it is much broken up; but from the occurrence of sands and gravels in the broad valleys and from the appearance of steeper slopes on the seaward side of some of the hills, we have supposed that the ocean has had a share in the opening of this country, in some portion of what is here called Millstone time, when the land stood lower than at present; but how far this is the case cannot now be determined. It is interesting to notice in this connection that here for the first time do we find the shore waves responsible for determining an element in the topography of the state.[2] The Central plain appears to be purely a subaërial product as far eastward as it has been traced. The Triassic portion of the Schooley peneplain has been for good reasons regarded as of subaërial origin, although later buried under marine deposits. The Highland portion of the same peneplain and its extension far and wide into Pennsylvania fail of evenness by just such amounts as a plain of nearly ultimate land erosion should; and the intermediate strip, where the shore line oscillated during Cretaceous deposition, has not yet been identified as bearing marks of littoral erosion. We therefore suppose that except during the Cretaceous transgression and the much smaller invasion of the sea

[1]A river pirate. Science, XIII, 1889, 108.

[2]McGee's Columbia shore line, already referred to, is an exception to this statement.

now under consideration, the coast line of Old Jersey has stood farther east than the present margin of the Atlantic. In later times, submergence and transgression appear to have occurred at least once.

During the depression of the land, as mentioned above, the topography of the coastal margin of the region must have been much like that now presented in Chesapeake bay: an irregular shore line, on which the sea waves fretted and from which they carried sands and gravels and clays to be spread out a little farther seaward as late Tertiary or Quaternary strata. The actual shore line of this time has not yet been identified, and is therefore probably not well defined: it may have shifted from one level to another, nowhere enduring long.

39. *The Southern Lowland Plain.*— A later subdivision of Millstone time saw the gravelly and sandy beds raised from the sea floor into the Lowland plains of the southeastern and southern portion of the state; and since then, comparatively little work has been done. The elevation was distinctly greater in the south than in the north; and hence the plains increase in width in that direction. About Long Branch and farther north, they are hardly visible, unless in the valleys: here the sea is still at work not far from the line that it occupied while the southern plains were forming; here it has straightened out its shore line into a rather mature form. In the southern part of the state, there are occasional residual hills,[1] of small size and moderate height; these seem to be remnants of beds not wholly destroyed either by subaërial or marine erosion, but the time of their deposit is considered to be post-Cretaceous and their deposition and erosion may imply oscillations of level not here considered. Between these hills, the streams wander over the broad plains in the simplest consequent fashion, merely flowing down the slopes offered them to the sea. They have cut only shallow valleys, and broad areas between them are untouched. East and West plains in Burlington and Ocean counties are surfaces of this kind; they are barren, bare of trees ever since the country has been known, but low bushes and dwarf pines and oaks grow in places; an object as tall as a man can be seen here for many miles.[2] The contoured maps show local gradients of only five or ten feet to a mile. A slight depression has estuaried the mouths of the streams for a small distance all along the coast and up Delaware

[1] Geol. N. J., 1886, 133. [2] Geol. N. J., 1868, 78.

bay, and long sand bars or "beaches" have been built by the waves off shore.[1] The previous greater depression, by which the Yellow Gravel[2] or Columbia formation[3] was deposited and from which the land has recovered, has left small geographic record; gravelly deltas were formed at the mouths of the larger rivers; terraces and bars were left along the shore line; and stones and gravel, sometimes twenty or more feet thick, were spread over the submerged part of the Central plain and Southern lowland: for further account of which the student should refer to McGee's papers already often quoted.

40. *Effect of the Glacial Invasion.* Brief mention may be made of the numerous lakes within the glaciated area; of the mounds and ponds along the morainic belt; of the drowned lands along many streams; of the occasional changes in stream courses due to drift barriers; and of the washed drift that spreads over many extra-morainic valleys; but the reader can refer to the annual reports of the New Jersey survey for detailed information on these headings.[4] The temporary glacial lake within the Watchung crescent[5] also calls for mention, as its deltas and shore lines are delicate geographic features of to-day.

The most considerable change of river course by drift barrier is that of the Passaic already mentioned. The heavy morainic ridge from Morristown to Chatham stands athwart the pre-glacial valley; Great swamp now lies behind or south of this barrier, and the Passaic makes its escape by a roundabout course to the east. The Rockaway is also deflected from its ancient course by the moraine at Denville; it turns northward over a divide between two lateral valleys, and descends rapidly over rocky reefs past Boonton on its new course. Many other examples will in time be described.

41. *Review.* The details with which an essay of this character is necessarily encumbered make the clear presentation of its theme a difficult matter. The effort to shorten what is necessarily so long gives at times more definiteness of statement than is desirable in subjects that are still wide open to discussion; but certain facts appear to stand out clearly enough. The Highland plateau is an elevated and faintly tilted peneplain of denudation, dissected

[1] Geol. N. J., 1885, 72. [2] Merrill, Geol. N. J., 1886, 129. [3] McGee, *l. c.*, 367.
[4] Especially in the Reports for 1880, 14; 1884, 112.
[5] Annual Report, 1880, 63, with map in frontispiece.

since its elevation by numerous valleys. The same peneplain determines the crest lines of Kittatinny mountain and of the many similar ridges of Pennsylvania on the west, and of the Triassic trap ridges on the east. It may be seen descending below sea-level where the Cretaceous beds lie on it below New Brunswick. Most of the streams that have opened valleys in the Highland portion of the peneplain are simply revivals of old streams of an earlier geographic cycle; but in the Triassic area, most of the streams are descended from courses superimposed upon the present rocks by the cover of Cretaceous strata that once stretched across them: and many of the streams appear to have been much affected by adjustments following upon their discovery of the trap ridges across which their initial courses had been unwittingly chosen. The elevation of the ancient peneplain occurred so long ago that its weaker rocks have been again baselevelled; and thus we find explanation for the even interstream surface of the Central plain. Another elevation of the land allowed the opening of shallow valleys in the plain, and in this shape we find it. The moderate distortion and numerous oscillations that accompanied the latest cycle of change still need much study, particularly with reference to their effect on river courses. As the preparation of good topographic maps is continued over the other states of our Atlantic slope, there will be opportunity to test many of the statements made here, for the sequence of changes we have considered is not local but widespread.

General Meeting, December 4, 1889.

The President, Prof. F. W. Putnam, in the chair.

Dr. R. T. Jackson read a paper on "Certain Points in the Development of the Shell of the Mollusca, with Especial Reference to the Pelecypoda."

Dr. J. Walter Fewkes called attention to excavations made in rocks at Grand Manan, New Brunswick, by our common sea-urchin (see American Naturalist, January, 1890).

General Meeting, December 18, 1889.

The President, Prof. F. W. Putnam, in the chair.

Dr. Frederick Tuckerman read a paper on "The Gustatory Organs of Mammals." (See later pages of this volume.)

Mr. S. H. Scudder made a few remarks on fossil plant-lice.

General Meeting, January 1, 1890.

The President, Prof. F. W. Putnam, in the chair.

The President announced that the evening would be devoted to a discussion of the Climatic Condition of the Glacial Period to be considered in relation to the existence of man at that time.

He called upon Prof. G. Frederick Wright, who had obtained important information in relation to the "Nampa Image," to open the discussion.

Professor Wright read letters relating to the Nampa Image, which are given below, and spoke of the probable climatic conditions at the time of the deposition of the deposits from which the image was obtained.

THE NAMPA IMAGE.

View from front, back and side (natural size).

Professor Wright said: I can best perform my duty to the public in reference to the image found by Mr. M. A. Kurtz of Nampa, Idaho, by simply submitting the entire correspondence respecting it, with such connecting comments as may be necessary for explanation. The subject was first brought to my notice by the following letter from Mr. Charles Francis Adams, president of the Union Pacific Railroad.

Boston, Sept. 8, 1889.

Professor G. F. Wright, Oberlin, Ohio.

My Dear Sir:

During a recent trip to Alaska I was greatly interested in your book on the Ice Age of America. After my return, and while the subject was still fresh in my mind, I had occasion to stop for a few hours with the party which accompanied me at Boisé City, in Idaho. While there I heard various references made to a curious clay image, evidently the work of human hands, which had recently been found while boring for artesian water.

As you are aware, this is a lava region, and the image in question was found at a depth of some three hundred and twenty feet below the surface.

The day after the image was thrown up by the borer, Mr. Cumming, the general manager of the Union Pacific lines in that district, chanced to be in Boisé City, and saw it. Mr. Cumming is a graduate of Harvard College, and a thoroughly trained man. His evidence I should take as conclusive in regard to the facts. Thinking the matter may be of interest to you, I send you the inclosed memorandum in relation to this image. It was taken down by me on the spot while examining the image, which is now in the possession of Mr. M. A. Kurtz, of Nampa, Idaho, who picked it up when thrown out of the pipe.

Yours, etc.,

Charles F. Adams.

MEMORANDUM OF IMAGE FOUND AT NAMPA, IDAHO.

Material, baked clay; size, about an inch and a half long; unmistakably made by human beings.

It was found about the first of August, 1889, at Nampa, in Ada County, Idaho, under the following circumstances:

M. A. Kurtz was engaged in boring an artesian well. The image was brought to the surface through the pipe in the usual way among some heavy, coarse sand, from a depth of three hundred and twenty feet from the surface.

The different strata which had been bored through were as follows:

Sixty feet of soil.
Twelve to fifteen feet of lava rock.
One hundred feet of quicksand.
Six inches of clay.
Forty feet of quicksand.
Six feet of clay.
Thirty feet of quicksand.
Twelve to fifteen feet of clay.
Then cláy balls mixed with sand.
Then coarse sand in which the image came up.
Then vegetable soil.
Then the original sandstone.

Upon receipt of this letter, I at once requested to be put in communication with Mr. Kurtz, and upon receiving a letter from Mr. Adams introducing me to him, immediately wrote Mr. Kurtz making inquiries about the general aspect of the country, and requesting a photograph of the image. The following letter is his reply.

Nampa, Idaho Territory, Sept. 27, 1889.

Prof. G. F. Wright.

Dear Sir:

In reply to your favor of the 23rd inst. I would submit the following:

1. The elevation of Boisé City is about 2875 feet and Nampa nearly 2,500. Boisé City is on an air line twenty miles from Nampa in a northeasterly direction.

2. The nearest point to the Boisé river is seven miles. The foot hills begin from one-half to two miles from the river and it is some seventy-five miles to the top of the range.

The nearest point to the Snake river is twelve miles, the foot hills skirt the river bank. It is fifty miles to the top of the range from Nampa.

3. The valley from Boisé City due south to the Snake river is about thirty-five miles and from our place about twenty miles. From Boisé City to the junction of the Boisé and Snake rivers fifty-five miles. The valley that forms the Boisé river bottom is from two to five miles in width and its formation is a sandy gravel, is very

productive and sub-irrigates. The foot hills show some signs of lava. The first plateau is some sixty feet higher than the river, from five to eight miles in width, is a rich, sandy loam soil with strata of heavy gravel and bowlders underlying it at a depth of from ten to thirty feet. It contains several dry creeks with sandy bottoms, but which contain plenty of water at a depth of from two to four feet. These creeks rise at the foot of the mountain range more than one hundred miles east of here and flow through the second plateau.

The second plateau is some thirty feet above the first and embraces the balance of the valley. The soil same as first and extends to the lava flow which seems to be uniform at a depth of say sixty-five feet; it sometimes contains a heavy coarse sand. This plateau is much broken with hilly elevations of lava rock, which contains caves and dark subterranean passages, that are full of strong currents of air.

4. We found no evidence of bowlders anywhere. I will inclose with the image some of the pebbles taken out at different times, although we did not find any deposit of them. The large clay ball may be of some interest to you, it stuck to the bottom of the sand pump; it and many of the smaller ones were found about the same time as the image and on top of the primitive formation. We have no means here of having the image photographed so I will send it by express, hoping it will interest you. Please examine and at your earliest convenience return to me. The image was dropped and the head broken and we fastened it on as well as we could.

Any further information I can give will be cheerfully given.

Very respectfully yours,

M. A. Kurtz.

Upon receipt of this I addressed another letter to Mr. Kurtz to draw out from him such explicit statements as should enable us to determine whether or not the image might have fallen in from the top, or been thrown in by some bystander. The letter of October 11th answers these inquiries. I would add that the "clay balls" referred to which came up in the pump are larger than the image, and equally fragile. They seem as I remember them to be of the same material with the image, but were coated over with a film of oxide of iron.

Nampa, Idaho Ter., Oct. 11, 1889.

PROF. G. F. WRIGHT.

DEAR SIR:

Your letter of the fifth at hand and contents noted. In reply would say that the well is tubed with a heavy six-inch pipe from the top and any light substance thrown in would float on the water and be ground to pieces by the sand pump.

We had been getting some of the clay balls and the character of the sand was changing. I had been at the well for several days and ran the contents of the sand pump through my hand as it was pumped out. I had the clay image in my hand and supposed it was a twig. I dipped it into a barrel of water standing near, washed it off and saw at once what it was.

Mr. Duffes, a prominent citizen of our town, happened to be standing by and saw it all. The driller and helper were the only other persons present. If convenient for you, I would be glad to have a brief opinion from you as to your idea of it.

Yours, very truly,

M. A. KURTZ.

My third letter to Mr. Kurtz answered his inquiry about the possible conditions under which the image may have been buried, in which I suggested that an overflow of lava in the lower part of the Snake river may have obstructed the water so as to make a temporary lake, in the vicinity of Nampa, which was filled with sediment, perhaps from melting glaciers in the head waters of the river near Yellowstone Park, and that subsequently a lava overflow had occurred near Nampa and so sealed the whole up. I also asked more particularly about the mode of drilling the well and about the size of the pump. The letter of the twenty-first is his reply.

The image itself has been submitted to Profs. H. W. Haynes and F. W. Putnam, with what results they can answer for themselves.

Nampa, Idaho, Oct. 21, 1889.

PROF. G. F. WRIGHT.

DEAR SIR:

Your kind favor of the sixteenth just received. We did not use the drill after we went through the lava rock. With our machinery we had a fishing tool with jars and the party drilling the well welded a piece of sharp, broad iron on the bottom of it which he used only when in the clay. The sand pump with the coupling at the top is a little over five inches in the chamber. The sand pump proper is $4\frac{1}{2}$ inches on the outside and the valve is about $3\frac{1}{2}$ inches on the inside. Anything put in from the top would have floated on top of the water and been ground to powder by the action of the sand pump. If there is any way to remove the implied doubt in your letter as to the genuineness of the image please inform me. You can have the affidavits of the only four persons present, any time you may think them necessary.

The obstruction noted in your comments in the lower part of the valley are not difficult to trace, and a gentleman of some scientific information and well informed as to this country made a statement to me several months ago that this wash or fill in the valley had occurred since the Spanish conquest of Mexico and that it was a matter of record.

Hoping to hear from you again, I am,

Yours very truly,

M. A. Kurtz.

In order to get information in regard to the geological horizon of the beds from which the image was taken I made inquiries of Prof. S. F. Emmons and received the following reply.

Department of the Interior,
United States Geological Survey.
Washington, D. C., Oct. 21, 1889.

Prof. G. F. Wright.

Dear Sir :

My reply to your letter of Oct. 9, asking information with regard to the geological horizon of the beds, from which the image from Nampa, Idaho, is said to have been obtained, has been delayed from day to day in the hopes that I might obtain additional information either by records or personal communications from fellow geologists that would supplement the rather meagre data which I myself possess. As I have as yet been unable to obtain any further knowledge on the subject, I must needs content myself with the surmises I was able to make during a visit of a few days to the Boisé region, in the summer of 1887, made for the purpose of looking into the merits of a scheme for diverting the waters of the Boisé river at a point about ten miles above Boisé city, where it emerges from the Upper Boisé basin through a cañon in the basalt, so as to irrigate a triangular area of country between Boisé and Snake rivers, some fifty miles in length from the junction of these rivers southeastward, and thirty miles wide at its base or southeastern end. To the engineers of the Irrigation Company, Messrs. A. D. Foote and C. H. Tompkins, jr., I am indebted for valuable topographical data with regard to this area.

Nampa, where the boring was made from which the image is said to have been obtained, is a station on the Oregon Short Line R. R. about midway in this area and, as you state, about twelve miles north of the Snake river and seven miles south of the Boisé river. It was obtained, you tell me, from a bed of coarse sand 320 feet below the surface after passing through beds of quicksand divided by thin beds of clay and one bed of lava ten to fifteen feet thick, and below this coarse sand was found vegetable soil and then what is described as the "original sandstone."

My experience with data given by persons sinking drill holes as to the material passed through leads me to accept with considerable reserve the descriptive names they give to this material unless I have an opportunity of verifying it by personal observation, yet those given by you accord very well with the general idea I was able to form of the material underlying the Boisé region. Stream erosion has been very slight in this region, and its topographical form, characterized by a succession of broad, level terraces descending in gentle steps, shows that it is underlain by practically horizontal deposits of recent age. Owing partly to the character of the erosion and partly to the loose, crumbly nature of the beds themselves no good cliff exposures were found where I could obtain a continuous section of these beds. The important point in the section, namely, whether the definition of the lowest stratum, as vegetable soil, is well taken or not, it would have been impossible to verify, since it must be at a lower level than the beds of either the Snake or Boisé rivers at any point within the region.

I could see that the basin, in which these beds were deposited, extended for a considerable distance to the south and west, but to the north it was bounded by a mountainous country not far beyond the Boisé river. As to how far it extended eastward toward the great lava plains of the Snake river I could form no idea, since unfortunately both eastward and westward-going trains pass over that country in the night.

On the banks of the Boisé river, just below where it emerges from the cañon I observed that the gravels, which form the first bench to the south of the river, rest on an eroded, white sandstone, which might correspond to the " original sandstone" struck at the bottom of the drill hole and form part of the bottom of the lake in which these beds were deposited ; this assumes a descent of about 700 feet in twenty miles giving a rather unusual but not impossible slope to the bed of the lake, and makes it probable that the cañon of the Boisé is near the northern shore line of this lake.

I had been unable to find any fossil evidence of the age of these beds, but on other grounds had assumed that they were late Tertiary or early Quaternary. They had a younger appearance than the pliocene deposits of Nevada, and on the other hand looked older in some respects than the Quaternary deposits of Lakes Bonneville and Lahontan.

The character of the Snake river valley in this region was of special significance to me. Instead of meandering to and fro in a broad alluvial bottom with large cottonwood trees along its banks, as is usually the case with such large streams, it runs in a comparatively straight course through a slightly rolling sage bush country, filling its bed from bank to bank with a swift, deep, turbid stream, with only a scanty growth of young willows along its shores, which are being constantly undermined and carried away. This, to me, was an evidence that, at some point below this, its bed had been lowered in recent geological time by the breaking of some barrier that had formerly held it back, and that it was now rapidly cutting back and deepening its bed in an endeavor to reach a baselevel of erosion. Its slope from the base of the mountains in eastern Idaho is very rapid for so large a river. It has not been surveyed so that it cannot be accurately determined, but if it ran in a straight line its descent would be ten feet to the mile, and, as its course through the lava beds is generally direct, it can hardly be less than seven or eight feet, making allowance for its meanderings and the falls it passes over. Of these there are several, the greatest being the Shoshone Falls which are 212 feet high.

It is also significant that after its junction with the Boisé river it bends abruptly and runs due north for about 250 miles, leaving the open country, which stretches westward through southern Idaho and Oregon to the base of the Cascade mountains, to make its way through the more mountainous region at the east base of the Blue mountains around which it flows. I know of no scientific explorations of this portion of the Snake valley, and the Oregon Short Line Railroad avoids it by crossing the Blue mountains, but the accounts of earlier explorers represent the mountain ridges as coming close to the river, and the latter as running through precipitous cañons deeper and more inaccessible than those of the lava plains of the Upper Snake valley. It seems probable that the cutting down of some barrier in this northern course—very likely as you suggest some lava flow that stretched across its valley—would account for its present relatively rapid slope.

The so-called placer bars which are found along its present course, often considerably higher than the present stream, not only in this region, but at various points above, also point to a recent rapid deepening of its bed. They carry gold in an extremely fine state of division and their material is generally much finer than the ordinary placer gravel, containing but few pebbles and these not entirely of quartz but sometimes of slate. They have evidently been brought from the mountains to the eastward at a much higher stage of the river, where its stream was longer and more rapid than at present.

The Nampa beds are, however, older than these gold-bearing gravels and probably older than the ancient gravels of the Upper Boisé basin at the southwest base of the Sawtooth mountains, which Mr. Becker, in his report on precious metals for the tenth census, compares with the deep gravels of California, from the fossil plants which they contain, from their great depth of 250 feet, and because they are said to be capped by basalt flows. I did not visit this basin but assume that the gravels are younger than the Nampa beds because of the higher levels which they occupy. I must confess that at present I see no evidence which would decide whether the Nampa beds are late Tertiary or early Quaternary except that furnished by the drill hole, which if authentic would be in favor of the latter. To the west of this region in southern Oregon, and along the Deschutes and John Day valleys at the east base of the Cascades, both Pliocene and Quaternary deposits are found. The latter in the

Harney lake and Christmas lake basins are at a much higher level than these being 500 to 1000 feet above the lava plains of the Snake river.

The fact that basaltic lava flows cover these beds is not decisive for either age. In the valleys of eastern Idaho, whence come some of the tributaries of the Snake, basaltic lavas both of Tertiary and of Quaternary age occur. Some of the latter fill present valley bottoms, extending up a short distance into the mouths of side cañons in the adjoining ridges. These flows have had some influence upon the direction of the present drainage, and it seems probable that before their eruption the Bear river flowed through the Portneuf valley into the Snake river, instead of into Salt Lake as it does now.

Gilbert has shown that Lake Bonneville, the quaternary tenant of the Salt Lake valleys, once overflowed into the Snake river, but whether this overflow was contemporaneous with the existence of the lake in which the Nampa beds were deposited, or accompanied the freshets which brought down the Snake river gold-bearing gravels, only a systematic study of the whole Snake river region can finally determine. Such a study ought to establish the time relations of the Bonneville and Nampa beds, and a still more definite determination of the age of the latter might be afforded by a careful study of the cañon of the Snake river below Shoshone Falls, and by a tracing of the upper limits of the lake in which the Nampa beds were deposited, and the relation of the Nampa beds to the last basaltic overflow of the Snake river plains. In a visit to the Shoshone Falls, in 1868, Mr. Clarence King found that the river above the falls runs in a cañon about four hundred feet deep cut in the upper sheet of basalt which covers the present surface of these plains, but that the cañon below the falls discloses an underlying mass of trachyte or andesite, which is probably of much earlier date. If, as seems not improbable, the basalt flows which cover the Nampa beds in the Boisé region were contemporaneous with those which cover the Snake plains in the vicinity of Shoshone Falls, at some point in the cañon of the Snake river these beds will be found resting on the underlying trachyte or andesite body, and separating it from the overlying basalt flow. It will then be proved that the cutting of the cañon of the Snake river below the surface of the basalt flows has been accomplished since the drainage of the Nampa lake, and it will only remain to estimate the time required for the cutting of the present cañon of the Snake river through these lava flows, by the rate of recession of the various falls.

While I am, as you see, unable to give any definite estimate of the age of the beds from which the image is supposed to have been derived, I regard them as probably of far greater antiquity than any deposits in which human implements have hitherto been discovered. If, as I am now inclined to think, they antedate the cutting of the present cañon of the Snake river through the great lava plains, their antiquity at once becomes very great, as is shown by a comparison of the conditions which prevail there with those of the Niagara river, whose rate of recession has been so closely determined. The gorge of the Niagara has been cut through limestone and shale for seven miles to a depth of not over three hundred feet. The Snake river from its entrance into the lava fields at American Falls to Shoshone Falls, a distance of one hundred to one hundred and twenty miles, has cut a gorge in hard basalt from seventy to four hundred feet deep, and below Shoshone Falls, for an unknown distance, a gorge six hundred feet deep in similar material.

In the present state of our knowledge I find it difficult to institute any comparison whatever between these deposits and the gold-bearing gravels underlying the lava flows of California. Comparison between so widely separated regions are hypothetical, unless based on such an intimate knowledge of the geological structure of the intermediate region as can hardly be arrived at in the present generation. That instituted by Mr. Becker with the gravels of the Upper Boisé basin has a slight basis of probability if his premises are reliable, but the connection between these and the Nampa beds remains yet to be determined.

Regretting that I am not able to give a more satisfactory answer to your question, I am

Very sincerely yours,

S. F. Emmons.

In reply to a letter requesting through Mr. Kurtz a statement from Mr. Duffes, and making other inquiries, I received the following:

Nampa, *Idaho Ter.*, *November* 7, 1889.

Prof. G. F. Wright.

Dear Sir:

Yours of Nov. 2, just received. I enclose letter from Mr. Duffes as requested.

When the head of the image was broken off I took my knife and cut into it between the shoulders in order to stick the head on again.

The head was not touched at all with the knife, but head and face are just as they were when taken from the sand.

I shall be very glad of the half dozen photographs you speak of sending, and any further information I can give will be given with pleasure.

Very truly yours,

M. A. Kurtz.

Nampa, Idaho, Nov. 7, 1889.

M. A. Kurtz, Esq.

Dear Sir:

In reply to your inquiry of this date in regard to the facts as regards the finding of the "Baby image" in the Nampa Artesian well, I beg to state the following:

I was present at the well along with yourself and saw you pick it out of the sand as it was discharged from the sand pump.

There were no others present except two men attending the engine and sand pump. And they could not by any means get it into the place where found, and were just as much astonished as ourselves at seeing the find. These are the facts of the case, to which I hereby certify, trusting this will thoroughly quiet all doubts.

I am yours truly,

Alex. Duffes.

It having been suggested that the image might have been inserted in the pump during the night, Mr. Kurtz wrote me again in answer to inquiries as follows:

Nampa, Idaho Ter., Nov. 18, 1889.

Prof. G. Frederick Wright.

Dear Sir:

Your favor of thirteenth inst. recd. this morning. I fear I cannot answer it satisfactorily. We paid no attention to the different strata more than to make a note of them, and all was dumped on one pile. Much of the dirt was hauled away in wagons, and the school children made it a play ground for some time so it is impossible to comply with your request.

All the specimens I send you to-day came out of the well except the lava rock which came from a well they are now blasting some three blocks from the artesian well and must be of the same character.

You will readily understand that with the heavy bit we used, ours came out of the well only in black powder and none of it was saved, neither was the vegetable soil, but was poured out with the rest. It impregnated the water so that it was of a stringy nature, very dark or deep brownish color. The package of sand marked from the bottom of the well may or may not be from that particular place, but I selected it from what I think came up last. I cannot tell from what particular place in the well the clay and other sand package came.

In order to handle the pipes we dug a regular well, about twenty-five feet deep. The coarse gravel and hard pan are out of that portion of the well and from under the surface from six to twenty feet.

The pieces of clay I had to pick up from the sand, and you understand it has all been exposed to the weather from three months to one year.

The person who suggested to you that it might have been put in the sand pump never saw one or he would know that one descent of the jars would have ground it into powder.

I found the image between eleven and twelve o'clock in the morning. I had handled almost every pumpful of sand for several days, as the driller expected to strike sandstone at any moment.

I was sent here three years ago by P. P. Shelby, then assistant general manager of the Union Pacific R. R. to investigate the country. I did so. He then employed me to go east and deliver a series of lectures on Idaho in Pennsylvania and New York which I did. I had parties near here at that time watch this point, and when the Idaho Central R.R. was located here I came on, took up 800 acres of land and own some of the town site. I am the manager and one of the owners of the artesian well, I have a letter from Mr. Adams asking me to give the image to Harvard, but have not yet decided what I shall do.

Thank you for your kindness in sending "The Independent" containing your article. If you wish to send some person here I shall take pleasure in giving him all information possible and he might find something of importance in the large pile of sand that still remains at the well.

As ever, very sincerely yours,

M. A. Kurtz.

Nampa, Nov. 30, 1889.

PROF. G. F. WRIGHT,
Oberlin, Ohio.

DEAR SIR:

Your letter of the twenty-fifth inst. at hand. We commenced work at 7 A. M. and the sand pump made a trip every six or eight minutes. Our sand pump is about eight feet in length and is worked very rapidly by steam.

The suction valve is attached to two steel rods, attached to a bent rod of steel at the top, the whole forming what is called jars. Now the valve fits and works so nicely on the inside of the pump that if you were to throw a pin in it while at rest, the quick and sudden raising of the jars would throw it out at the top, and if the image had been thrown in as you suggest, it would have bounded out at the top, in good shape. The only other possible way would have been for the helper to have put it in after he had emptied the pump, and the only result would have been that on the descent of the jars, the valve would have knocked the image into pieces. I hope you may understand what I mean.

No clay balls of any kind are found on the surface here. We went through them for a distance of twenty-five feet before getting the image and brought a great many to the surface in all sorts of shapes, many of them being cut by the driving of the pipe. Will be pleased to see you here at any time. Now is as good as any time of the year. Our winters are very mild. Please return "image," etc., as soon as convenient.

Yours truly,

M. A. KURTZ.

The following is the letter of Mr. Cumming, in reply to one of my own.

Green River, Wyoming, Dec. 2, 1889.

DEAR SIR:

Your letter of the 25th ult. has been forwarded to me here from Salt Lake City.

I appreciate the importance of weighing the evidence carefully before accepting the Nampa image as genuine, and I understand of course that a discovery of this sort is so extraordinary that one is reluctant to accept even the strongest circumstantial (indirect) evidence as conclusive.

As I was not present when the image is said to have been discovered, my own evidence is of no value whatever except as to the character and intelligence of Messrs. Kurtz and Duffes. I have known these gentlemen for some time and in the case of Mr. Kurtz for several years. They are intelligent and well-informed men of the highest character and no one of their acquaintance would hesitate for a moment to accept and believe their testimony on any question of business. In the case of the Nampa image, they would have no motive to mislead the public, even if they were willing to do so, unless they were seeking a cheap notoriety or wished to play a practical joke. From my knowledge of these gentlemen, however, I cannot believe that they would lend themselves to a fraud of any kind, even by way of jest, and I think you may safely rely upon their statements as being correct in all respects.

The only other evidence which I can furnish on the subject is wholly circumstantial and that has already been communicated to you.

In conclusion I may say that Messrs. Kurtz and Duffes exhibited the image to me at Nampa on the day after its alleged discovery and their manner and actions at that time convinced me that their statement, however incredible it might seem, was neither a joke nor a fraud.

So far as my own opinion is concerned, I am prepared to accept the image as what it purports to be, namely, as having been found at a depth of more than three hundred feet beneath the lava beds of the Snake River valley.

I remain, very respectfully yours,

G. M. Cumming.

G. Frederick Wright, D.D., LL.D.,

Oberlin, Ohio.

The only other letter of Mr. Kurtz which it is necessary to submit is dated Dec. 17, 1889.

Nampa, Idaho Ter., Dec. 17, 1889.

Prof. G. F. Wright.

Dear Sir:

In reply to yours of the thirteenth inst. would say: *First*, after we reached the depth of sixty feet we struck water and it has remained at that distance from the top of the well, except when it was shut off for a short time as we went through the clay beds.

Second. We purchased the entire well-boring outfit new at Utica, N. Y.

Third. The engineer's name is H. Grumbling, a Pennsylvanian, who has sunk a good many oil wells in Pennsylvania. He lives here, but is now employed at Boisé City. The helper's name I do not know. He was a common laborer who had been working on an irrigating ditch. I do not know where he is now.

Fourth. The engineer is a capable man in his line. You ask if he would have been capable of making an image of this sort. He might if his attention had been called to the matter, if he had had a model and if he had known the clay from the small balls would have made such an image, and had he had some unobserved place to have made and burned it, but I think not.

The helper would not have been capable of the thought or the execution.

Fifth. My recollection is that we found the clay balls the day before we found the image. The largest I took to my home. I did the cutting on the largest one myself.

Sixth. A letter directed to H. Grumbling here or at Boisé City would reach him at any time. If I could have a few minutes' conversation with you I could explain the matter to your satisfaction; also why I cannot afford to give the image to Harvard or to any institution at present.

As ever, very truly yours,

M. A. Kurtz.

The image was in my own hands nearly three months in all, so that we had ample opportunity to examine it. I placed it in the hands of my associate Albert A. Wright, professor of natural history at Oberlin and a most skilful and careful observer. I submit his report which you will perceive is perfectly unbiassed. It was also carefully examined by F. F. Jewett, professor of chemistry, and I submit their opinions.

An examination of the Nampa Image.

By Albert Allen Wright.

Professor G. F. Wright has submitted to me, for examination, the little image from Nampa, Idaho, which is said to have been pumped up from an artesian boring. The results of my examination are given herewith.

I must premise that in order to make the report as definite as is desirable, it will be necessary to mention some details which cannot be fully appreciated without an inspection of the objects discussed.

DIMENSIONS.

The total height of the image is just one and one-half inches (1.5)=48 mm. A few other measurements are:

Width at the shoulders . . .	0.54′ (in.)	= 14 mm.
Width at the hips	0.43′	= 11 mm.
Thickness of body, breast to back .	0.25′	= 6.5 mm.
Thickness at hips	0.35′	= 9 mm.
Width of head	0.30′	= 7.5 mm.

SHAPE, FEATURES, ETC.

It represents a human body; and from the slight depression between the breasts it is evident that a female figure is intended.

As to the quality of the modelling, it may be said that, with the exception of the head, the general proportions of the body are harmonious, showing a good degree of approach to a correct model. The work upon the back side of the body is especially good, and the natural bending of the arms at the elbows, together with the easy manner in which they rest at the side of the hips, make the nearest approach to an artistic touch. It could not have been the work of any child or mere novice. The surface is not smoothed nor polished, but is, for the most part, of a rough, granular nature. The strokes of the graving tool can be easily recognized in many places, and the whole gives the impression at once, that it was moulded from clay, the work having stopped as soon as the principal parts of the body were outlined. There are no hands nor feet, and I think there never were any. The left leg is preserved in nearly its whole length, while the right leg is missing from a point above the knee. Neither of these was broken at the extremity by any recent fracture. If the short leg was ever of equal length with the other, it was broken and rounded before it came up from the well. The head is large and pushed to one side. It was never carved into any good shape. There are three rude depressions upon the face, suggesting the eye-orbits and mouth.

COLOR.

The general color of the image is a fulvous or reddish brown. The departures from this general color are in two different directions.—*First*, to a deeper reddish upon the back side of the body, and upon the left arm. Upon the top of the head also there is a distinct layer of darker rusty color, in which some grains of quartz are imbedded. *Secondly*, some parts have a blackish or smoked appearance. This is seen upon the leg, thigh and breast.

The color of the interior of the image has been revealed by accidental fractures of the neck and of the longer leg since it was taken from the well. It is a yellowish fulvous, quite uniform, and distinctly lighter than the exterior. It is precisely the color now presented by the face of the image; from which fact I am confident that the face has been recarved recently, after the image was first finished, and before it came into my hands for examination. I scarcely need to say that while the object was in my possession, no reagent nor test nor tool was applied to it, which could in the slightest degree affect its color or external appearance.

The interior color of the short leg, differs from that of the body, in being of a distinct dark gray, without any of the fulvous element. I think I shall be able to account for this difference of color in a later part of this report.

THE MATERIAL: WAS IT RIGID, OR PLASTIC?

The image was moulded out of a plastic, gritty clay, and afterwards burned in a fire.

The evidence for the previous plasticity of the material is so strong, that I am confident that any who have come to a contrary opinion, as, for example, that it was carved from a tufaceous or pumiceous rock would, if they could have the ample opportunities for examination which have been accorded to me, recall that conclusion. A detailed study of the surface will show that the graving tool sometimes took long, sweeping strokes, leaving a plane surface with sharply defined margins. Moreover, the direction of the strokes can, in some instances, be determined by the transverse, minute crevasses left in the substance under the tool, such as one sees when a glazier spreads his putty. Thus, the strokes in the crevice between the right arm and the body, on the front side, were downward, while those in the corresponding crevice on the left side were upward.

Again, we know that whenever a pointed stylus or tool is drawn along a plastic surface, so as to plow a furrow in that surface, the material upon each side of the furrow will be thrown up into an elevated ridge, and if the substance is gritty, the ridges will have a ragged summit. There are many such ragged-topped ridges along the margins of the strokes upon this image, especially in the protected hollows, where some of them are as sharp and distinct as if freshly made.

And still again, there are certain excavated, V-shaped troughs or grooves between the members of the body, as between the arms and the trunk, which had once been moulded into final form; but into these excavations there were afterwards pushed out, by maladroit strokes of the tool, ridges of the material which partially roofed over the cavity, yet leaving the original excavation underneath plainly discernible. To specify, this may be seen in the grooves behind the right arm, both forearm and upper-arm, and in the space between the lower limbs. It is a disposition of material that could not have been left in a brittle substance. Finally, there are some cuts left by the tool, so sharp and clean and deep, as to demonstrate that the material was not brittle, but which at the same time give us a record of the exact dimensions of the tool that was used. At the junction of the limbs there is one such stroke, which left a gash only one seventy-fifth of an inch wide, by measurement, though many times as deep and long. The margins are perfectly sharp and parallel and smooth, and show that some tool, like a knife blade or piece of tin, must have been used. The crevice will just admit a thin knife blade.

I regard the external markings, therefore, as sufficient to show the original plasticity of the material, but it will be seen that all the subsequent steps of the examination also confirm this theory.

MICROSCOPIC EXAMINATION OF THE MATERIAL.

The unaided eye readily distinguishes two elements in the material of the image. The first is the fine-grained, homogeneous, fulvous powder that constitutes the principal part of the whole. By a little boring with a knife blade at the fracture of the leg, this material was found to break down with greater facility than would be experienced with an ordinary red brick. The tenacity of the material is not great. The powder was too fine to be called sand and yet not so fine as the elements of porcelain clay. When moistened, the particles adhered together with much less tenacity than is seen in the common, sticky drift clays, yet there was enough adhesion to form a plastic mass.

The second element in the material consisted of grains of quartz and possibly of other minerals, scattered at random through the finer substance. In size, these will measure from one-sixteenth to one thirty-second of an inch and smaller. They are sufficiently numerous to make the whole material gritty and to account for the roughness of some of the tool-work. Many of these come just to the surface of the body, as, for example, three on the back between the shoulders, three or four on the inner side of the left leg, and one on the front of the arm at the right shoulder. Upon the right hip is one that projects a little, not having been sufficiently pressed down by the moulding tool. One was taken from the interior of the leg, at a point of fracture, and the rough summit of the head is liberally supplied with them. The loose grains which are lodged in the crevice between the right arm and the body, and which are shown in the photographs and engravings of the image, are of the same sort. These grains were, in my opinion, not accretions from without, cemented there by the slow deposit of ferric oxide, but were constituents of the original material, thrown out by the point of the graving tool and left where they are, either by accident or design.

The material of the image was so friable that it would have been well nigh impossible to make a thin section for microscopic examination. It was not attempted, and it would have been of no value unless the image were carved from a piece of rock. Samples of the finer material of the image, however, in the form of powder, were mounted in balsam and submitted to optical examination. The object in view was to obtain a clew as to the source whence the material of the image was derived. The microscopical examination was not made thoroughly exhaustive because, before it was finished, other satisfactory evidence on this point came in. Still, the principal elements of the powder were determined, as follows:

First, and most prominent, constituting more than half of the material, *quartz*, in brilliant, sharp-angled fragments. The colors upon revolution between crossed nicols were frequently from brilliant blue to yellow, but for the most part they brightened only into a cold gray. Quite a number of the larger grains were sketched in outline with a camera and measured, the average mean diameter being three one-thousandths of an inch (0.003 inch) = 76.2 μ (mikrons).

Second, red-brown scales of biotite, smaller than the quartz scales, averaging about two one-thousandths of an inch (0.0019 inch) = 48.26 μ (mikrons) in diameter. The hexagonal angles are frequently distinct, though usually the margins are ragged. Although the flakes must all have been basal cleavages, nearly half of them showed some alterations between crossed nicols.

Third. Small and large colorless flakes, always appearing isotrope, some of them, possibly, of a volcanic, glassy nature, others showing a few sharp angles of 60 degrees and 120 degrees, doubtless muscovite.

Fourth. Opaque, red-brown flakes and aggregations of ferric oxide, showing gradations from a powdery ochre up towards scales of biotite, from which they were undoubtedly derived.

Fifth. Very fine-grained material, having no distinct optical characters. In the dry powder it forms aggregations of a whitish color. It is, doubtless, kaolinic and forms the cement for the whole image.

Nothing was detected which seemed to be of the nature of vegetable tissue.

The above analysis suggests at once, in fact, practically proves, that the material, as a whole, consists of the finer elements resulting from the breaking up of granitoid rocks.

SOURCE OF THE MATERIAL.

Upon application to the parties who discovered the image, samples were obtained: (1) of the surface soil in the vicinity of the well; (2) of the sand from various depths in the well, taken, however, from the dump heap where it had lain for three months; (3) of the lava rock, taken from an adjacent well; and (4) of clay balls which were said to have been first encountered at twenty feet above the depth at which the image was found.

All of these have been examined to see if any of them could have furnished the material for the image. The surface soil will not make a clay that can be worked, and when burnt it falls to powder. The sand and the lava are also out of the question. It should be remarked, however, that the sand is a clean, whitish-yellow sand, containing some mica scales and gravel, and is also of granitoid origin. The clay balls fit the case precisely, and I am satisfied that it was one of these, or at any rate clay of identical composition, from which the image was moulded. Under the microscope they show precisely the same elements that were detected in the image, and they form, when moistened, a plastic material that can be moulded.

The clay-balls are in themselves of much interest as a geological phenomenon. The interior of each ball is very different from the exterior. The interior is nearly white and very fine-grained, while the exterior is covered with coarse sand embedded in rusty-brown material. The largest specimen, which was four inches in diameter, exhibits upon cross section a series of concentric rusty rings, from one-eighth to one-sixteenth of an inch apart, thus showing that it is composed of a series of concentric layers and was formed upon the concretionary principle, like the nodular iron ore of the coal measures. The interior of the balls furnished the finer elements of the image, while the coarse quartz grains came from the exterior, the two being mixed together in the hands of the artisan.

The material of the clay balls, when subjected to heat, was found to undergo rather complicated changes of color. Moderate heat blackens the exterior without greatly changing the interior, as if organic matter were present. Stronger heat develops the reddish or fulvous color, both internally and externally. Yet, unless the strongest heat is at the same time strongly oxidizing, the result will be a dark gray. If the flame of a Bunsen gas burner is allowed to play upon a piece, the portion that was in the centre of the flame will be left gray, while only the outer portions will be reddened. It is thus very difficult to produce a uniform reddish color over the entire surface of a moulded specimen. These facts will, I think, account for the different shades of color observable upon the surface of the Nampa image, to which previous allusion has been made. The dark gray at the end of the shorter leg is due to a lack of oxygen at the time of burning, and the distribution of black and red was due to the inequalities of the flame.

A DUPLICATE OF THE IMAGE.

Having proceeded thus far with the investigation, it was natural to go a step farther and see if the image could not be reproduced in all its essential features. A clay-ball with a liberal coating of sand was selected, crushed together in a mortar, moistened into a putty and moulded with a knife-blade into some similarity of form to the original. In the process of moulding it was discovered that all the exposed parts of the body inevitably became smoothed and rounded by the touch of the fingers in holding it, so that only the hollows and crevices retained the marks of the tool in all their sharpness. It was also seen that the gritty material had considerable tendency to adhere to the graving tool, so that loose sand grains and rough ridges were left along the strokes.

The burning of the image was accomplished in a porcelain dish, heated from beneath by a Bunsen burner, so that the flame did not come in contact with the material. The gradual steps of its evolution, through Ethiopian blackness toward Indian red, were observed, but the process ceased before a suitable redness was produced. The object was then supported upon a wire gauze and the flame allowed to play through the gauze, directly upon it. Some improvement was obtained in this manner. But finally, certain parts, which retained too much blackness, were brightened up by the oxidizing flame of a mouth blowpipe and the result is what may be seen in the object as it now appears.

This is the only attempt that was made, and I may say that the success of the imitation was far beyond my anticipations. The general tone and variations of color in the two are exceedingly similar. Whether viewed by the unaided eye, or examined with a Coddington lens, nearly every surface feature of the one is reproduced in the other. There is a larger supply of quartz and mica grains in the duplicate than in the original, but this depends, of course, upon an arbitrary selection of materials at the beginning. The interior color of the two is precisely the same and the tenacity of the material is also identical. The duplicate has suffered the accident of having its head broken off, so that an opportunity was afforded of comparing the two side by side. The comparison has been made by a large number of persons, professors in Oberlin College, and others.

There is only one point, which seems of any importance, in which the duplicate fails to reproduce the original, and that is a superior tint of redness at one or two points upon the surface of the original, notably upon the back, and at the left hand. This raises the question whether the extremer tint in the original may not be due to a slow deposit of iron rust from external, or even internal sources, and thus furnish evidence of its antiquity. To this it may be replied that the extremer color can be obtained by using a few drops of hydrochloric acid upon the clay, and the reheating. Even deeper tints than are seen in the original can thus be secured. This process has not been tried upon the duplicate image, but has been upon other portions of the same material, not, however, until after the original had been returned to its owner, so that exact comparisons have been, as yet, impossible, or, it may be said that the extreme color may be due to a different selection of materials, including more iron oxide, for example, or, to some accidental feature in the process of burning. In none of my own experiments, however, has that apparent tint been obtained, excepting by the use of an acid.

IS THE IMAGE AN ANCIENT ONE?

Without entering at all upon the other lines of evidence which bear upon the theory of the antiquity of the image, I have only to state in conclusion, that I have not been able to find, in this examination, anything that is satisfactory in confirmation of such a theory. If the image is really older than the three hundred feet of sedimentary and volcanic deposits under which it was buried, its age must at least be many hundreds, and probably many thousands of years. While it would be difficult, even if all the chemical conditions were known, to tell beforehand what the effects of such protracted burial might be, we should still expect that some tangible evidence would appear. As to the proper interpretation of the characters which the image does present, we might well be uncertain, so long as there was no standard with which to compare it. But when we find that it is possible in a few hours to produce a duplicate which exhibits all the external and internal characters of the original, there is nothing left in the image itself to sustain the theory of its antiquity. Whoever compares the two will see that the tool marks are as distinct and fresh in the original as in the duplicate. He will see the same corroded surface on the duplicate as on the original. The interior tenacity, composition and color are the same in both. The variations in the external color have been fully set forth.

While therefore it would be a great pleasure to be able to confirm the evidence of its antiquity brought forward from other sources by my friend and co-laborer Professor G. F. Wright, I am still compelled to say that I can find no satisfactory marks of the tooth of time upon it.

Oberlin, O., Dec. 25, 1889.

Prof. G. F. Wright.

Dear Sir :

A careful examination of the Nampa image, and experiments made upon clay taken from the same well, lead me to the conclusion that the image must be of considerable age. I cannot account for the accumulation of the oxide of iron upon the grains of sand, lying between the body of the image and its arms, except by supposing it to have been the result of the slow decomposition of substances containing iron, in its immediate vicinity. Although I have been able to reproduce the color of this oxide tolerably well by heating clay coated with a solution of iron chloride, yet I have not been able to reproduce it by simply heating clay to different degrees of temperature.

Yours truly,

F. F. Jewett.

In conclusion I would say that the direct evidence in the case seems to be of as high order as could well be obtained. The character of Mr. Kurtz and of Mr. Duffes is amply vouched for, not only by Mr. Cumming, but by other parties whom I have met who personally know them. The whole appearance of Mr. Kurtz's letters show him to be a genuine man. There was no sensational publication in the papers, nor has there been any suggestion of mercenary motives. There were no archæologists or scientific men on the ground to be humbugged. Apparently the image would have disappeared and dropped out of notice but for the fortunate chance which brought it to the attention of Mr. Adams, when his own mind was interested in that class of subjects. The evidence is most direct as to the impossibility of the image's having fallen into the well from the surface, or of its having been put in by design.

Professor A. A. Wright's examination, it is true, is not of itself conclusive as to age, but there is nothing in it bearing indubitably against its age ; while the similarity of the material composing the image and that composing the clay balls, seem to me strongly confirmatory of the genuineness. I also attach much weight to Professor Jewett's opinion as to the character of the iron oxide upon the original image. It seems in the highest degree improbable that anyone should have manufactured such an object on the spot, and have been so successful in meeting all the conditions present. I am therefore prepared to accept without further question the genuineness of the image, and shall look for further confirmation as time elapses.

Note.—Since the meeting of the society a letter has been received from the engineer, H. B. Grumbley (the only other person from whom information could be obtained), who says, "I was present at the finding of the image. Circumstances were such that there could have been no mistake. I don't think there was any chance for the helper to have placed it in the sand, nor do I think he was capable of so doing."

President Putnam spoke of the evidences of the age of the image as shown by the deposit of oxide of iron on parts of the image, particularly the cementing of quartz grains by the iron under the right arm, which he considered as extraneous and not as particles pushed out in carving that part.

Prof. E. S. Morse made some general remarks on the antiquity of man.

Mr. S. H. Scudder spoke of errors liable to occur in mistaking natural for artificial forms and exhibited a specimen of rock formation from the Silurian which had a remarkable likeness to a fossil beetle.

Prof. H. W. Haynes said that he regarded the Nampa image as a most important evidence of the great antiquity of man in America. He presented the following additional documentary evidence:

Boston, November 6, 1889.

My dear Mr. Haynes:—Professor Wright sends me a note saying that the first paper will be read on the subject of the Kurtz image before the Boston Society of Natural History this evening. He wishes something said in relation to the opportunities enjoyed by Mr. Cumming to know the facts both about the discovery and about the man who made it.

I believe Mr. Cumming has been personally communicated with on this subject. I can only say of Mr. Cumming that I should regard his evidence in this matter as entitled to as much consideration as the evidence of any scientific man would be. He was on the spot the day the "find" was made, and his estimate of it would in my mind carry very great weight. He is, as you are aware, not only a graduate of the college, but he was educated as a lawyer, passed several years of study in Europe, and is a man of the highest personal character, accustomed to weigh evidence, and not likely to be deceived.

I remain, etc.,

CHARLES F. ADAMS.

Adams Building, 23 *Court Street.*

The following abstracts of the remarks made by those who took part in the discussion of the "Climatic Conditions of the Glacial Period" have been prepared by the speakers.

THE GROWTH, CULMINATION, AND DEPARTURE OF THE QUATERNARY ICE-SHEETS.

BY WARREN UPHAM.

As the character of a man is discerned by his life and work, so we may learn what were the climatic conditions of the glacial period by the study of their results in the formation of ice-sheets whose farthest extent and stages of recession are known by the limits of glacial striation and deposits of till or boulder clay and by the course of terminal moraines. In this inquiry we may profitably consider the climatic changes producing glaciation in their manifestation successively by the growth, culmination, and departure of the ice-sheets. The most interesting and difficult climatic problem presented in all the geologic record is that of its latest period, immediately preceding the present, to discover the causes of the accumulation of its vast sheets of land-ice. So wide and careful investigations have been bestowed on the glacial drift that we are enabled to outline definitely the boundaries of the ice-sheets both at their time of maximum extent and during pauses or times of re-advance interrupting the general retreat. Furthermore, evidence is found both in America and Europe showing, as many geologists believe, that there were at least two principal epochs of glaciation and between them a very long interglacial epoch when the ice was restricted as now to alpine glaciers and polar regions.

The fossil floras of Greenland and Spitzbergen indicate that those far northern latitudes enjoyed a temperate climate in the Miocene period; and from the absence of glacial drift through the great series of Tertiary and Mesozoic formations we infer that climates as mild as those of the present day had prevailed during long eras before the ice age. With suddenness, geologically speaking, there came at the close of the Pliocene period a great refrigeration of the climate of northern regions, overwhelming the Siberian herds of mammoths, and covering the surface of the northern half of North America and of northwestern Europe with snow and ice which increased to thousands of feet in depth. The conditions that seem requisite for the formation of these ice-sheets are long continued rather than an excessive cold and an abundant supply of moisture by storms, giving plentiful precipitation of snow during more of the year than now, so as to include in the time of snow accumulation not only the present winter but also the autumn and spring months. The summers too were probably cooler than now, for their heat was not sufficient to melt away the accumulated snow, which gradually increased in thickness from year to year, its lower part being changed to ice. When large portions of continents became thus ice-covered, the storms sweeping over them would be so rapidly cooled that the greater part of their snowfall would take place upon the borders of the ice-sheet, within probably fifty to two hundred miles from its margin; but the snowfall during the advance of the ice was probably in excess of the amount of evaporation and melting over the whole ice-covered area. In New England and New York the average ascent of the surface of the ice was twenty-five to thirty feet per mile for the first one hundred to two hundred miles from its boundary. Toward its centre the slope diminished, as on the interior ice of Greenland; but the ice-sheet enveloping the northeastern part of North America probably attained, as estimated by Professor Dana, a maximum thickness of about two miles on the Laurentian highlands between the river Saint Lawrence and Hudson bay.

When the Quaternary ice-sheets occupied their greatest area, at the culmination of the effects of the extraordinary climatic conditions of this period, the southern border of the ice crossed the northern United States from Nantucket, Martha's Vineyard, Long Island, and northern New Jersey, through Pennsylvania into southwestern New York, thence west-southwesterly to southern Illinois and

Saint Louis, thence westward nearly to the junction of the Republican with the Kansas river, thence northward through eastern Nebraska and north-northwest through South Dakota, bending from this course about thirty miles west of Bismarck, thence passing westerly through northern Montana, Idaho and Washington, reaching the Pacific ocean not far south of Vancouver island. It extended beyond the Ohio river only for short distances in the vicinity of Cincinnati; but the Missouri river lies mainly within the glaciated area. On the Mississippi river three hundred to four hundred and fifty miles north of the boundary of the ice-sheet where it reached farthest south, a large driftless area including southwestern Wisconsin and parts of adjoining states escaped glaciation. In the Rocky mountains, the Cascade range, and the Sierra Nevada, ice-fields of great extent were accumulated along distances of seven hundred to eight hundred miles south from the border of the continental ice-sheet, to latitude 37° S.; but no evidences of such local glaciation south of the ice-sheet are found in the Appalachian mountains.

Upon British America the directions of the glacial striæ and transportation of the drift show that there were two general ice-sheets, one reaching from Newfoundland and Labrador to the Rocky mountains and the Arctic ocean, having its greatest thickness over the Laurentian highlands and James bay, with outflow thence to the east, south, west, and north; and the other west of the Rocky mountains, covering British Columbia, attaining a maximum thickness of about one mile, and outflowing south into the United States, west into the Pacific ocean, and northward to the upper part of the Yukon basin. The glaciers of the Rocky mountains were doubtless confluent with these ice-sheets, so that at the time of maximum extent of the ice it was continuous from the Atlantic to the Pacific, covering approximately 4,000,000 square miles of this continent.

Half as large an area was ice-covered in Europe, the principal center of outflow being the plateau and mountains of Scandinavia, whence the ice moved west and north into the Atlantic, southward over northern Germany, and eastward over a large part of Russia. Smaller ice-sheets were formed upon Scotland and Ireland, and these became confluent with each other and with the Scandinavian ice which crossed the present bed of the North Sea to the borders of Great Britain. Glaciers also were far more extensive than now in the Alps, Pyrenees, Caucasus, and Himalayas; but no large portion of Asia is known to have been overspread by ice.

The most anomalous feature of the accumulation of these ice-sheets was their absence from Siberia and northern Alaska, while so heavily massed in the same and more southern latitudes of British America, the northern United States, the British Isles, and northwestern Europe. Within the past year Dall's observations of the absence of drift over large portions of Alaska have been confirmed and extended by the explorations of Russell and McConnell, whose communications read last week before the Geological Society of America define the limits of our glaciated area by a line that crosses the upper Yukon in British America near lat. 62° N., long. 135° W., and thence extends northward to the Arctic ocean somewhat west of the mouth of the Mackenzie. Russell also states that no glaciers now exist on the mountains of Alaska north of the Yukon, though they are grandly developed on the south along the high ranges of the Pacific coast. Probably the study of the present climate of that country will contribute much toward explaining why the ice-sheet failed to extend over the lower Yukon region, and will herewith help greatly toward the solution of the broader and very complex problem of the whole earth's climatic conditions during the ice age.

But the course of the southern glacial boundary in the United States shows important points of resemblance between the climate of the glacial period and that of the present time. Where rainfall now is deficient in the interior, on the arid plains east of the Rocky mountains, the precipitation of snow in the Ice age was similarly deficient, causing the great northward deflection of the ice-margin from the latitude of St. Louis to that of Bismark; and Dana has shown that the driftless area of Wisconsin now receives less rainfall than the contiguous regions that were ice-covered. The courses of storms and precipitation of moisture having been thus nearly the same as now, the great accumulations of ice on the continents bordering the North Atlantic suggests that a large element in the causation of the cold was probably a subsidence of the Isthmus of Panama, allowing the equatorial oceanic current to pass west into the Pacific, instead of being turned northward in the warm Gulf Stream.

To this cause of the refrigeration of climate upon the glaciated portions of the globe, we may add the influence of their elevation as continental plateaus much above their present height. The fiords of these regions indicate that they had generally stood higher than now during probably the whole Pliocene period; and the submerged fiord of the Hudson shows that when this uplift culminated, being as I believe the most important part of the causes of the ice-accumulation in the glacial period, its extent on our coast at New York was about 2,800 feet. But after the earth's crust became heavily loaded by the ice-sheets it sank until the coast from Boston northward was depressed below its present level, submerging the border of northeastern Massachusetts, New Hampshire, Maine, and New Brunswick, and carrying the sea inland along the valleys of the St. Lawrence, the Ottawa, and lake Champlain. This depression of the submarine Hudson fiord was so rapid that a bar 1,600 feet in height was formed across its mouth while the deep fiord behind the bar remained unfilled by the alluvial sediment of the river.

The greater part of the drift deposits exposed to observation, including the moraines of recession, their accompanying kames and overwashed frontal plains, the osars and their associated plains, the valley drift and its terraces, the drumlins, the contour of the general sheet of till, and even the glacial striæ, tell us far more of the retreat of the ice-sheet than of its advance and action during its maximum extension. A very great change of climatic conditions restored again prevailingly mild and warm temperatures, melting away the vast ice-sheets; but the returning warmth and the glacial cold several times contended for the mastery, recessions of the ice being succeeded by stages of re-advance, spreading till in many places over interglacial soil and fossiliferous beds.

From my studies of the glacial lake Agassiz for the geological surveys of Minnesota and the United States, I am much impressed with the suddenness of the departure of the ice-sheet. This lake, which grew to be six hundred miles long, probably as large as the combined areas of the Laurentian lakes, and seven hundred feet deep, confined in the northwardly sloping valley of the Red river of the North and lake Winnipeg by the barrier of the waning ice-sheet, is recorded by very definite beaches and occasional low escarpments of shore-erosion; but the total amount of wave action on its shores is far less than that shown by the extensive deposits of dune sand and the high cliffs of till bordering lake Michigan. Now the whole of postglacial time, during which these effects have been produced on lake Michigan, cannot be much more, according to the investigations of N. H. Winchell, Andrews, Gilbert, and Wright, than 7,000 to 10,000 years. Only a minor fraction of this time could have been occupied in the retreat of the ice from lake Traverse, at the mouth of lake Agassiz on the west side of Minnesota, to Hudson bay, finally allowing this glacial lake to be drained by the Red and Nelson rivers flowing northward as now to the ocean. During this short time, however, several prominent moraines were formed on the country adjoining lake Agassiz. It thus appears scarcely less difficult for the meteorologist to explain the climatic causes of the rapid departure of the ice than of its becoming accumulated so thick upon so large areas of the earth's surface.

CHANGES OF CLIMATE INDICATED BY INTERGLACIAL BEDS AND ATTENDANT OXIDATION AND LEACHING.

BY FRANK LEVERETT.

A study of the climate of the glacial period involves not only a consideration of the conditions necessary to produce glaciation, but also of the changes of climate that occurred. Owing to the complexity of the phenomena that evidence these changes, their extent has not been demonstrated to the satisfaction of all students of the subject. As is well known, opinion is divided on the question of the unity of the period, many now considering the evidence to be conclusive that there were two distinct invasions of the ice, with an interglacial period of great length; others still maintaining the occurrence of one continuous glacial period.

The main evidence brought in support of the former theory is (1) a sheet of carbonaceous soil, called by Dr. Newberry the forest-bed, and fossiliferous interglacial sands and clays, all of which are found extensively between sheets of till, both in America and in Europe; (2) the great erosion of the older drift (*i. e.*, of the deposit belonging to the so-called first glacial epoch) previous to the deposition of the newer, shown by the unconformity of the newer drift sheet, covering as it does great valleys and eroded ridges in the older drift; also a more eroded and more aged surface in the uncovered portion of older drift lying south of the margin of the newer.

In defence of the latter theory it is maintained that the forest-bed was rapidly formed and covered during the numerous oscillatory retreats and advances, and the erosion of the so-called older drift was effected by glacial floods attending the retreats; the more aged appearance of the drift near its southern margin being accounted for by its supposed larger derivation from residual material gathered by the glacier as it first pushed across the country.

Whether the forest-bed was formed rapidly or not; whether preglacial leaching or postglacial age was the more important factor in the production of the aged appearance of the southern margin of the drift; and how far the great erosion is attributable to glacial torrents and how far to smaller streams of longer action;— are problems doubtless possible of solution. Already much has been done toward solving them, but much remains to be done before it will be definitely known to what extent each theory is applicable.

I wish to present here a line of evidence in support of the theory of two distinct epochs, drawn from studies made under the direction of Pres. T. C. Chamberlin, in the eastern part of the Mississippi basin,—one which I think has not yet received due attention, namely, the depth to which the carbonates were leached from the drift surface during an epoch of deglaciation in the midst of the glacial period.

There are in Illinois, Indiana and Ohio, a series of about ten more or less distinct moraines, all having at surface a fresher drift than that lying outside their southern limit. Several of these have at some depth a till corresponding in character to, and seemingly a continuation of, the outlying drift. The southernmost moraine has been traced from southwestern Illinois eastward to the Scioto river, its further distribution being as yet undetermined.[1]

The till is soft and fresh in appearance to a depth of at least twenty feet in this southernmost of the series, and to a depth of one hundred feet or more beneath later moraines in central Illinois and Indiana. Below it is a hard, partially cemented till, frequently capped by a dark colored soil a few inches in thickness, and oxidized to a depth of several feet. The oxidized portion is of a brownish yellow color, differing from the oxidized portion of the surface tills of the same region which are yellowish gray. This

[1]The following cities are situated near it: in Illinois, Litchfield, Hillsboro', Pana, Shelbyville, Mattoon and Paris; in Indiana, Terre Haute, Rockville, Greencastle, Edinburgh, Columbus, Greensburg, Connersville and Brookville; in Ohio, Lockland, Lebanon, Hillsboro', Bainbridge and Chillicothe.

hard till below the newer drift is frequently exposed in ravines in the moraines toward the south, and can be traced continuously back from the district south of the outermost moraine until the fresher drift becomes too thick for ravines to reach it. Along these ravines the following section is frequently exposed:

1.	Surface soil and leached subsoil,	2–6 feet.
2.	Yellowish-gray till,	6–10 "
3.	Blue till, soft and fresh in appearance,	0–50 "
4.	Soil and leached sub-soil,	3 " ±
5.	Brown till, hard, dry, and partially cemented,	5–10 "
6.	Blue till, hard, dry and partially cemented, traversed by brown streaks,	5–50"

Where ravines fail to reach the lower drift sheet it has frequently been struck in wells, so that its occurrence is known as far north as Mendota, Illinois, the vicinity of the Kankakee river and in central Indiana, a distance of not less than two hundred and fifty miles from the southern margin of the drift in Illinois, and nearly one hundred and fifty miles from the southern moraine of the newer drift in that state.[1]

It is not the great extent of retreat and subsequent advance of the ice nor the mere presence of a buried soil that I wish to emphasize, but the amount of oxidation and leaching which took place in and below the buried soil during this retreat. Near Mendota, Illinois, I examined specimens of the buried soil, subsoil and underlying till from several borings, the depth to the buried soil ranging from ninety-four to one hundred and twenty-eight feet. The soil and subsoil resemble the underlying till in containing commingled sand, clay and pebbles, but they lack the limestone fragments and calcareous rock-flour which characterize the till. The leaching is so perfect that no response with acid was obtained within three feet of the surface of the buried soil, but below this depth the till became within a foot or two very calcareous. Similar results followed the test applied along the ravines in southern Indiana and southwestern Ohio, both in exposures beneath the newer drift, and in the district south of its margin, the depth of leaching being little, if any, greater than at Mendota.

The surface of the newer drift of this region is leached to various

[1]Buried soils are reported from various places in northeastern Illinois and southern Wisconsin, but I have had no opportunity to examine them, and have been unable to ascertain whether or not the leached subsoil is found in connection with them.

depths, the variation depending largely upon drainage facilities. Where drainage is good and denudation moderate it is two to six feet, but beneath marshes there is little leaching below the black muck, such places having frequently marl beds at the surface of the till. In the level tract near Chicago (not marshy) leaching has in many places scarcely reached a foot in depth. Few analyses of the unleached tills of this region have been made from which the percentage of carbonates may be ascertained. Two analyses, by R. B. Riggs,[1] of a glacial and glacio-lacustrine till, near Milwaukee, Wisconsin, show about forty per cent. of carbonates. Three analyses of glacial sands from hillocks of angular gravel in Ohio, made by R. B. Smith,[2] show a wide difference in the amount of carbonates, one giving 70.364 per cent; the second, 75.604 per cent. soluble in hydrochloric acid, the greater part being in the form of carbonates of lime and magnesia; the third giving 38.964 per cent. of carbonates. My observations lead me to think that forty per cent. represents approximately the amount of calcareous material in the till from which the buried soil is derived. There is, therefore, if we may reason from the few analyses made, and if we take no account of surface denudation which goes on more or less rapidly wherever drainage is good, a probability that fully two-fifths of the upper five feet of the surface of the older drift sheet have been removed by leaching leaving the three feet of leached drift now associated with the buried soil. To accomplish this would certainly require the lapse of a long interval of time.

The land surface south of the margin of the newer drift in Illinois, Indiana, and Ohio, is covered by two to five feet or more of silt, showing that it was extensively submerged after the soil had formed on the old drift surface. This silt is itself leached but has probably prevented the leaching from extending to greater depth beneath the old soil, it being very compact.

The question may be raised whether the absence of carbonate of lime in the soil and subsoil and its presence in the underlying till of the older drift may not be due to original difference in structure. It is my own opinion based upon numerous comparisons of the soils with the till that the material forming the soil has the same original structure as the oxidized till, both being commingled drift con-

[1] Sixth Annual Report, U. S. Geological Survey, p. 250.
[2] Am. Journ. of Sci., May, 1884, pp. 383–384.

taining pebbles, sand and clay. The change from noncalcareous subsoil to the calcareous till is usually gradual, seldom, if ever, so abrupt as should be expected on the theory of the superglacial origin of the one and the subglacial origin of the other,— not so abrupt as is usually the change from the oxidized to the unoxidized till. If we accept, with some, the theory that the oxidized till is all superglacial, the extent and character of the leaching have still the same significance in denoting a lapse of time as on the theory of its subglacial origin.

The forest bed occurs at several other horizons than the one indicated above. It is found to a limited extent between the sheets of newer drift, but here it has a calcareous till immediately below it, and this till is not perceptibly older than that above the soil, there being little or no oxidation. Similarly, in the older drift there are frequently exposed thin carbonaceous beds between the oxidized and unoxidized tills of which it is composed, and also interstratified with the unoxidized tills, but accompanied by little or no leached subsoil. Such soils may have been formed and buried during periods of oscillatory retreat of short duration and of limited extent.

In brief, the evidence from this district, so far as its buried soils and leached tills have a bearing, seems to teach that there were two main epochs of glaciation, each characterized by oscillatory retreats, between which was an epoch of deglaciation of considerable length.

Dr. J. Playfair McMurrich, Messrs. C. P. Bumpus, J. E. Clarke, H. L. Rich, Harris Kennedy, H. S. Hunnewell, Marshall H. Saville, Charles P. Bowditch, Nathaniel Allen and Miss Julia B. Platt were elected Associate Members.

General Meeting, January 15, 1890.

The President, Prof. F. W. Putnam, in the chair.

The meeting was called to continue the discussion of the "Climatic Condition of the Glacial Period" begun at the last meeting.

The following remarks were made on this subject:

NOTE ON GLACIAL CLIMATE.

BY N. S. SHALER.

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EVERY fragment of evidence, which can serve to show us the character of the climatal conditions during the last glacial period, is so important that I venture to present certain facts which so far as I am aware have hitherto escaped attention. The evidence I mean to discuss is found in this country and Europe in the regions immediately south of the glaciated areas of the two continents. It is a well-known fact that in the present condition of the climates of the earth, the decrease in temperature as we rise above the sea is about 3° F. for each 1000 feet of altitude. Local circumstances may considerably affect this variation, but the range is not great. If glaciers were by the refrigeration of the climate restored to the surface which they occupied during the last ice period, we should expect to find the line of perpetual snow rising as we went southward about 3030 feet for each degree of latitude.

If on an inspection of the areas glaciated during the recent ice epoch we should find that this principle in the distribution of the glacier did not hold, we should apparently be justified in the supposition that the glacial climate was not due to greater cold than that which exists at present. Any departure from the normal rate of ascent of the perpetual snow line in the region south of the glacier would be likely to throw some light on the climatal conditions prevailing during the time when the continental ice sheets were developed.

Beginning our inquiry with the Appalachian section of eastern America, we find there a region in many ways well suited for the determination we seek to make. The principal front of the ice stretched across the continent on a line which is now well determined. It is unmistakably evident that it crossed the valley of the Ohio at Cincinnati and extended a little distance south of that stream into Kentucky. I have recently reëxamined the evidence which goes to show the presence of the ice at the above-named point and have no doubt as to the goodness of the determination. At this point the surface of the country lies at a height at no point exceeding 900 feet above the level of the sea. From this position the level of the country gradually rises in a southerly direction until in the synclinal mountains near Cumberland Gap it attains a height probably exceeding 3500 feet. From this elevation the profile descends in the broad valley of the upper Tennessee to about a thousand feet above the sea level; thence it again rises until in the mountains of North Carolina, we enter a field where many peaks rise to more than 6000 feet in height. From the front of the ice sheet near Cincinnati to the central part of the North Carolina mountain district is about 200 miles. It is to be observed that the whole of this district is within the same great valley and in a region where the isotherms at the present time follow each other with normal curves. We may therefore fairly conclude that under the usual conditions of climate such as prevailed in North America, the ice line should be found in the mountains of North Carolina at the height of 2000 feet above the base of the glacier at Cincinnati, or say at 3000 feet above the level of the sea. From that level to the top of the North Carolina mountains or say for the height of 3500 feet we should have indications of glacial conditions. A tolerably careful investigation of this country has shown me no evidence of ice action whatsoever and all the other students of the subject who have visited this area have failed to find any facts which might afford even a supposition of glacial work in that field. I am therefore compelled to assume that the slope of the snow line rose so rapidly from the ice front at Cincinnati southward that it passed above the summits of these mountains.

If the elevation of western North Carolina was in the form of an isolated peak, we might have less confidence in this indication. But the district of land which should have lain much above the snow level is some thousand square miles in area, a field sufficiently great to have developed very extensive glacial areas in case the peaks lay above the line of perpetual snow. The same considerations, though in a less accented way, are met when we examine the highlands of the Blue Ridge in Virginia or the Alleghany mountain district on the uplands of Virginia and West Virginia. A large part of the Blue Ridge in Virginia is high enough to have been the seat of glaciers, provided the snow line were anywhere near the level of the glacial sheet where it crossed the existing Atlantic coast. The traces of glacial work in the Blue Ridge are extremely scanty. At the western extremity of Rock Fish Gap, immediately south of the Chesapeake and Ohio Railway, near its junction with the Shenandoah Valley Railway, there are accumulations which apparently are to be classed as glacial. This point is about 1600 feet above the level of the sea. If this accumulation be really of glacial origin, it apparently establishes the height of the ice front in the Shenandoah, but as yet I must regard the indication as somewhat questionable. In the Alleghany Mountains west of Covington, Va., there are deposits which I am disposed to consider of a glacial nature. At this point the deposits lie about 2000 feet above the sea level. These are the southernmost points at which I have found any satisfactory indications of glacial work, in the region south of the Potomac, and until further investigated, both of these deposits must be regarded as of doubtful character.

In Europe in the region south of the Alps, we find the facts similar in their character to those existing in North America. During the last glacial period the ice sheet extended down on to the Italian plains, unquestionably attaining levels less than 1000 feet of altitude above the level of the sea and probably occupying positions not more than 500 feet above that level. From my observations on the field I am disposed to think that the general mantle of the ice covered the southern face of the Alps down to within a few hundred feet above the sea. From one hundred and fifty to two hundred miles south of the Alps in the mountains of Tuscany, we have an extensive surface rising 4000 or 5000 feet above the sea. A careful search over much of this field showed me no evidence of occupation by ice. At the present rate of rise in the perpetual snow line in Switzerland we should expect an ascent of that plane about 1500 feet in passing from the foot of the Alps to the Apennine mountains north of Florence. We have thus a case similar to that we find in the North Carolina mountains in which there are elevations just south of the continental glaciers of a sufficient height to have been covered by ice under normal circumstances, but where the evidence of such coating is conspicuously wanting.

I have endeavored to apply the same considerations to the glacial phenomena of the Rocky Mountains, but the facts are as yet so imperfectly in hand that I have not been able to determine the relative attitude of the sheet in a satisfactory manner. This, however, may be said, the distinct glacial accumulations in Colorado probably do not extend below the level of 6000 feet. As this region is about on the parallel of the mountains of western North Carolina, it may perhaps indicate that the snow line lay throughout the southern parts of the United States above the summits of the Carolina mountains. It seems to me, however, that in the existing state of our knowledge of the distribution of the glacial sheet in the Cordilleran section, we cannot attach much importance to this evidence.

We have now to consider the possible explanation of the facts above adduced. Assuming that the relative height of the surface occupied by the glacier, when it crossed the Ohio River and that of the region within two hundred miles south of it, even during the ice epoch, were what they are at the present day, it at first sight seems necessary to suppose that there was a rapid change in the temperature in passing from the ice front towards the Gulf of Mexico. Before we adopt this consideration, however, we must bear in mind the fact that the ice sheet of the last glacial period probably advanced for a considerable distance south of the perpetual snow line, in substantially the same way in which an Alpine glacier descends in many cases to the depth of a thousand feet or more below the fields of enduring snow by which it is fed. Accepting the elevation of the continents as they now exist and allowing 3° of temperature for each 1000 feet of altitude, it seems likely that the snow line just touched the summit of the Carolina mountains and came to the surface of the sea near the southern end of Hudson's Bay. In other words, the protrusion of the ice to the south of this glacial snow line carried it at a distance of near 1000 miles south of the gathering ground. This supposition, however, is of little value, for the reason that the level of the continent was clearly much disturbed during the glacial period, the surface declining to the northward within the glacial envelope and probably rising to the southward of the ice front.

It seems to me most likely that during the occupation of the northern part of the continent by glaciers, the southern portion of the continent was considerably elevated. All the streams which discharge into the ocean south of the former ice front between New York and the Rio Grande show in their lower parts only moderate accumulations of alluvium which has been deposited since the close of the glacial period. They generally enter bays which appear to be the lower parts of gorges which were formed during the period when the area was more elevated than it is at the present time. These facts make it probable that if the mountains of North Carolina varied in elevation from the present height, they were more elevated than at this day. All the facts are against the supposition that we can explain the absence of glaciers in their highlands by supposing that the summits were lower during the ice period than they now are.

It seems to me we are compelled to suppose that the climate in the mountains of North Carolina and probably in the great portion of the Apennine section south of the Alps had during the glacial period a temperature not much if any lower than they have at the present time. As far as it goes the evidence is thus opposed to the supposition that the glacial period was brought about by a general refrigeration in climate of the continents occupied by the sheet.

Within the basin of the Ohio, especially in the valleys of the upper Tennessee system of waters, we find certain phenomena which lead us to the conclusion that the rainfall in a recent period, probably contemporaneous with the glacial epoch, was more considerable than at the present day. In many valleys which I have observed in that section the débris built into the imperfect alluvial plains is of a much coarser nature than that now brought down by the rivers. The channels bear the aspect of having recently been the seat of more voluminous streams than now occupy them. This evidence gained from many points in the southern Appalachians leads me, independently of the hypothesis I am now suggesting, to the conclusion that during the last glacial epoch the rainfall of this country was much greater than it is at present. At Big Bone Lick in Kentucky which lies within a few miles of the southern boundary of the ice sheet excavations made by me in 1868 show embedded in the deposits formed by the springs, an abundant set of herbivorous mammals, including the mastodon and elephant, an extinct species of buffalo and a musk ox kindred to our arctic species but of much larger size, a species of carabou, indistinguishable from our living American forms. The conditions of this deposit led me to suppose that these animals were probably not more ancient than the glacial period, and that they most likely occupied the surface during the time of abundant rainfall when the marshes were more extensive than at present, a period which if not exactly coincident with the extreme advance of the ice must fall within the glacial epoch.

The abundance of these large herbivora, the relatively great size of the species, point also to the coincident occurrence of a rather abundant vegetation. If the period indicated by the massive gravels of the torrential streams and the herbivora of Big Bone Lick be identical, and if this period coincides with the glacial period, as it appears to do, then we may fairly assume that the climatal conditions immediately to the south of the glacial sheet were not those of extreme cold. This evidence has nothing like the sure foundation, as that obtained by the lack of glaciers in the mountains of North Carolina, but as far as it goes it confirms the results of those observations.

It is not my purpose, however, in the present writing to consider the perplexing question as to the cause of glacial climate. I desire only to call attention to the extent to which our glacial streams appear to have advanced, by what we may term forced marches, far to the south of the line of perpetual snow. Although the value of the evidence above noted cannot be determined until the matter has been more carefully brought together and abundantly discussed, the facts seem to me to militate against any hypothesis which seeks to account for the glacial period on the supposition that the climate in the glaciated regions was cooler than at present.

In the subsequent discussion, Mr. Upham spoke of the very exceptional character of the climate of the glacial period. He believes, with Nordenskiöld and Wallace, that there was no widespread glaciation at any time during very long preceding geologic eras. The ice-brought blocks in Miocene deposits south of the Alps, and other local glacial formations of Tertiary and Mesozoic age are so infrequent that they seem to be best explained by reference to alpine glaciers at times of great uplift of neighboring mountains. But more widely distributed evidences of glaciation occur in the Carboniferous and Permian series, boulder-bearing deposits of so remote age, closely like the Quaternary till, and also striation of the underlying rock, being found in Natal near latitude 30° S., and in India only 20° N. of the equator. Apparently contemporaneous glacial deposits are also known in southeastern Australia, in Great Britain, and elsewhere. Croll has shown that the coal measures were laid down under cool temperate climates, attended by frequent oscillations of the land, like those of the Quaternary period ; and it is very probable that many Carboniferous and Permian conglomerates were formed by ice-sheets.

Looking for causes of glaciation which could have acted efficiently at the close of Palæozoic time and again after the Tertiary era, upon the threshold of the present, Mr. Upham thinks that great earth movements at these times elevated portions of the globe to such heights that they had cool climates with most of their precipitated moisture as snow instead of rain. Deformation of the earth was doubtless the means of its relief from the strains due to its continuous contraction during the ages of quietude between epochs of mountain-building; and the extent of the deformation would be greatest, elevating extensive areas as high plateaus, just before the plication of sections of the earth's crust and their upthrust as mountain ranges. These culminations of the effects of terrestrial contraction Mr. Upham finds, associated with the Carboniferous and Permian glaciation, in the folded Appalachian ranges of eastern North America and the Sinian mountains system of eastern Asia, both formed in the Permian period and constituting parts of the grandest disturbances of the earth's crust between the end of the Archæan era and the beginning of the Quaternary. Again, the latest and probably most extraordinary glacial period that our earth has passed through is known to have been attended by uplifts of the Cordilleran ranges in both North and South America, and especially by mighty throes of mountain-building in the Himalayan chain and considerable disturbances along its western continuation in the Caucasus, Alps, Pyrenees, and Atlas mountains.

Thus the chief cause of the climatic changes producing ice-sheets and local glaciers seems to be found in the elevation of broad areas for the former, and of mountain districts for the latter, to heights much above their present levels, bringing cooler temperatures throughout the year. On the other hand, the return of warmth and departure of the ice were coincident, at least in the case of the Quaternary ice-sheets, with subsidence of the glaciated portions of the earth's crust, which indeed appears to have been due to the weight of the ice and to have become in turn the principal influence leading to amelioration of climate and the final glacial melting.

Prof. W. O. Crosby referred briefly to some examinations of the till or bowlder clay in the vicinity of Boston which he has made during the past year with a view to determining the normal proportions of mechanical detritus (bowlders, pebbles, sand and rock flour) and the residual product of chemical decay (clay) in its composition. The rock flour, which must be ascribed mainly to the scoring and grinding action of the ice-sheet, proves to be the most prominent constituent of the till, amounting usually to from forty to fifty per cent of the whole mass; while only from ten to fifteen per cent of the till is found to be true clay, the remainder consisting of sand and coarser materials of mechanical origin. This small proportion of clay is no more than it is necessary to regard as belonging to the preglacial sedentary soil of this region. Therefore, we are forced to the conclusion that, although the ice age is supposed to have lasted many thousands of years, the chemical action of air and water upon the rocks during that time must have been, probably, on account of the intense cold, almost nothing.

It was also pointed out that while the exposed surfaces or natural ledges of even the more acidic rocks, like granite, show appreciable or considerable decomposition in postglacial times, this action is usually less marked or entirely inappreciable where the rocks have been covered by the till, and that even the fragments and minute grains of feldspar disseminated through the till, being hermetically sealed in the well compacted clay, have almost entirely escaped subsequent chemical change. The conclusion is thus reached that the glacial climate was not only very cold, but that free access of warm meteoric waters is essential to the rapid chemical decay of the silicate rocks.

Prof. W. M. Davis discussed the probable climate of the glacial period from a meteorological standpoint, and Mr. T. T. Bouvé spoke of the formation of conglomerates in azoic rocks.

General Meeting, February 5, 1890.

The President, Prof. F. W. Putnam, in the chair.

Mr. Samuel H. Scudder called the attention of the Society to a small collection of the elytra of Coleoptera made by Prof. G. J. Hinde in the postpliocene clays of the neighborhood of Scarboro', Ontario.

These clays had been carefully studied by Mr. Hinde,[1] and regarded by him as interglacial in character; the assemblage of insects found there is the largest ever obtained at such a spot, and

[1]Can. journ. sc., n. s., xv: 388–413 (1887).

they are mostly in excellent condition. Twenty-nine species have been obtained, some of them in considerable numbers. Five families and fifteen genera are represented; they are largely Carabidæ, there being six or seven species each of Platynus and Pterostichus, and species also of Patrobus, Bembidium, Loricera and Elaphrus.

The next family in importance is the Staphylinidæ, of which there are five genera, Geodromicus, Arpedium, Bledius, Oxyporus and Lathrobium, each with a single species. The Hydrophilidæ are represented by Hydrochus and Helophorus, each with one species, and the Chrysomelidæ by two species of Donacia. Finally a species of Scolytidæ must have made the borings under the bark of juniper to which reference has elsewhere been made.[1]

Only two of these beetles, besides the scolytid, have been described,[2] but most of the others will be published and figured in a forthcoming government report. Looking at them as a whole and noting the distribution of the species to which they seem to be most nearly related, they are plainly indigenous to the soil, but would perhaps be thought to have come from a somewhat more northern locality than that in which they were found; not one of them can be referred to existing species, but the nearest allies of not a few of them are to be sought in the Lake Superior and Hudson Bay region, while the larger part are inhabitants of Canada and the northern United States, or the general district in which the deposit occurs. In no single instance were any special affinities found with any characteristically southern form, though several are most nearly allied to species found there as well as in the north. A few seem to be most nearly related to Pacific forms, such as the Elaphrus and one each of the species of Platynus and Pterostichus. On the whole, the fauna has a boreal aspect, though by no means so decidedly boreal as one would anticipate under the circumstances.

Prof. F. W. Putnam spoke of early man in America and brought forward some new evidence of the contemporaneity of man with the mastodon and mammoth. This evidence is a rude figure unquestionably representing a mammoth, scratched on portion of a Busycon shell found under peat in Clairmont County, Delaware. Professor Putnam also spoke at length on early man of both sides of the American continent and of the relationship of the modern Indians to the early peoples of America.

[1]Can. ent., xviii: 194–196 (1886).

[2]Bull. U. S. Geol. Surv. terr., iii: 763–764 (1877).

Mr. H. T. Cresson has furnished the following additional information in relation to the shell: "It was found in 1864, near Holly Oak station (two and a half miles from Naaman's Creek), by M. Surault in the presence of Michael Furlin, Timothy Leary, and myself. The shell lay in a peat bed, which at the spot named, rests on red gravel (Lewis), covered by the Philadelphia brick clay (of Lewis). It was discovered while Furlin and Leary (farm laborers) were digging muck and bastardpeat, to be used for fertilizing purposes. Human bones, charcoal, bones of animals and stone implements surrounded the shell. These remains of early man have been carefully preserved, and at present are in the possession of Mrs. Spencer of New York. They will shortly be sent to the Peabody Museum for examination, and I hope will remain there, either permanently, or as a loan exhibit. I regret that more details upon the subject cannot be given at present until the specimens have been carefully studied at our Museum. It may be interesting to add that the engraved shell has been examined by Professor Putnam of Harvard University, and Professor Dall of the Smithsonian Institution, and if I am not mistaken they deem it a beautiful specimen of aboriginal American art. The shell is heavily incrusted with dendrites, and has to be handled with great care in order to prevent it from disintegrating."

General Meeting, February 19, 1890.

The President, F. W. Putnam, in the chair.

Mr. Samuel Garman read a paper on some "Recent Discoveries in Caves," in which he spoke of animals collected in caves in Missouri. He was unable to explain their peculiarities by Darwin's theory of natural selection.

Professor Hyatt agreed with the essayist that other influences besides natural selection had led to the peculiarities among animals inhabiting caves.

Dr. R. T. Jackson called attention to certain results bearing on the origin of peculiarities of structure which he had observed in the Ostreidæ.

Professor Putnam spoke of several blind fishes which he had kept alive in Cambridge for a long time several years ago. He suggested the desirability of studying the embryology of the blind fishes.

The Secretary regarded natural selection as amply sufficient to account for peculiarities of eyeless animals in caverns. He considered that the loss of eyes in these animals resulted from disuse of these organs in genera from which blind genera were derived by natural selection.

Professor W. O. Crosby then described a large bowlder from Madison, New Hampshire. Remarks on this communication were made by Professor F. W. Putnam and Mr. Frank Leverett.

The following paper was read at the meeting on December 18, 1889.

ON THE GUSTATORY ORGANS OF THE MAMMALIA.

BY FREDERICK TUCKERMAN.

Before taking up for consideration the gustatory organs of mammalia, it may perhaps be as well to review very briefly what is known respecting the homologous organs of fishes, batrachians, and reptiles.

In 1851, Franz von Leydig discovered in the external skin of fresh-water fishes peculiar goblet-shaped bodies, which he was disposed to regard as organs of a tactile nature. In 1863, Franz Eilhard Schulze redescribed the goblet-shaped bodies of fishes, and considered them organs of taste. He found them in greatest number where the fibres of the glosso-pharyngeal nerve are most thickly distributed, *i. e.*, in the mucous membrane of the palate, upon the gums and tongue rudiment, on the inner side of the gill arches, and upon the lips. In structure he found them to agree, in most respects, with the end-discs of the frog. The goblets he described as composed of two kinds of cells, viz., *Sinneszellen* and *Stützzellen*, or sensory and supporting cells; the former having a peripheral and central process. In 1867 Schulze observed that the peripheral extremity of the taste-cell bears a fine hair-like process, as in mammals.

In 1870, he discovered in the mouth of a larval amphibian (*Pelobates fuscus*) bodies resembling in structure the goblet-shaped organs of fishes, which he considered taste-organs. In 1872, Francesco Todaro described, in the papillæ covering the rudimentary tongue of *Trygon pastinaca*, a number of club-shaped bodies connected with the ultimate ramifications of the glosso-pharyngeal nerve, which he regarded as organs of taste, and analogous to those of mammals. E. Jourdan, in 1881, pointed out on the gills and in the buccal cavity of *Peristedion cataphractum* and other fishes cup-shaped bodies, composed of central and peripheral cells, which, in structure and position, differ completely from the organs of touch, and which he regards as gustatory organs. The goblet organs, or terminal buds as Merkel calls them, have been lately studied in *Amia calva* by E. P. Allis. They are present in large numbers on the external surface of the head, including the operculum, gular plate, and branchiostegal rays. They occur in the mouth and branchial cavities, and also extend on the top of the body as far as the dorsal fin. From the fact that the goblet-shaped sense-organs of fishes are not confined to the mucous membrane of the mouth, but occur in the skin at different parts of the body, Jobert, Merkel, and the later observers were led to regard them as organs of a tactile nature.

Leydig, in 1857, described in the epithelium covering the upper exposed surface of the fungiform papillæ of batrachians, peculiar end-organs of the glosso-pharyngeal nerve. These sensory terminal organs, which received the name of taste-discs, have been studied in the Urodela and Anura. According to Key and Engelmann, the upper surface of each papilla fungiformis of the frog bears a taste-disc (or, as Merkel terms it, end-disc). These discs are composed of three kinds of cells, viz., cup-shaped, cylinder and forked, the latter alone being sensory in function. The fork-cells Engelmann considered the end-organs of the gustatory nerve, and probably directly continuous with non-medullated nerve-fibres, which, in their chemical reaction, they resemble. The taste-discs rest upon a stratum of modified connective tissue, the so-called "nerve cushion," to which medullated nerve-fibres run, and within which they lose their medullary sheath.[1]

[1] Fajersztajn, in a recent paper on the terminations of the nerves in the end-discs of batrachians (*Arch. de Zool. exp. et gén.*, t. vii, 2e Serie, 1889, p. 705), describes four kinds of cells in the disc, viz., cylinder, winged, forked, and staff-shaped. The forked cells, and not the staff-cells of Merkel, he regards as the true sensory elements of the disc. He believes in the contiguity, but not in the direct continuity, of nerve-fibrils and the central processes of the sensory cells. Contiguity being effected either by the terminal buds of the nerve-fibrils applying themselves to the bodies of the sensory cells, or by the central processes of those cells adhering to the nerve-fibrils of the subepithelial plexus.

Leydig was likewise the first to call attention to the goblet-shaped sense-organs of reptiles. He found them in the skin and mouth of various snakes. According to Merkel, they are present in the Saurians only. They have been found in *Anguis* and *Lacerta*, on the inner side of the upper and lower jaw, on the tuberculum palatinum, and on the tongue. Structures homologous to the goblet-shaped organs of fishes and reptiles, the end-discs of batrachians and the taste-bulbs of mammals have not yet, as far as I am aware, been discovered in birds.

There is still some difference of opinion among physiologists as to what regions of the mouth are endowed with taste; but at all places where experiment has shown this sense to be present, there have been found, concealed in the stratified epithelium of the mucous membrane, small ovoidal or flask-shaped bodies. These structures are the peripheral organs of the gustatory nerves (that is, of the glosso-pharyngeal and of certain fibres of the lingual, the latter being probably primarily derived from the chorda tympani). These organs were discovered almost simultaneously, but quite independently, in 1867, by Otto Christian Lovén, of Stockholm, and Gustav Schwalbe. Schwalbe, now professor of anatomy in the university of Strassburg, was at that time a student in the laboratory of Max Schultze, at Bonn. To these newly discovered sensory terminal organs of mammalia Lovén gave the name taste-buds or taste-bulbs, while Schwalbe called them taste-goblets, from their likeness to the homologous goblet-shaped bodies present in the epidermis of fishes. They have also been called epithelial-buds by Krause, end-buds by Merkel, and taste-knobs by Henle. Lovén found them in the epithelium of the circumvallate papillæ of the rat, rabbit, pig, sheep, calf, horse, dog and man, and in the fungiform papillæ of the rat, rabbit and calf. Schwalbe studied them in the circumvallate papillæ of the guinea-pig, rabbit, hare, pig, deer, sheep, ox, horse, dog, cat and man. He at first denied their existence in the fungiform papillæ, but afterwards found them there. He also detected them in the rudimentary papillæ foliatæ of the pig. The anatomical description of these organs, as given by Schwalbe, agrees in the main with the slightly earlier account of Lovén.

Within a year or so following the discovery of the taste-bulbs of mammals, Verson called attention to somewhat similar structures on the posterior surface of the epiglottis of man. Engelmann and v. Wyss discovered in 1869, but independently of each other, taste-bulbs in the papillæ foliatæ of the rabbit and hare. v. Wyss also studied them in many mammals, including the hedgehog and squirrel, and at the same time made some attempt at grouping them. Krause observed taste-bulbs in the fungiform and foliate papillæ of man, and also found bulb-like structures on the posterior surface of the epiglottis of the sheep and rabbit. Ditlevsen made a comparative study of the taste-organs of mammals, investigating in all some twenty-five species. About one-half of these, however, had already been studied. Hoffmann found taste-bulbs on the anterior surface of the soft palate and on the upper part of the uvula. Schofield has described them in the lower half of the posterior surface of the epiglottis of the dog and cat. Davis studied the bulb-shaped organs in the epiglottis of the rabbit, pig, calf, dog, cat and man, and found them on the upper and lower part of the posterior surface of that organ. In the dog he found them on the inner side of the arytenoid cartilages, on the ary-epiglottic folds, and in the epithelium of the true vocal cords. Later observers have found them on one or both surfaces of the epiglottis in the musk-rat, squirrel, mink, fox and other mammals. In 1873, v. Ebner pointed out that certain glands, differing in many respects from the mucous glands, and which he classed with those of the serous type, always occur in the parts of the tongue which contain taste-organs, and their ducts open into the furrows and trenches lined by the taste-bulbs.

To recapitulate, the taste-bulbs of mammals have been found on the lateral area of the circumvallate and foliate papillæ (and more rarely on their free surface), in the epithelium of the outer wall of the trench facing the circumvallate papilla, at the upper part of the fungiform papillæ, in the soft palate and uvula, at the upper and lower part of the anterior and posterior surface of the epiglottis, on the inner side of the arytenoid cartilages, on the ary-epiglottic folds, on the vocal cords, and in other parts of the larynx. Of all these regions the lateral area of the circumvallate and foliate papillæ is preëminently the place where the taste-bulbs are found. The bulbs have been demonstrated in all mammals in which a careful search has been made for them. In addition to those already mentioned they have been found in the Insectivora, Chiroptera, Marsupialia, and Monotremata. They have yet to be studied in detail in the Quadrumana, Cetacea, Sirenia, and Edentata.

It may be of interest at this point to say a word about the gustatory papillæ themselves. In the highly ancestral *Ornithorhynchus* we find the primitive form of the circumvallate papilla. At the posterior region of the tongue of this mammal are two pairs of gustatory areas. The anterior pair lie below the surface in a furrow, the floor of which is invaginated upwards into a ridge. The ridges of the posterior pair reach the surface. The ridges of both areas bear taste-bulbs over the whole of their convexity. Ascending in the scale, we find in the gustatory ridges of *Belideus* structural characters which are common to both the circumvallate type of taste-area and the bulb-bearing ridges of *Ornithorhynchus*. The ridges of *Belideus* furnish us with an intermediate stage in the process of development of the former from the latter, the more recent from the more primitive form of taste-area. In the higher mammals it is probable that in some cases, the number of the circumvallate papillæ may be added to by direct development from fungiform papillæ. The hypothesis, however, that a fungiform type of papilla is always a forerunner of the circumvallate form, and that all circumvallate papillæ are but modifications of the fungiform type, is, I think, no longer tenable.

In marsupials and in some rodents, as the squirrels, beaver and prairie-dog, there are but three papillæ of the circumvallate form, and they are nearly always arranged in a triangle, the apex of which looks towards the epiglottis. Frugivorous bats, apes and monkeys, have also three circumvallate papillæ similarly arranged. Edentates, hares and rabbits, moles and shrews, usually have two circumvallate papillæ, while the musk-rat and pouched gopher have but one. Among the domesticated animals the horse and pig have each two circumvallate papillæ, the calf and sheep twenty to thirty each, and the goat twelve. The elephant has six and the giraffe fifty. In the Carnivora the number varies from two to twenty. Man has usually eight, and sometimes twelve, but never less than four. The only mammals in which the circumvallate papillæ are apparently wanting, as far as known, are the *Hyrax*, or coney of "Scripture," and the guinea-pig. Both of these forms, however, possess the lateral organs of taste (papillæ foliatæ), those in the *Hyrax* being very beautifully developed.

The papillæ foliatæ, or lateral organs of taste, were described by Albinus in 1754 as degenerated papillæ. In 1832 Rapp observed on the hinder part of the tongue in different mammals a series of transverse fissures lying close together, and found them also in man. The function of these fissures, however, remained unknown to him. Two years later Elsässer observed that the sense of taste was most intense on the papillæ circumvallatæ and at a place on the hinder part of the lateral edge of the tongue. This place he called, quite correctly, the "gustatory fissures" of the tongue. In 1842, Mayer, unaware of the observations of Rapp and Elsässer, described folds in the lingual mucous membrane of man and many mammals, and called them *papilla lingualis foliata seu interlocularis*. These folds he regarded as nerve-papillæ. It was not, however, until 1869 that the true nature of these organs was demonstrated by v. Wyss and Engelmann.

The lateral gustatory organs have been found in the Marsupialia, Edentata, Insectivora, Rodentia, Chiroptera, Proboscidea, in several of the Carnivora, and in the Quadrumana. Of the Ruminantia but three are known to possess them, *Tragulus javanicus*, *Cephalolophus mergens*, and *Camelopardalis giraffa*. In the bandicoots, kangaroos, and phalangers of Australia the lateral gustatory organ may be studied in its most primitive form. In *Perameles* it consists of a single gland-duct, in the walls of which scattered bulbs are developed. In *Halmaturus*, *Macropus*, *Petrogale* and *Dasyurus*, there are several of these ducts, with a proportional increase in the number of bulbs. In *Phalangista*, *Belideus* and *Acrobates*, the organ is less simple, and gland-ducts open at the bottom of slit-like furrows. Between the complex lateral gustatory organ of rodents (in which there is but little to suggest its true origin) and these simple types, there are many intermediate forms.

The microscopic structure of the end-organs of taste of mammals varies according to their location, and according to the different species of animals. In general they are not unlike a flask or bulb with a short neck; and they occupy cavities in the epithelium, which they completely fill. Their inner part or base rests upon the connective tissue of the mucous membrane. Their outer, and more slender portion, perforates the superficial layers of the epithelium and opens on the surface with a minute, circular or slightly oval aperture. This opening is called the taste-pore. The margin of the pore is usually formed by three or four cells, though it may be formed by two, or, more rarely, as in the fungiform papillæ, by a single epithelial cell being perforated about the centre. The diameter of the taste-pore varies from 0.002 to 0.0045 of a millimetre. In the circumvallate papillæ the bulbs are disposed at the sides in a zone several tiers deep, the uppermost tier usually being about opposite the middle of the trench. In the papillæ foliatæ they are as a rule restricted to the sides of the folds, which they sometimes very nearly fill. In the fungiform papillæ the bulbs are smaller and more irregular in their distribution. They are embedded in the epithelium at the upper part of the papillæ and, not infrequently, communicate with the free surface by a minute canal, which leads from their apex to the taste-pore. The bulbs vary greatly in size and shape, even in the same individual; but their length always exceeds their greatest transverse diameter. (The dimensions of the bulbs of a number of mammals are given in the table appended to this paper.)

The mammalian taste-bulb consists of two distinct kinds of cells, the outer or investing cells, which appear to function as supporting and protecting elements, of which there may be several layers, and which are modified epithelial cells; and the inner, sensory, or taste-cells, which lie in the interior of the bulb, and which are doubtless directly continuous with the terminal branches of the gustatory nerves. The outer or cover cells are elongated, slightly flattened fusiform structures, with an oval nucleus containing nucleoli. The outer end of these cells is generally drawn out into a point. The inner or basal end, which rests on the mucosa, is usually slightly rounded, though it may be notched or even branched.

Of the taste or sensory cells, of which there are probably from twelve to sixteen in a bulb of average size and maturity, several forms have been described, but the majority of observers distinguish but two forms. The first form comprises the taste-cells of Lovén, with which the *Stiftchenzellen* of Schwalbe are identical. These are highly refractive elements consisting of an elliptical-shaped nucleated enlargement, usually situated near the middle of the cell, and two poles or processes. The peripheral process is cylindrical in form, and frequently terminates in an obliquely truncated apex from which projects a very delicate hair-like or styliform process. In successful preparations the styliform process may be seen protruding through the taste-pore. The central process of the taste-cell, more slender than the peripheral, and occasionally slightly varicose, sometimes divides below the cell-body into two or more branches, but more commonly it terminates in a somewhat pointed extremity. The second form of taste-cells Schwalbe called *Stabzellen*, or staff-cells. They differ from those just described in being slightly larger, less numerous, and less highly refractive ; and, moreover, they lack the styliform process. They are also placed more externally than the cells of Lovén, the latter having a tendency to group themselves nearer the axis of the bulb. A third form of taste-cell, quite similar in structure to the fork-cells of the end-discs of batrachians has been described by Ditlevsen and Krause, but this form has not been very generally recognized by later observers. A third element which enters into the construction of a taste-bulb is a fine network, composed of very delicate filaments, through the meshes of which the sensory cells pass, and which may be derived from the subepithelial nerve plexus.

Hermann, a recent writer on the gustatory organs of mammals, describes three kinds of supporting cells in the taste-bulb of the rabbit. First, the outer or "pillar cells," which constitute the true supporting element of the bulb ; second, the inner supporting cells, which resemble the "staff-cells," of Schwalbe and heretofore supposed to be sensory in function ; and, third, "basal cells" which he regards as compensating cells for the bulbs.

The cells within the bulb which fail to conform structurally to either the taste-cell of Lovén or the staff-cell of Schwalbe, may possibly represent intermediate or degenerate forms of the one or the other, as the case may be, and what is observed may be either cells in process of growth or the remains of degenerated ones. As far as the finer structure of the bulbs is concerned subsequent research has really done little more than confirm the results reached by the early investigators. Of late years, however, something has been accomplished towards a better understanding of the nature and distribution of the mammalian taste-organs, and something, too, has been learned about their mode of development.

The gustatory papillæ of the back of the tongue are supplied by the glosso-pharyngeal nerve. Fine medullated branches of this nerve, containing small groups of ganglion cells, are distributed to the circumvallate papillæ and break up in their interior, ramifying in all directions. After dividing and subdividing they form a plexus at the upper part and sides of the papilla. Many of these branches have lost their medullary sheath, but retain the primitive sheath. In the mucosa directly underlying the layer of columnar cells of the epithelium, the nerve-fibrils form a fine delicate network. In the common hare, in gold preparations, the subepithelial network is very beautifully shown, the nerve-fibrils and small ganglia, which are scattered through the membranous stroma, being stained deep violet or black. Engelmann early called attention to the resemblance in their chemical reaction of nerve-fibrils and the central processes of the taste-cells. Hönigschmied, by means of chloride of gold, traced the nerve-fibrils directly into the taste-cells in the fungiform papilla of the cat, the investing cells not being stained, while the taste-cells were. A portion of the terminal fibrils of the subepithelial network (probably axis cylinders) enter the bulbs at their base, while others pass between them to end freely in the epithelium, or form an intra-epithelial network.

Within the circumvallate papillæ of *Perameles nasuta* and *Fiber zibethicus* a large and distinct ganglion has been found. It is in the form of a thick axial column, making up a great part of the bulk of the papillary body. It is surrounded by a clearly defined connective tissue capsule, which enters the body of the ganglion and gives it support. Above the ganglion, and also at the sides, branches radiate outwards towards the sloping side containing the taste-bulbs. The nerves are non-medullated, but possess a distinct primitive sheath. It thus appears almost certain, as Poulton observes, that nerve-cells are intercalated in the course of sensory impulses from the peripheral organs to the nervous centres. This is of interest in bringing these terminations into closer connection with the related terminal organs of sight and hearing, where ganglion cells similarly intervene.

Drasch has lately published the results of an investigation of the intimate structure of the papilla foliata, or lateral gustatory organ, of the rabbit and hare. Speaking of the nerves, he says: "Beneath the basal membrane of the secondary lamella of the papilla foliata is a plexus formed of medullated nerve-fibres. From this plexus, fibres, corresponding in number to the sum of the sensory cells, go directly to the bulbs. Other fibres, more numerous, pass between the bulbs to the epithelium situated above them. Many fibres, however, terminate in the membranous stroma beneath the epithelium. Below the bulb region, in the entire width of the lamella, is found a connected stratum of ganglion cells which contribute to the multiplication of the fibres."

The experiments of v. Vintschgau and Hönigschmied, carried on conjointly (and afterwards repeated, and with similar results, by Ranvier), appear to prove beyond question a direct continuity between nerve-fibrils and taste cells. Their experiments show that after section of the glosso-pharyngeal nerve the taste-bulbs of the papillæ on the corresponding side entirely disappear, while in those on the normal side (where the nerve remained intact) no change takes place. The bulbs of the side supplied by the divided nerve, degenerate within a short time and disappear completely by the fortieth day, while the investing cells are changed in a few months into ordinary epithelial cells.

The experiments of v. Vintschgau and Hönigschmied have quite lately been reconfirmed and added to by Griffini, who studied the reproduction of the gustatory papillæ and regeneration of the taste-bulbs in the rabbit and dog. From his experiments, it appears that after excision of a foliate papilla of the rabbit, the area, corresponding to the part removed, is shortly revested with pavement epithelium. Later, from the sixteenth to the twentieth day a few small hemispherical elevations make their appearance, and these subsequently increase in size and number. During this period also many of the injured gland-ducts undergo repair, and communicate with the free surface of the epithelium. Within the secondary papillary processes of the elevations above referred to, taste-bulbs, lying partly in the mucosa (and in process of formation), first make their appearance. Thirty days after the complete removal of the circumvallate papilla of the dog, a newly-formed papilla makes its appearance, having, however, the characters of the fungiform type. At the fortieth day (in a single instance only) a few taste-bulbs, situated at the lateral margin of the new papilla, were seen. Following section of the glosso-pharyngeals, the papillæ are changed but slightly, but the taste-bulbs begin to degenerate within twenty-three hours. The taste-cells are first destroyed, disappearing completely by the fifth day; the supporting cells soon after undergo atrophy, and by the twenty-eighth day no bulbs are visible. At the seventy-sixth day after the division of the nerves, bulbs in various stages of formation were seen; but by the two hundred and ninth day, their development was still incomplete.

The development of the taste-organs has been studied to some extent in the rabbit and in man. Hoffmann investigated the human embryo and new-born child for the purpose of studying the distribution of those organs in man. The earliest gustatory structures examined by him came from an embryo three and one-half months old, and the oldest from a woman about sixty years of age. In a fungiform papilla of a four-and-one-half months fœtus, and also in the papillæ of one at the sixth month, taste-bulbs were present. Hoffmann concludes that taste-bulbs are more frequent in embryos and the newly-born than in older individuals; that in embryos and new-born children they occur more frequently and in greater number on the free surface of the papillæ than in the adult, and that in old persons they are but rarely met with in this region.

In a rabbit's embryo, some 50 mm. in length, Hermann found taste-bulbs in the first stages of formation, on the free surface of the circumvallate papillæ. In an embryo rabbit, 70 mm. long, the bulbs of this area were perfectly developed and numerous. In the secondary lamellæ of the foliate organ and lateral wall of the circumvallate papillæ of an embryo, 95 mm. long, were seen the forerunners of the definite or permanent taste-bulbs in the form of modified basal-cells of the epithelium. In embryos of a later period, these fusiform cells traverse the entire thickness of the epithelial investment of the papilla. At birth a few of these bulbs had matured, and by the sixth day of life their development was completed. With the appearance of the permanent bulbs those of the free surface (having attained their completion during intrauterine life) undergo degeneration, and by the third day there is scarcely a vestige of them remaining.

Recently the tongue of the human embryo has been reëxamined for gustatory structures by the present writer. In an embryo of about the tenth week (the earliest investigated) the gustatory papillæ, and the lingual papillæ in general, were undeveloped nor was it possible to determine with any degree of certainty their future position. In the tongue of a fœtus of the fourteenth week several papillæ of the circumvallate type, in the early stages of development, were present. The trenches of the papillæ were undifferentiated, but their future position was clearly indicated. The proliferations of the epithelium also marked the future position of the glands and their ducts. Fungiform papillæ in various stages of growth were scattered over the dorsum, and at the sides of the back of the tongue the lateral gustatory organs (the papillæ foliatæ) were sufficiently advanced to be perceptible. A few bulbs were detected in the circumvallate papillæ of this fœtus, but unfortunately, little could be learned of their structural details. The best marked bulb was spheroidal in shape, and in some respects resembled those of the soft palate and epiglottis. It measured 0.030 mm. in length and 0.027 mm. in breadth, and was placed vertically in the long axis of the papilla, with its lower two-thirds resting in a cavity of the mucosa. The outer extremity of the bulb penetrated the superficial layers of the epithelium. While embryonic taste-bulbs were wanting in the tongue of a ten weeks embryo, it is not improbable that they may yet be found in the incipient stages of growth in one of the twelfth week of intrauterine life.

The same observer has also found bulbs in the human fœtus at the fourth month, the middle of the fifth, and at later periods of intrauterine life. They always make their appearance first at the upper part of the papilla, that is on the exposed surface. The more advanced among them being epithelial in position, while the less mature are largely embedded in the stroma of the mucosa. By the sixth month of fœtal life, bulbs begin to appear on the lateral area of the papilla, but they are much less advanced than those of its free surface. In the new-born child, and until the fourth month of life, isolated bulbs may still be found on the free area of the papilla; at a later period they occur but rarely there.

What purpose the temporary taste-bulbs (for such they seem to be) of the free upper surface of the circumvallate papillæ subserve in the embryo is difficult to comprehend. With the appearance of the bulbs of the lateral area they gradually disappear, and, from all indications, perish. By the time the bulbs of the free surface of the papillæ have attained their full development, bulbs in early stages of formation make their appearance on the wall, the lowermost bulbs being the most elementary. Were it otherwise it might be conceivable, as Hermann suggests, that by an unfolding of the papilla laterally the bulbs of the free area are shifted to the sides. In the present state of our knowledge, there seems to be no better way than to believe with Hoffmann, that "the bulbs of the free surface perish through the proliferation of the ordinary epithelium." It is not improbable that, after the bulbs have once disappeared from the upper surface, certain altered conditions of the epithelium prevent, save in rare instances, their recurrence there.

TABLE.[1]

	NUMBER OF CIRCUMVALLATE PAPILLÆ.	NUMBER OF BULBS IN CIRCUMVALLATE PAPILLÆ.	MEAN DIMENSIONS OF BULBS.		PAPILLÆ FOLIATÆ OR LATERAL GUSTATORY ORGANS.	NUMBER OF BULBS IN PAPILLÆ FOLIATÆ.	MEAN DIMENSIONS OF BULBS.	
			LENGTH.	GREATEST TRANSVERSE DIAMETER.			LENGTH.	GREATEST TRANSVERSE DIAMETER.
			mm.	mm.			mm.	mm.
Bandicoot (*P. nasuta*).	3	2,160	0·070	0·043	Present.	. . .	0·060	0.030
Bat (*V. subulatus*).	2	800	0·026	0·014	?	. . .	. . .	. . .
Musk rat (*F. zibethicus*).	1	520	0·050	0·027	Present.	800	0·046	0.027
Woodchuck (*A. monax*).	3–5	800	0·060	0·032	Do.	. . .	0 057	0·035
Porcupine (*E. dorsatus*).	2	. . .	0·054	0·024	Do.	. . .	0·048	0·027
Gray squirrel (*S. carolinensis*).	3	750	0·057	0·032	Do.	2,200	0·052	0·028
Red squirrel (*S. hudsonius*).	3	1,200	0·054	0·024	Do.	4,500	0·051	0·021
American hare (*L. americanus*).	2–3	1,200	0·051	0·033	Do.	8,000	0·056	0·035
Rabbit,	2	2,400	0·050	0·033	Do.	14,500	0·055	0.036
Horse,	2–3	. . .	0·080	0·070	Do.	. . .	. . .	. . .
Pig,	2	10,760	0·092	0·036	Do.	4,800	0·066	0·033
Sheep,	24	9.600	0·085	0·045	Wanting.	. . .	. . .	. . .
Ox,	24	35,200	0·100	0·040	Do.	. . .	. . .	. . .
Goat,	12	15,400	0·062	0·030	Do.	. . .	. . .	. . .
Cat,	6	600	0·070	0·032	Do.	. . .	. . .	. . .
Dog,	4–6	. . .	0·071	0·040	Present.	. . .	. . .	. . .
Fox (*V. vulgaris*).	4	9,500	0·042	0·020	Do.	. . .	0.045	0·021
Skunk (*M. mephitica*).	2	4,000	0·045	0·028	Wanting.	. . .	. . .	. . .
Mink (*P. vison*).	4–5	2,000	0·039	0·024	Rudimentary.	. . .	. . .	. . .
Raccoon (*P. Lotor*).	7–10	14,400	0·055	0·023	Present.	. . .	0.045	0.021
Man,	9	6,000	0·079	0·040	Do.	3,000	0.070	0.038

THE LIFE-HISTORY OF DREPANA ARCUATA, WITH REMARKS ON CERTAIN STRUCTURAL FEATURES OF THE LARVA AND ON THE SUPPOSED DIMORPHISM OF DREPANA ARCUATA AND DRYOPTERIS ROSEA.

BY ALPHEUS S. PACKARD.

THE epoch-making work of Weismann,[2] and the writings of Fritz Müller, Meldola, Lubbock, W. H. Edwards, Mr. S. H. Scudder,

[1] The bulbs of the circumvallate papilla of the flying phalanger (*B. ariel*) measure 0.042 mm. in length and 0.022 mm. in breadth. On one of the gustatory ridges of *Ornithorhynchus*, Poulton estimated the number of bulbs to the square millimetre of surface at about 500.

[2] Studies in the theory of descent. English translation, 2 vols., London, 1882.

Mr. E. B. Poulton, and others, have given a fresh impetus to the study of the larval histories or ontogeny of Lepidoptera. The direct relation between nearly each step in the larval life of these insects and the temporary surroundings of the larva at different periods of its larval life have been forcibly impressed upon me by a more or less careful examination of the ontogeny of the Notodontians. Moreover, a study of the rapid development and final suppression of certain structural features, in the course of growth from the egg to the final larval stage has, in some cases at least, given a clew to the probable causes of variation and of adaptation in the Bombyces. Indeed, after tracing out the ontogeny of several genera of a family or sub-family group, one is impressed with the great fact which underlies these frequent and sudden changes of caterpillar habiliments, *i. e.*, that a change of habit, due generally to a change of environment, induces change of structure, and not the reverse.

These laws are perhaps more admirably exemplified in the life-history of some other Bombyces than in the present genus and the group to which it belongs; at the same time the larvæ of the group of Platyptericidæ are in some important respects very curious, and they differ in some interesting characters from the groups of Notodontidæ and Bombycidæ (*B. mori*) between which they stand, both as regards their larval and their adult features.

The larva of the present species in its final stage has been described by Mr. W. Beutenmüller,[1] who remarks that in this stage it "lives singly on the upper surface of the leaf on a white silken web, slightly drawing the leaf together." He found it on *Betula alba*. The late Mr. S. Lowell Elliot once informed me that it is in the habit of rolling up a leaf, and after eating a little of it, going to another leaf, cutting it and bending it over, and thus is quite destructive to the white birch. I found at Princeton, Mass., June 7th, several of the moths resting on the leaves of the common poplar-leaved birch (*Betula alba* var. *populifolia*). A few days after capturing them, they laid their eggs on the sides of the box and on enclosed bits of paper in straight or curved rows of four or five, end to end. We have no observations on the mode of oviposition of our native species. All that I can find in European works is the following statement of Buckler,[2] referring to *Drepana sicula*. "The eggs are laid by the parent moth on the very edges of the leaves, so that when hatched

[1]Entomologica Americana, v, 38, Feb., 1889.

[2]The Larvæ of the British Butterflies and Moths. Ray Society, 1889, III, 71.

her progeny shall find themselves exactly where their food is most suitable, for however much they may wander at first, it is there, in preference to any other part, the young larvæ invariably begin to feed on the cuticle of the upper surface ; there also they spin a small quantity of silk, on which to rest, and be secure while moulting." The egg is " roundish-oval, the surface very finely pitted."

The same author states that *Drepana hamula*[1] laid a dozen eggs " on the edges of leaves of oak, here and there one on the very edge of a leaf." The egg of this species is " oval with a depression on its upper surface and ribbed longitudinally." My descriptions and studies have been made on both living and alcoholic specimens, the colors and general form being described from life.

The egg.—Length, 8 mm. Regularly oval, cylindrical, rounded alike at each end ; the shell very thin and transparent, the surface slightly granulated and divided into minute flattened, faintly marked polygonal areas. Some of the eggs are flattened, and possibly they are generally so.

First stage.—Hatched June 17. Length 2 mm. Head moderately large, a little wider than the body, smooth and rounded, shining black, with long scattered hairs. The body is nearly of the same width to and including the eighth abdominal segment ; the ninth segment is nearly as large as the eighth, while the tenth is somewhat conical, unusually well developed, the suture between it and the ninth being unusually distinct ; it ends in a long large spine, and the anal legs are obsolete, being represented by small, short, low, obtuse tubercles which hardly project from the segment. The last three segments form a "tail" which is somewhat elevated, the spine being decidedly upturned while the larva walks. The great posterior development of the supra-anal, or suranal, plate is unique so far as I am aware ; that of Cerura is unusually long and narrow, but its posterior end is rounded and obtuse and presents but a slight approach to that of the Platyptericidæ. The spine is flattened from above downwards and is about half as long as the ninth segment is broad ; it is bifid at the end, each short fork bearing a forked glandular hair or bristle a little longer than the spine itself.

On the front of each segment is a transverse ridge made rough by piliferous warts, those on the second and third segments being a little larger than the others on the body.

[1]The European *Drepana hamula* belongs to Dryopteris, and its larva in its structure is congeneric with the American *D. rosea.*

The dorsal and lateral setæ or bristles of the larva, in this stage, are all "glandular hairs," as they have been well termed by Dr. G. Dimmock.[1] They all arise from the conical warts, which seem to bear no other kind of setæ ; they vary slightly in length, the longer ones being nearly as long as the body is thick. These setæ widen towards the flattened end, which is deeply split or forked. The much smaller setæ arising from the lower side of the body along the base of the legs are minute, very short and tapering.

The body is black-brown, but the prothoracic, and first and seventh abdominal segments are pale flesh colored.

The abdominal legs are rather short and thick, and what is rather unusual except in the Cossidæ and Hepialidæ, the hooks, or crochets, of which I can count from sixteen to eighteen, form a nearly complete circle. The larva moulted June 20th, having been in this stage from two to three days.

Second stage.— June 20. Length, 4–6 mm. (described from an alcoholic specimen 6 mm. long, nearly ready to moult). Head still dark brown ; the vertex on each side pale yellowish, and a narrow pale transverse line farther down in front ; these lines not being so distinct as in the third stage. The general shape of the body has not changed, but the piliferous warts are as a rule smaller than in stage I, and each gives rise to a single fine tapering short whitish hair, which replaces the glandular hair of stage I. (In the Notodontians these glandular hairs usually persist through the second stage.) The two dorsal prothoracic piliferous warts are situated nearer together than in the third stage, and the two sub-dorsal ones, on the second and third thoracic segments, are larger than those on the prothoracic segment, and also larger than any on the abdominal segments.

The suranal spine is not quite so distinctly forked as before, it is two or three times as long as broad, and each short fork bears a fine tapering whitish hair. Near the base of this spine, the tenth segment bears on each side two piliferous warts. The anal legs are very short and rudimentary, forming two short obtuse tubercles, which scarcely project beyond the body, and bear each a short singular tenant hair, which is broad and flat at the end. There are no traces

[1]Pysche, III, 389, Sept.–Oct., 1882. On some glands which open externally on insects, 387–401. These glandular setæ or hairs appear to be of the same structure as the tenant hairs of the feet of adult insects, which secrete a viscid fluid to aid in walking.

of hooks, and these legs form a singular contrast to the long filamental anal legs of the species of Cerura and of *Heterocampa marthesia.*

The crochets of the other membranous or abdominal legs form a nearly complete circle ; beside the inner series of crochets, twenty-four in all, of which those (six to ten) at each end are larger forming two alternating rows, the circle is nearly completed by an outer curved single series of six hooks or crochets.

It is not improbable that these extra crochets, completing the circle on the planta of each of the four pairs of middle abdominal legs are developed as a compensation for the loss by disuse of the anal legs, enabling the caterpillar to grasp or anchor itself more firmly to the surface over which it creeps, while it holds up the heavy end of the body. The larva moulted the second time June 28–29.

Third stage.— June 28, 29. Length 7–8 mm. Much as in the second stage, but the body is a little paler on the other segments than before, the first thoracic, and first and seventh abdominal being light yellow, mottled with pale brown. The head is as broad as the body, the latter being widest across the thoracic segments, thence gradually tapering to the tip. The head is black-brown, with three transverse pale yellowish bands ; the upper one composed of two oval spots ; the second one forming a long narrow stripe becoming a little sinuous on the sides of the head ; the third stripe is a broader and shorter V-shaped band situated just over the clypeus, which is of nearly the same pale hue. The subdorsal prothoracic piliferous warts are now smaller than the lateral ones, those of the second and third thoracic segments being larger and more conspicuous than before, and one of them is double, thus forming a group of three warts on each side. The ninth abdominal segment is in this stage as distinctly and completely developed as the eighth, a very unusual feature in lepidopterous larvæ in which the suture between the ninth and tenth (terminal) segment is usually obsolete, these segments being more or less rudimentary. The tenth is almost wholly represented by the enlarged suranal plate, while the paranal lobes, together with the anal legs, are nearly obsolete. Across the top of the ninth segment is a slightly curved row of four prominent piliferous warts, much larger than those on any other abdominal segments, and on each side low down is a large wart covered with about eight fine sharp dark short bristles. The supra-anal spine is now simply square and docked at the end, but bears two fine terminal hairs, and seen sidewise forms an elongated cone. The larvæ moulted for the third time July 2–3.

Fourth stage.—July 2–3. Length, 12 mm. No essential difference from the third stage. The proportionate size of the warts on the thoracic segments is as in stage III, but the two dorsal warts on the ninth segment are smaller than in the preceding stages. The suranal spine is a little more hirsute than before. The last ecdysis occurred July 10–12. The larva, as in the previous stage, spins a slight web on the surface of the leaf.

Fifth and last stage.—Length, 15–20 mm. The head is short, rounded, distinctly bilobed, each half full and rounded, and is not much over one-half as wide as the body behind the middle; it is greenish-yellow, stained reddish-brown above with three black-brown, broad transverse lines in front; one is situated on the vertex; the middle one is curved, bending down on each side of the head to the ocelli; the frontal line is paler and connected with the clypeus. The two dorsal warts on the prothoracic segments are now minute, the lateral ones are broad and flat, one of the two being double and bearing two hairs. Those on the second and third thoracic segments are larger than any others on the body. On the abdominal segments the four small inconspicuous dorsal piliferous warts are arranged in a low trapezium, the two in advance being the smaller, the four warts on the eighth segment nearly forming a square. The suranal spine, seen from above, is broader at its base than before and is more conical than in the fourth stage, the upper surface is rather convex, and the spine is rust-red, the tip blunt and very slightly notched, each side bearing a fine hair. The spiracles are yellowish with a blackish ring.

The body is pea-green, brown and brick-red above on the abdominal segments, and mottled with livid clouds varying much in distinctness and in number, while the lower edge of the dorsal rust-red area is of a not very distinct livid hue. The three thoracic segments are green above, but brick-reddish near the lateral tubercles. The "frass," or pellets of excrement, are short and barrel-shaped.

On the 13th of July one turned over the end of a leaf, tying it down with several silk cords, forming a covert within which to pupate, and where it spun a thin but quite dense cocoon. It pupated July 17–19.

The pupa is securely held within the cocoon not only by the cremaster with its well developed excurved hooks, but I noticed upon endeavoring to remove the alcoholic specimens from the cocoon that it strongly adhered to and was entangled in the threads of the cocoons by a very remarkable double armature of hooks on the extremity of the head, which were quite novel and interesting to me. These hooks in addition to the ordinary cremaster, are evidently a special adaptation enabling the insect to rest securely within its cocoon and not be shaken or blown out of the leaf while on the tree.

The pupa.—Length, 11mm. Body rather thick, of the normal shape, the wings and hind legs reaching near the hinder edge of the fourth abdominal segment. The surface in general is rather coarsely pitted, and the hinder edge of the fourth to sixth abdominal segments is dark, with the surface finely shagreened. A pair of minute sharp warts on the under side of the fifth and sixth abdominal segments, those on the fifth being the largest. The cremaster is large with the surface rough with radiating ridges and rugosities. The end forms an elongated smooth projection, rounded and polished at the tip just before which is a semicircle of six recurved hooks.

On the head is a pair of stout, short tubercles, separated by a deep narrow chasm, and ending each in a stout upcurved conical hook.

The length of the different stages approximately in days is as follows: egg stage 7–8 days; larva: stage I, 2–3 days; stage II, 7 days; stage III, 4–5 days; stage IV, 8–9 days; stage V, to date preparatory to preparation, 10 days; prepupal stage, 4–5 days; pupal stage not noted, as date of emergence was not observed.

The second brood of larvæ appears in September, as Mr. J. Bridgham found on the white birch a larva ready to pupate September 20, and those reared by Mr. Beutenmüller were of the second or September brood. Of the two broods of moths in New England, the first seems to appear the first week in June, and the second at the end of July.

RECAPITULATION OF THE SALIENT FEATURES IN THE ONTOGENY OF DREPANA ARCUATA.

A. *Congenital adaptational characters of the larva.*

1. Anal legs obsolete; suranal plate already ending in an elevated rod-like spine in stage I.
2. Glandular hairs (split at the end) present only in stage I.
3. Piliferous warts well developed, but of uniform size on all the segments, in stage I.

4. Head and body dark-brown, but the warts pale ; uromeres 1 and 7, pale-yellowish, in stage I.

5. Crochets of abdominal legs more numerous than usual, forming an incomplete circle, compensating for the lack of anal legs and crochets.

6. These congenital characters are of generic value, the specific characters appearing at and after stage III.

B. *Evolution of later adaptational characters.*

1. Reduction in size and length of hairs after stage I, glandular hairs being replaced by ordinary, tapering ones.

2. At the beginning of stage III, the body becomes yellowish-green, and the dorsal region, previously dark, becomes broken up into pale yellowish-green spots. Head distinctly banded with yellow.

3. In stages IV and V the greenish portions of the body become darker, like that of the food plant, and the reddish-brown parts are assimilated to the hue of the leaf stalks and twigs.

4. In stage III, the prothoracic dorsal warts degenerate, and those of the two succeeding stages slightly progress in development.

5. The ninth uromere becomes as large as if not slightly larger than the eighth, and separated by a distinct suture from the tenth, a very unusual feature in caterpillars.

6. The chief adaptational features are: (1) colorational, to enable the partly or fully-grown caterpillar to escape observation ; and (2) structural, the unusually large ninth and tenth abdominal segments, being upraised, with the upturned threatening suranal rod or spine fitted to frighten away ichneumons or tachinæ, and possibly insectivorous birds.

C. *A special adaptation in the pupa.*

The pair of cephalic stout hooks serving to entangle the head in the web of the cocoon, the cremaster also being unusually well developed, so that the pupa is slung head and tail and cannot be thrown out of the curled leaf which in the first brood remains on the tree.

D. *Protective coloration of the moth.*

When I first noticed the moths with their broad wings outspread and resting on the upper side of the leaves, I mistook them for pieces of dead, dry, yellowish leaves which had fallen upon and become fastened to the surface of the fresh leaf.

THE LARVA OF DRYOPTERIS ROSEA.

In order to compare this caterpillar with that of *Drepana arcuata*, as well as to show in what different ways the larvæ of two allied genera may be ornamented and colored to secure the same ends, I have prepared the following description from a blown larva kindly loaned me by Professor Riley. The caterpillar has been briefly described by Mr. Grote (Can. Ent., XIX, 50), who found the full-grown larva "in the beginning of July, feeding on *Viburnum acerifolium*." He described the caterpillar from life and stated that it is "olivaceous brown, pale dorsally; dorsal line single, dark; a triangular dark patch on each side of the body commencing on segment four (I do not count the head) and bordered above the abdominal feet with pinkish." "In resting, the terminal segment is slightly elevated." Grote adds: "Pupation in a light, close web of pale-brown silk, between the leaves (July 6–8). Coloration protectional, concealing the larva as it rests on the stem of the leaf. The spotting of the 'tail' with pale is part of the protective coloration. After three weeks in the pupa the moth appears." We may add that nearly thirty years ago we found this larva on the edge of a Viburnum leaf; it was probably in next to the last stage and had a good deal of yellow about it, and was thus assimilated to the general color of the faded edge of such a leaf. Professor Riley's specimen was collected at Washington, D. C., June 30, 1884.

The full-grown larva.—Length 21 mm.; and of the suranal appendage 5 mm. The head is small, very narrow, not much over one-half as wide as the body across the middle, the vertex ending in two high conical lobes, each bearing a large, rounded, tuberculated knob; seen from in front the head is squarish, while the entire surface of the head is densely covered with coarse, prominent piliferous warts. The clypeus is of unusual shape, not being as in Drepana, nearly triangular, but the apex is rounded, giving a tongue-shaped appearance to the upper portion, which is separated from the lower broader portion by a sudden contraction in width, which is not present in *Drepana arcuata*.

The larva also differs greatly from that of *D. arcuata* in the lack of dorsal piliferous warts. On the middle of the back of the third thoracic segment is a large, fleshy, round, knob-like projection, covered with minute piliferous warts. The ninth abdominal segment is not so large as the eighth, but it is well developed. The tenth is conical, merging insensibly into the remarkably developed suranal plate, which is drawn out into a long, thick appendage, blunt at the end and with two constrictions dividing it into three segments; it is about one-fourth as long as the body and covered with coarse spinules which are larger on the filamental portion than on the base of the plate, while those on the outer half of the appendage are as large beneath as above and beneath are arranged in three rows. These spinules are slender, papilliform and give rise at the end to a stiff, sharp seta, resembling those on the body of Empretia, Euclea and other Cochlidiæ. The anal legs are more distinctly developed than in Drepana, but still are only represented by two rounded tubercles scarcely projecting beyond the body and bear at the end four or five elongated piliferous warts, but no paddle-shaped, tenant hair like that in Drepana. The thoracic legs are rather small and short, as are those of Drepana.

The abdominal legs, though distorted and dried in the blown specimen, are seen to have the same arrangement of crochets as previously described in the case of *Drepana arcuata.*

The head is dark, rust-red, with the surface between the warts highly polished.

The colors of the dried blown larva are, in general, as described from life by Mr. Grote.

It will be seen that the larva of Dryopteris differs in some remarkable respects from that of Drepana, viz.: (1) the head is much smaller and ends above in two knobbed cones, while (2) the clypeus is of a peculiar shape; (3) there are no piliferous warts visible on the body; (4) the large, fleshy median dorsal tubercle is an unique feature, while (5) the suranal plate is greatly developed over that of Drepana. And yet, with all these striking differences, the larva of Dryopteris is as well fitted as that of Drepana by its protective mimicry to avoid the gaze of birds and insect enemies, while its longer, bizarre "tail" renders it still more forbidding to any insect assailants.

SEASONAL DIMORPHISM IN DREPANA ARCUATA AND IN DRYOPTERIS ROSEA.

As is well known, Mr. Alfred R. Wallace applied the expression "seasonal dimorphism" to cases like that of the European butterfly, Araschnia, which has two forms, previously regarded as distinct, which appear at different seasons of the year, the one in early spring, the other in summer. To these forms Weismann, in his great work, "Studies on the Theory of Descent," gives the name of summer and winter form. Other European butterflies were found to be dimorphic, and several species in the United States by Mr. W. H. Edwards, and Dr. Speyer communicated to Weismann the fact that he had also found that two Geometrids, species of Selenia, are seasonably dimorphic, while Professor Meldola adds in the same footnote (p. 4), that Professor Westwood had found that two species of Ephyra were also dimorphic.

What I have to state in regard to the seasonal dimorphism of the two species of Platyptericids above named is not the result of my own observations, but of those of the late Mr. S. Lowell Elliot, so well known for his success and skill in rearing Lepidoptera. In conversation in 1887, about a year before his death, Mr. Elliot told me, and I took notes at the time, that *Drepana arcuata* Walk. and *D. genicula* (Grote) were the same species, but belonged to different broods; that *D. genicula* comes from the first of June and early July brood of caterpillars, and *D. arcuata* from the second. He also gave me specimens of the two forms, and I noted the fact on the label of each that *D. arcuata* came from a pupa which had hibernated, and *D. genicula* from a summer pupa. Mr. Elliot also added that a part of the brood of *D. arcuata* appears in the autumn, and a part hibernate, and he told me also that some of the chrysalids of *D. genicula* hibernate.

Having found *D. arcuata* both in Massachusetts and in northern New York in June, I am inclined to believe that the species, *D. arcuata*, is seasonally dimorphic, and that *D. genicula*, heretofore regarded as a good species, is simply the summer form of *D. arcuata.* The larvæ of the two forms appear to be the same.

Comparing the males, *D. arcuata* is the paler, with much paler hind wings, and is generally, if not always, of larger size. *D. genicula*, which I have determined from Grote's description, figure and type, differs in the following points: the markings and their arrangement are the same, but the ground color of the summer form (*genicula*) is much deeper in tone; the fore wings being a shade darker and deeper and more uniformly brown, while the hind wings are yellow-ochreous rather than whitish-ochreous as in the winter form (*arcuata*), and both wings beneath are deeper ochreous. The lines and other dark markings are, owing to the deeper and more uniform ground color, more distinct in the summer form. As the lines and dots vary somewhat in my specimens of the more common winter form (*arcuata*), my material will not allow me to say that there are any other differences than that of the ground color, although the apex of the fore wings is more produced in the summer form.

In this species, then, temperature, *i. e.*, the hibernation of the pupæ of the second brood, seems to be the main factor in causing the variation in the two broods of moths, and this results in a slight change of form of the wings, in a deepening of the colors of the entire moth, and probably a diminution in its size.

Seasonal dimorphism in Dryopteris rosea Walk.—Mr. Elliot at the same time told me that he had raised *D. rosea* and *D. irrorata* Pack., from caterpillars feeding on the birch and Viburnum, and that the larvæ of both forms are "exactly the same in markings, shape and habits." He also told me that *D. irrorata* comes from the second brood of *D. rosea*, adding that *D. rosea* varies a good deal, some females being nearly all yellow. If these results obtained by so acute, careful and experienced an observer should be confirmed, then *irrorata* may be regarded as the summer form of *D. rosea*. It should be observed that Mr. R. Thaxter has collected *D. irrorata* in Newfoundland. Walker's *D. marginata* is a yellow variety of *D. rosea*.

Drepana siculifer Pack., *probably a climatic variety of D. arcuata*.—So far as I can judge from a single female received from California, this form appears to be only a climatic variety of our eastern *D. arcuata*, of which I have several males and a female. The Californian form is larger[1] than the eastern ones. I have a male of *arcuata* which differs in no important respect from the Californian female, except in the size of two of the discal dots, the outer two being very large in the Californian form. I should say, however, that the specimen now before me differs considerably from my description, and that I cannot at present examine my type. But, however this may be, my second Californian female is evidently not different specifically from the eastern *arcuata* and follows the law of climatic variation referred to in my "Monograph of Geometrid Moths" (p. 587), where it is stated that thirty-one species of moths, mostly Geometrids, have larger and longer wings on the Pacific coast than Atlantic coast individuals.

[1] The length of the fore wing of my Californian female is 21 mm.; that of my largest eastern female 18 mm.

HINTS ON THE EVOLUTION OF THE BRISTLES, SPINES AND TUBERCLES OF CERTAIN CATERPILLARS, APPARENTLY RESULTING FROM A CHANGE FROM LOW-FEEDING TO ARBOREAL HABITS; ILLUSTRATED BY THE LIFE-HISTORIES OF SOME NOTODONTIANS.

BY ALPHEUS S. PACKARD.

It is not improbable that, as a rule, all caterpillars at first lived on grasses, herbaceous and low-growing plants generally, and that gradually they began to climb trees, as the latter became developed, and in time became adapted to an arboreal station. As is well known, no deciduous trees or flowering plants appeared in such numbers as to form genuine forests before the cretaceous period, and about that time in geological history began to appear the kinds of insects which visit flowers and trees that blossom.

The species of the great lepidopterous family Noctuidæ, of which we have in the United States alone over a thousand species, are, as a rule, low feeders. Certain species of Mamestra and of Agrotis, ordinarily feeding on grasses and low herbs, will, however, especially early in the spring, ascend trees and shrubs of different kinds, and temporarily feed upon the buds; and in summer a species of Mamestra will ascend currant bushes in the night, and cut off the young, fresh shoots.

In the group of forms represented by Catocala, Homoptera and Pheocyma, we have true tree-inhabiting caterpillars, and, like the Notodontians and dendricolous Geometrids, their bodies differ remarkably from those of the low-feeders, being variously spotted and mottled with shades of brown and ash, to assimilate them to the color of the bark of the tree they rest upon, and are, besides, provided with dorsal and lateral humps and warts, to further assimilate them, in outline as well as in color, to the knots and leaf-scales on the smaller branches and on the twigs among which they feed. And then there is the small group of Noctuo-bombyces, represented by species of Apatela, Platycerura, Raphia, Charadra, and their allies, which closely "mimic" the hairy, pencilled, or spiny arboreal Bombyces.[1] It should, however, be observed that this is scarcely a case of mimicry, but rather of adaptation; the presence of hairs, pencils, spines and bristles being apparently due

[1] Of thirty-four species of North American Noctuo-bombyces, whose transformations are known, all except one feed upon trees. (See Edwards' catalogue.)

to the caterpillars having changed their environment from herbs to trees, and being subjected to the same conditions as the Bombyces themselves.[1]

In the exclusively low-feeding caterpillars of certain groups of butterflies, the body is usually smooth, and adorned with lines and spots, while the general feeders and many arboreal forms are often variously spined and tuberculated, yet many spined caterpillars of butterflies feed on low herbs.[2] The Sphingidæ in part feed on low plants and in part on trees, and they do not, except as regards the caudal horn, exemplify our thesis.

Of the great group of Geometridæ, many kinds are arboreal (Dendrogeometrids), and in such cases are almost invariably tuberculated in manifold ways. We know of no hairy or tufted caterpillars of this group, or of any family below them, with the exception of the Pterophoridæ.

The arboreal Pyralidæ, Tortricidæ and Tineidæ live in such

[1] It is hardly necessary for us to express our entire disagreement with the view of Mr. A. G. Butler, that these Noctuidæ are really Notodontians, or in any way allied to them. It seems to us that the characters which he uses to remove them from the Noctuidæ are superficial and adaptive. Nearly twenty-five years ago I satisfied myself, after an examination of the denuded head and wings, that the Noctuo-bombyces were true Noctuidæ, and did not depart essentially from the typical genera.

[2] While many, though not all butterfly larvæ, as shown by Scudder and W. H. Edwards, have spine-like glandular hairs in the first stage, which may in some cases persist into one or two later stages, the body in many species, especially in those which are not general feeders, but select low-growing, herbaceous plants, becomes smooth and ornamented with stripes or spots. However, as a rule, butterfly larvæ cannot be divided, as the Bombyces, etc., into high- and low-feeders; yet, from Scudder's "Classified list of food plants of American butterflies" (Psyche, 1889), the following facts and conclusions may be stated:

Hesperidæ.—Out of forty-five species enumerated all but six feed on herbs and especially on grasses, and those which feed on tall shrubs or trees, such as *Epargyreus tityrus* and five species of Thanaos, stand at the head of the group, which, as everybody knows, is the lowest family of butterflies, and nearest related to the moths.

Papilionidæ.—Of the six species enumerated, three feed on trees, as well as shrubs and herbs; one of these, however (*P. cresphontes*), feeds on trees alone. None of this family are hairy or spined when mature, except *P. philenor*, with its peculiar flexible, spike-like growths.

Pierinæ.—Of ten species, all feed on herbs, rarely on low shrubs, and none are armed with hairs, bristles or spines. The other two groups (*Lycænidæ* and *Nymphalidæ*) are general feeders, occurring indifferently on herbs, vines and trees, except the striking case of the eight Satyrinæ, which feed exclusively on grasses and herbs (*E. portlandia*, however, sometimes frequenting the Celtis). The very spiny Argynnis larvæ feed on Viola. It should also be noted that many moths, Notodontians among them, which in the northern states feed on trees alone, in the Gulf states, according to Abbott, feed on shrubs, vines and low plants, as well as trees.

In reply to an inquiry, Mr. W. H. Edwards kindly writes me: "I do not think that the butterfly larvæ which live on trees are under more favorable conditions than low-feeders, as to healthiness, or ease of rearing."

concealment, between leaves, or in buds, or as miners, that they differ little in their surroundings from the low-feeding forms, and are thus scarcely ever tuberculated or spiny ; in fact, we cannot recall one of these groups which are so. The Pterophoridæ are to be sure spiny, but they are low-feeders, and their peculiar excretory setæ (the drüsenhärchen or glandular hairs of Zeller[1]), are similar, as Dimmock has observed, to the glandular or long hairs of plants, Miss Murtfeldt adding that " there is a very close imitation in the dermal clothing of the larvæ [of *Leioptilus sericidactylus*] to that of the young leaves of Vernonia, on which the spring and early summer broods feed." (Psyche III, 390, 1882).

Returning to the Bombyces, all the Notodontians, without any exception known to us, have trees as their principal, if not exclusive, food plants. Thus, of the thirty-seven species of this group, whose larval forms are known, and which are enumerated in Mr. H. Edwards' " Bibliographical catalogue of the described transformations of North American Lepidoptera," together with an additional species (*Ichthyura strigosa*) omitted from the catalogue, all are known to feed on trees, unless we except *Datana major*, which feeds on Andromeda, and *Schizura mustelina*, which Professor French has thus far only found feeding on the rose ; and these are shrubs. It is noteworthy that the only species found thus far on an herbaceous plant is the caterpillar of *Apatelodes torrefacta*, which Harris found on the burdock, though usually it is an arboreal insect. This apparently omnivorous feeder resembles the species of Halesidota, all of which occur more commonly on trees than on herbs, and thus differ markedly from the majority of the Lithosians and Arctians, unless we except the Nolidæ. Now the larva of Apatelodes is hairy, the long, white hairs having scattered among them black ones, with more or less black pencils, thus resembling the peculiar yellowish or white caterpillars of Halesidota, with their black tufts and pencils. Similar forms are some of the arboreal, hairy Noctuidæ, as *Charadra deridens*. It seems evident that the resemblance to each other in such different groups is the result simply of adaptation, brought about by two factors, the primary one being a change from a low-feeding to an arboreal station, and consequent isolation or segregation, and the secondary one being natural selection, the latter further tending to preserve the specific form.

[1]Revision der Pterophoriden. Linnæa entom., 1852, vi, 356. Mentioned by Dimmock.

It will be seen by the following review that the North American Bombyces in general, with the exception of the Arctians and Lithosians, live on trees, and this will in general apply to the old world species. In the group of Lasiocampidæ, represented by Tolype, Artace, Heterocampa, Gastropacha and Clisiocampa, the station is an arboreal one, none being known to feed on herbaceous plants. All the Ceratocampidæ, all the Hemileucini and Attaci, the Platyptericidæ, all the Cochlidiæ (Limacodes) including both the naked and spiny genera, as well as the Psychidæ, live exclusively on trees. Of our North American Liparidæ, all are arboreal in station, except the Californian *Orgyia vetusta*, which lives on the lupine. Finally we come to the Arctians and Lithosians, whose hairy, or rather setose, larvæ in general feed on herbaceous plants, and sometimes on trees, being in many cases omnivorous, while those of the Nolidæ and Nycteolidæ, whose history is known, are arboreal.

Of the Zygænidæ, including the "Ctenuchidæ," the species are low-feeders, living on lichens, grasses and other low plants, or upon vines. The Dioptid genus Phryganidia feeds on the oak. Of the Agaristidæ, some are low-feeders, *Euscirrhopterus gloveri* feeding on Portulacca, while the majority prefer vines (*Vitis*, etc.). As to the boring habits of the Hepialidæ and Cossidæ, which we now consider as independent groups, standing between the Sesiidæ and the Castniidæ, rather than belonging to the superfamily Bombyces; these seem to be the result of comparatively recent adaptation.

An examination of the food-plants of the British species of Bombyces, taken from Stainton's manual of British butterflies and moths (1857), gives the same results for the Old World, as will be seen by the following statements:—

Nolidæ.—Of the three British species, two feed on the oak, and one on the hawthorn and sloe.

Liparidæ.—Of the twelve species all feed on trees and shrubs, except *Lælia cœnosa*, which lives on reeds and other water plants. It is tufted.

Notodontidæ.—Of twenty-four species, one (*Diloba cœruleocephala*, which is smooth, with no protuberances) feeds on the hawthorn and other plants.

Platyptericidæ.—Of the six species, five feed on trees, and one on a shrub.

Endromidæ.—The single species is arboreal.

Psychidæ.—The two species, whose larval habits were known, feed on trees and shrubs.

Cochliopodidæ.—The two species feed on trees.

Saturniidæ.—The single British species feeds on the heather, a shrubby plant.

Lasiocampidæ.—Of eleven species, five feed on trees, the others on shrubs and herbs.

Noctuo-bombyces.—All the British species are reported as "living on trees and shrubs quite exposed."

Bombycidæ.—All the species of Acronycta live on trees and shrubs.

Influence of a change from low- to high-feeding plants, i. e., from living on an herbaceous to an arboreal station.—It appears, then, that the more typical Bombyces, such as the Ceratocampidæ, Hemileucini, Attaci, Notodontians, Cochlidiæ, and Liparidæ are arboreal in their station, their bodies being variously protected by spines, spinulated tubercles, hairs or tufts. The group is indeed particularly distinguished for the manifold modifications undergone by what are morphologically setæ, and it is an interesting inquiry whether the great development of these spines and hairs may not have originally resulted from a change in environment, *i. e.*, from low-feeding to high-feeding or arboreal habits.

It may be objected that the setæ and spines were originally due to the stimulus arising from the attacks of parasitic insects, such as ichneumons and Tachinæ, or that, as hairy caterpillars are not usually devoured by birds, these hairs and spines have originated through natural selection, and are danger-signals, indicating to birds that the wearers of such hirsute and bristling armature are inedible. But while the final purpose or ultimate use of such an armature may serve the useful purpose of protection, and while natural selection may have been the leading secondary factor in the preservation of varietal and specific forms of hairy and spiny caterpillars, this does not satisfactorily account for the initial causes of the growth of tubercles, spines, etc.

If spines and hairs form hedge-like guards against the attacks of parasitic insects, why are they not developed as well in the great multitude of low-feeders as in the less numerous high-feeders? Every one knows how efficacious any hairs or bristles are in deterring ichneumons and Tachinæ from ovipositing on caterpillars, and it is well known that naked or slightly piliferous larvæ are more subject to their attacks than those which are densely hairy or spinose.

The eruciform type of larvæ.—In endeavoring to account for the origin of the tubercles and spines, as well as the hairs of caterpillars, let us glance at the probable causes of the origin of the caterpillar form, and of the more primary colors and markings of the skin.

It was Fritz Müller who in his Für Darwin (1864) maintained that "the so-called complete metamorphosis of insects, in which these animals quit the egg as grubs or caterpillars, and afterwards become quiescent pupæ, incapable of feeding, was not inherited from the primitive ancestor of all insects, but acquired at a later period.[1]

In 1869, Dr. F. Brauer[2] divided the larvæ of insects into two groups, the campodea-form and raupen-form, and in 1871[3]–73 we adopted these suggestive views, giving the name of *eruciform* to the larvæ of weevils and other coleopterous larvæ of cylindrical form, as well as to the larvæ of Diptera, Lepidoptera and Hymenoptera, all of which are the result of adaptation, being derivatives of the primary campodea type of larva. Brauer's views on these two types of larvæ were also adopted by Sir John Lubbock, in his Origin and Metamorphoses of Insects, 1873.

While the origin of the eruciform larvæ of the Cerambycidae, Curculionidæ, Scolytidæ and other wood-boring and seed-inhabiting and burrowing Coleopterous larvæ in general, is plainly attributable to adaptation to changed modes of life, as contrasted with the habits of roving, carnivorous, campodeiform larvæ, it is not so easy to account for the origin of the higher metabolous orders of Diptera, Lepidoptera and Hymenoptera, whose larvæ are all more or less eruciform. We are forced to adopt the supposition that they have independently originated from groups either belonging to the Neuroptera (in the modern sense) or to some allied but extinct group.

Restricting ourselves to the Lepidoptera; as is well known, the Lepidoptera are now by some believed to have descended from the

[1]Facts and arguments for Darwin, with additions by the author. Translated from the German by W. S. Dallas, F. L. S. London, 1869.

[2]Betrachtungen über die Verwandlung der Insekten im Sinne der Descendenz-theorie. Verh. K. K. Zool. bot. Ges. Wien, 1869.

[3]American Naturalist, Sept., 1871. Embryology of Chrysopa.

Trichoptera, or from forms allied to that group. We should, however, prefer the view that the Lepidoptera and Trichoptera had a common origin, from some earlier, extinct group. The similarity of the imagines of certain of the lower Tineidæ and certain of the smaller Trichoptera is certainly very marked, the most significant feature being the fact that the mandibles in the two groups are either absent, or minute and rudimentary.

We have attempted, however,[1] to show that the larvæ of the Panorpidæ, judging from Brauer's figures and descriptions, are much nearer in shape and ornamentation to caterpillars than to case-worms. Hence, it seems to us probable that the ancestral or stem-form of the Lepidoptera was probably a now extinct group, somewhat intermediate between the Mecaptera (Panorpidæ) and the Trichoptera.

The primitive caterpillar.—We would suggest that the earliest type of Lepidopterous larva was allied to some Tineid which lived not only on land but on low herbage, not being a miner or sack-bearer, as these are evidently secondary adaptive forms. It is evident, when we take into account the remarkable changes in form of certain mining Tineid larvæ described and figured by Chambers[2] and by Dimmock,[3] that the flattened, footless, or nearly apodous mining larvæ of the earlier stages are the result of adaptation to their burrowing habits. The generalized or primitive form of the first caterpillar was, then, like that of Tineid larvæ in general, and was an external feeder, rather than a miner. The body of this forerunner or ancestor of our present caterpillars (which may have lived late in carboniferous times, just before the appearance of flowering plants and deciduous trees), was most probably cylindrical, long, and slender. Like the Panorpid larvæ, the thoracic and abdominal legs had already become differentiated, and it differed from the larvæ of Panorpids in the plantæ of the abdominal legs being provided with perhaps two pairs of crochets, thus adapting them for creeping with security over the surface of leaves, and along twigs and branches. The prothoracic or cervical shield was present, as this is apparently a primitive feature, often reappearing in the

[1]Third Report U. S. Entomological Commission. Genealogy of the Hexapoda, pp. 297–299, 1883. Also American Naturalist, Sept., 1883, 932–945.

[2]American Entomologist, III, 1880, 255–262; Psyche, II, 81, 137–227; III, 63, 135, 147; IV, 71. Refers to the larvæ of the "Gracilaridæ" and "Lithocolletidæ" together with Phyllocnistis.

[3]Psyche, III, Aug., 1880, 99–103.

Noctuidæ, and sometimes in the Bombycidæ, and always present in the boring larvæ of the Hepialidæ and the Cossidæ.

As tactile hairs, defensive or locomotive setæ, and spines of manifold shapes occur in worms, often arising from fleshy warts or tubercles, it is reasonable to assume that the piliferous warts of lepidopterous larvæ are a direct heirloom of the vermian ancestor of the insects. In our primitive caterpillar, then, the piliferous warts were present, eventually becoming arranged as they now are in ordinary Tineid, Tortricid, Pyralid, Geometrid and Noctuid larvæ.

Origin of the green color of caterpillars.—The cuticle may at first, as in that of case-worms and Panorpid larvæ, have been colorless or horn-colored. But soon after habitually feeding in the direct sunlight on green leaves, the chlorophyll[1] thus introduced into the digestive system and into the blood and the hypodermal tissues, would cause the cuticle to become green. Afterwards by farther adaptation and by heredity this color would become the hue in general common to caterpillars. Moreover some of the immediate descendants of our primitive caterpillars were probably lighter in hue than others; this was probably due to the fact that the lighter colored ones fed on the pale-green underside of the leaves; this difference becoming transmitted by heredity.

Origin of the lines.—As Weismann has shown, the primitive markings of caterpillars were lines and longitudinal bands, the spots appearing from interruptions or what may be called the serial atrophy of the lines or bands. It is not difficult to account for the origin of the dorsal line as this would naturally be due to the presence of the heart underneath. This dorsal line is, for example, wanting in the freshly hatched larvæ of *Spilosoma virginica* and *Hyphantria textor;* but after the first moult of *S. virginica*, there is a slight, diffuse dorsal line of no decided color, though after the second ecdysis it is decidedly whitish, or at least much paler than the surrounding dorsal region. In pale caterpillars the dorsal line may be darker. In the first stages of the two moths in question there are no lines or bands; only the piliferous warts. Whether the subdorsal or the spiracular lines were the first to originate is uncer-

[1]See the important and quite conclusive footnote by Professor Meldola on p. 310 of Weismann's Studies in the Theory of Descent, vol. I (" I have already given reasons for suspecting that the color of green caterpillars may be due to the presence of chlorophyll in their tissues, Proc. Zool. Soc., 1873, 159.—R. M.")

tain, but probably from what Weismann has concluded from his studies of the Sphingidæ, the subdorsal arose first. In the second stage of *Spilosoma virginica*, the subdorsal lines are reddish lines extending between the two subdorsal rows of alternating subdorsal piliferous warts; the line becoming more decided however in the third stage of this species, there being as yet no signs of a spiracular or of any lateral line. In the freshly hatched larva of *H. textor*, however, what may be the first beginnings of the subdorsal line are elongated brownish linear spots enclosing the subdorsal row of larger piliferous dots, but not reaching the sutures between the segments. These patches, however, do not in the second stage unite to form continuous lines, but two rows of decided black elongated spots, enclosing the black piliferous tubercles. In the freshly-hatched larva of *Edema albifrons* each of the two subdorsal lines is a row of elongated black spots connected on the three thoracic segments, but separated by the sutures along the abdominal segments.

The spiracular line is seen in the same larva of the same stage to be a yellowish band enclosing the spiracles; and there seems to be a tendency in some, if not many, larvæ for the spiracles to be enclosed and connected by a parti-colored or bright line, and for this to have a darker (as in Edema) or lighter edging. Why the spiracles themselves are so apt, as in Bombyces and Sphinges, to be enclosed by a dark or conspicuous line remains to be explained.

To return to the subdorsal lines in the pale reddish larva of Datana, probably *D. integerrima*, these lines before the first moult are also enclosed by the two rows of subdorsal piliferous spots, and in both the first and second stages there are pale spiracular lines, which appear to be contemporaneous with the subdorsal line. In the third stage a new dark red line is interpolated between the subdorsal and spiracular. In the fourth stage, the spiracular line has disappeared, and there is a supra- and an infra-spiracular pale line on the now brown dark skin of the caterpillar. Seen from above there are four pale lilac lines; but after moulting two of them disappear and in the last stage there are only two subdorsal lines to be seen, if my colored drawings very carefully made by Mr. Brigham are correct. We thus see that after the subdorsal and spiracular lines are formed, others are rapidly introduced, and some may as rapidly vanish, as necessary features of certain stages, which when they become useless are discarded.

The admirable and most suggestive work of Weismann has placed on a sound basis the theory of the origin of the lines, bands and spots of the Sphingidæ. The additional notes by Professor Meldola, and the beautiful researches of Mr. Poulton, have added to the strength of the arguments of Weismann. The lines, bars, stripes, spots, and other colorational markings of caterpillars, by which they mimic the colors and shadows of leaves, stems, etc., have evidently been in the first place induced by the nature of the food (chlorophyll), by the effects produced by light and shade, by adaptation to the form of the edge of the leaf, as in the serrated back of certain Notodontians, by adaptation to the colors of different leaves and to the stems, often reddish ; shades of greens, yellows, reds, and browns being as common in the cuticle of caterpillars as on the surface or cuticle of the leaves and their stems, or in the bark of the twigs and branches. We (and probably others) have observed that the peculiar brown spots and patches of certain Notodontians do not appear until late in larval life, and also late in the summer or early in the autumn contemporaneous with the appearance of dead and sere blotches in the leaves themselves.

Now to say that these wonderful adaptations and marked changes in the markings of caterpillars are due to "natural selection," and to let the matter rest there, is quite unsatisfactory. Natural selection may account for the elaboration of these larval forms with their markings after they have once appeared, but we want to discover, if possible, the original causes of such ornamentation, *i. e.*, the primary factors concerned in their evolution. Weismann, in his earlier work, repeatedly asserts that these changes are due to the direct action of external conditions together with natural selection. Within a few years past many naturalists have returned to a more profound study of the causes of variation along some of the lines vaguely pointed out by Lamarck[1]. It is noteworthy that

[1]Herbert Spencer says: "The direct action of the medium was the primordial factor of organic evolution." (See The Factors of Organic Evolution, 1886.) Claude Bernard wrote: "The conditions of life are neither in the organism, nor in its external surroundings, but in both at once." (Quoted from J. A. Thompson's Synthetic Summary of the influence of the environment upon the organism, Proc. Roy. Phys. Soc., IX, 1888.) Sachs remarks: "A far greater portion of the phenomena of life are [is] called forth by external influences than one formerly ventured to assume" (Phys. of Plants, 1887, 191, English translation). Semper claims "that of all the properties of the animal organism, variability is that which may first and most easily be traced by exact investigation to its efficient causes" (Animal Life, etc., preface, VI). "External conditions can exert not only a very powerful selective influence, but a transforming one as well, although it must be the more limited of the two" (Ib., 37). "No power which is able to act only as a selective, and not as a transforming influence, can ever be exclusively put forward as the proper efficient cause—*causa efficiens*—of any phenomenon (Ib. 404).

Darwin changed his views somewhat in his Variation of Animals and Plants under Domestication, and laid more stress on the influence of the surroundings than at first.

Neither Weismann nor other authors, however, so far as we know, have formally discussed the probable mode of origin of humps, horns, tubercles, spines and such outgrowths in larvæ. They are so marked and so manifold in their variations in form, and so manifestly related and in fact have so evidently been directly developed by adaptation to changes in the habits of the Notodontian caterpillars and tree-feeding larvæ in general that this group affords favorable material for a study of the general problem.

Spines and prickles in animals, like those of plants, serve to protect the organism from external attack, and also to strengthen the shell or skin ; they are adaptive structures, and have evidently arisen in response to external stimuli, either those of a general or a cosmical nature, or those resulting from the attacks of animals. It is almost an axiomatic truth that a change of habit in the organism precedes or induces a change of structure.

What has caused the enlargement and specialization of certain of the piliferous warts? As remarked by Sir James Paget: "Constant extra-pressure on a part always appears to produce atrophy and absorption ; occasional pressure may, and usually does, produce hypertrophy and thickening. All the thickenings of the cuticle are the consequences of occasional pressure ; as the pressure of shoes in occasional walking, of tools occasionally used with the hand, and the like ; for it seems a necessary condition for hypertrophy, in most parts, that they should enjoy intervals in which their nutrition may go on actively." (See Lectures on Surgical Pathology, I, p. 89, quoted by Henslow, who remarks in his suggestive work: "The origin of floral structures through insect and other agencies" that "the reader will perceive the significance of this passage when recalling the fact that insects' visits are intermittent."[1])

[1] Henslow also adds that "atrophy by pressure and absorption is seen in the growth of embryos; while the constant pressure of a ligature arrests all growth at the constricted place. On the other hand, it would seem to be the persistent contact which causes a climber to thicken."

It may here be noted that the results of the hypertrophy and overgrowth of the two consolidated tergites of the second antennal and mandibular segments of the Decapod Crustacea, by which the carapace has been produced, has resulted in a constant pressure on the dorsal arches of the succeeding five cephalic and five thoracic segments, until as a result we have an atrophy of the dorsal arches of as many as ten segments, these being covered by the carapace. Audouin, early in this century, enunciated the law that in articulated animals one part was built up at the expense of adjoining portions or organs, and this is beautifully exemplified by the changes in the development

It is now assumed by some naturalists that the thorns, spines, and prickles of Cacti and other plants growing in desert or dry and sterile places are due either to defective nutrition, or to "ebbing vitality" (Geddes) ; or by others, as Mr. Wallace, to the stimulus resulting from the occasional attacks or visits of animals, especially mammals. It should be borne in mind that the great deserts of the globe are of quite recent formation, being the result of the desiccation of interior areas of the continents, late in the Quaternary epoch, succeeding the time of river-terraces. Owing to this widespread change in the environment, involving a drying up of the soil, much of it alkaline, the direct influence on plant-life must have been profound, as regards their protective defences, and after spines began to develop, one can well understand how their shapes should have been regulated for each species and preserved by the set of minor factors which pass current under the term " natural selection."

Animals may also, in some cases, have developed spines in response to a change of environment. If we glance over the epochs of palæontological history we shall see that at certain periods, trilobites, brachiopods, ammonites, and perhaps other groups, showed a tendency to become tuberculated, spiny, or otherwise excessively ornamented. These periods must have been characterized by great geological changes, both of the relative distribution of land and water, and perhaps of climate and soil. Among the Brachiopods, more spiny species occur in the Carboniferous period than in the earlier Palæozoic times.[1] Among the trilobites, although in Paradoxides and in other genera, the genæ and sides of the segments are often greatly elongated, we only find forms with long dorsal spines at the close of the Silurian and during the Devonian.[2] There

of the carapace of the embryo and larval Decapod Crustacea, and also in insects. For example, note the change in form and partial atrophy of the two hinder thoracic somites of some beetles, as compared with the large prothorax, due probably to the more or less continual pressure exerted by the folded elytra and wings.

[1] Although there are spiny Brachiopods in the Silurian, they become more common in the Devonian (*e. g.*, *Atrypa hystrix*, *Chonetes scitula*, *C. coronata*, *C. muricata*, *Productella hirsuta*, *P. hystricula*, *P. rarispina* and *Strophacosia productoides*), and are apparently more numerous in the Carboniferous formation (*e. g.*, *Productus longispinus* *P. nebrascensis*, *Chonetes ornata*, *C. mesoloba*, *C. variolata*, *C. salmaniana*, *C. setigerus* (also Devonian), *C. fischeri*, etc. *Productella newberryi*, besides the Permian *Productus horrida*.

[2] Besides Paradoxides, there are such forms as the Cambrian *Hydrocephalus carens*, the Silurian *Dalmania punctata*, *Cheirurus pleurexanthemus* and *Eurycare brevicauda*, while the spiny species of Acidaspis seem to be more abundant in the Devonian than in the Silurian strata, but those which bear dorsal spines, such as *Deiphon forbesii* and *Arges armatus*, are Devonian.

are no such spiny forms of Ammonites as in the uncoiled Cretaceous Crioceras,[1] etc.

These types, as is well known, had their period of rise, culmination and decline, or extinction, and the more spiny, highly ornamented, abnormal, bizarre forms appeared at or about the time when the vitality of the type was apparently declining. Geddes claims that the spines of plants are a proof of ebbing vitality. Whether or not this was the case with the types of animal life referred to, whether the excess of ornamentation was due to excess or deficiency of food, it is not improbable that the appearance of such highly or grotesquely ornamented forms as certain later brachiopods, trilobites and ammonites was the result of a change in their environment during a period when there were more widespread and profound changes in physical geography than had perhaps previously occurred.

If the tendency to the production of spines in past geological times was directly or indirectly due to a change in the *milieu*, and if plants when subjected to new conditions, such as a transfer to deserts, show a tendency to the growth of thorns, or if those which are constantly submerged tend to throw out ascending aerial roots,[2] or if, like epiphytes, when growing in mid air, they throw out descending aerial roots, I have thought it not improbable that tubercles, humps, or spines may have in the first place been developed in a few generations, as the result of some change in the environment during the critical time attending or following the close of the Palæozoic or the early part of the Mesozoic age, the time when deciduous trees and flowers probably began to appear.

I have always regarded the Bombyces, or the superfamily of silkworm moths, as a very ancient one, which has lost many forms by geological extinction. We thus account for the many gaps between the genera. Both the larvæ and the moths differ structu-

[1] Quite long spines occur in the Cretaceous species of Crioceras and *Ancyloceras matheronianum* of Europe, but none, so far as we are aware, in earlier times.

[2] See N. S. Shaler: Notes on *Taxodium distichum*, Mem. M. C. Z, XVI, 1, 2, and W. P. Wilson: The production of aerating organs on the roots of swamp and other plants, Proc. Acad. Nat. Sci. Phil., April 2, 1889. Quoted in "Garden and Forest," Jan. 1, 1890. Shaler conjectures that the function of the " knees " is in some way connected with the aeration of the sap. Mr. Wilson shows that " besides the cypress, other plants which habitually grow with roots covered with water (the water gum, *Nyssa silvatica*, var. *aquatica*, *Avicennia nitida* and *Pinus serotina*) develop similar root-processes; and what is still more suggestive Mr. Wilson has induced plants of Indian corn to send roots above the surface of the soil by keeping it continually saturated with water." It is to be observed that the aerial roots of the latter develop in a single generation.

rally far more than the genera of Geometrids and of Noctuidæ, and the number of species is less. The two latter families probably arose from the great specialization of type in Tertiary times ; while evidently the great group or superfamily Tineidæ and allied forms, in some of which the mandibles still persist,[1] and which in other features (besides having as in Nepticula and Phyllocnistis nine pairs of abdominal legs[2]) show their affinity to the Trichoptera and Mecaptera, originated at an earlier date. As is well known the Cretaceous land was covered with forests of oaks, liquidambars, maples, willows, sassafras, dogwood, hickory, beech, poplar, walnut, sycamore, laurel, myrtle, fig, etc., at, or soon after, the close of the Laramie epoch, and this may have been the time, if not earlier in the Mesozoic, when in all probability the low-feeding caterpillars of that time began, perhaps through overcrowding, to desert their primitive herbaceous food plants and to ascend trees in order to feed on their leaves.

Darwin[3] has made the significant remark "that organic beings,

[1] Dr. A. Walter has discovered the presence of minute rudimentary mandibles in the European *Micropteryx caltella*, *Tinea pellionella*, *Tineola biseliella*, *Argyresthia nitidella*, *Crambus tristellus*, and two genera of Pterophoridæ (Sitzungsb. Jena, Ges. für Med. u. Naturwiss. 1885). I have also detected them in *Coleophora coruscipennella* and in another Tineid of a genus as yet undetermined.

[2] The larvæ of Phyllocnistis have no thoracic legs, but have eight pairs of membranous retractile abdominal legs, and an anal pair. (American Entomologist, III, 256.) Mr. H. T. Stainton kindly informs me that the larvæ of Nepticula have no thoracic legs "but possess nine pairs of abdominal legs," which however bear no hooks; "they look like so many fleshy prominences."

[3] The Variation of Animals and Plants under Domestication, second edition, revised, London, 1888. In the same work Darwin says: "Nathusius states positively (p. 99, 103), as the result of common experience and of his experiments, that rich and abundant food, given during youth, tends by some direct action to make the head [of the pig] broader and shorter, and that poor food works a contrary result."

Darwin also states that "the nature of the food supplied during many generations has apparently affected the length of the intestines, for according to Cuvier, their length to that of the body in the wild boar is as 9 to 1,— in the common domestic boar as 13.5 to 1,—and in the Siam breed as 16 to 1" (Ib., 77). See also the cases mentioned by Semper in his Animal Life, etc., pp. 60–62, and Neumayr's Stämme der Thierreichs, 1889, 123. Virchow claims that the characters of the skull depend on the shape of the jaw, this being due to differences in food; and here might be quoted the witty remark of Brillat-Savarin, "*Dis-moi ce que tu manges, je te dirai ce que tu es.*"

The most remarkable case and one directly applicable to our subject of the probable cause of the growth of spines is that cited by Prof. J. A. Ryder. "Even certain species of fishes, when well fed and kept in confinement, not only spawn several times during a season, instead of only once, as I am informed by Dr. W. H. Wahl, but also when kept from hibernating, as he suggests, tend to vary in the most astounding manner. The wonderful results of Dr. Wahl, attained in the comparatively short period of six years, show what may be done in intensifying the monstrous variations of Japanese gold-fishes, through selection, confinement in tanks and aquaria, with comparatively limited room for swimming, plenty of food, etc., all of which conditions tend to favor when subjected during several generations to any change whatever in their conditions, tend to vary." Farther on he refers to the general arguments, which appear to him to have great weight, "in favor of the view that variations of all kinds and degrees are directly or indirectly caused by the conditions of life to which each being, and more especially its ancestors, have been exposed" (p. 241), and he finally concludes: "Changes of any kind in the conditions of life, even extremely slight changes, often suffice to cause variability. Excess of nutriment is perhaps the most efficient single exciting cause" (p. 258).

When in Mesozoic, or possibly still earlier times, caterpillars began to migrate from herbaceous plants to trees, they experienced not only some change, however slight, in the nature of their food, but also a slight climatic change, so to speak, involving a change in the temperature. Insects living in trees or shrubs, several or many feet above the ground are certainly exposed to a more even temperature, as it is colder at night even in midsummer within a few inches of the ground, say about a foot, the usual height to which grasses and herbs grow. The changes, therefore, by day and night are greater at the surface of the ground than among the leaves and branches of a tree. Moreover forests, not too dense for insect-life, with glades and paths to admit the sunlight and heat, must necessarily have a more even temperature and be less exposed to cool winds, and less subject to periods of drought than grassy fields. There is also a less free circulation of air among grasses and herbs, which may be more or less matted and lodged after heavy rains,

growth and metabolism, and the expenditure of energy under such wholly new and restricted conditions as to render it almost certain, as he thinks, that these factors have something to do with the development of the enormous and abnormally lengthened pectoral, ventral, dorsal, double anal and caudal fins of his stock. Some of the races of these fishes have obviously been affected in appearance by abundant feeding, as is attested by their short, almost globular bodies, protuberant abdomens, and greedy habits as I have observed in watching examples of this short-bodied race living in Dr. Wahl's aquaria. In these last instances we are brought face to face with modifications occurring in fishes under domestication which are infinitely in excess, morphologically speaking, of anything known amongst any other domesticated animals. That the abundant feeding and exposure to a uniform temperature during the whole year, and confinement in comparatively restricted quarters have had something to do with the genesis of these variations, through an influence thus extended upon the metabolism affecting the growth of certain parts of the body, which have tended to become hereditary, there can scarcely be any doubt" (American Naturalist, Jan., 1890).

Darwin states that in India several species of fresh-water fishes "are only so far treated artificially, that they are reared in great tanks; but this small change is sufficient to induce much variability" (Variation of Animals and Plants under Domestication, II, 246).

than among the separate and coarser leaves of trees, such as the different species of oak, which in North America, at least north of Mexico, harbors a far greater number of species of insects (over five hundred) than any other plant known. On the whole, forest trees support a far larger number of kinds of phytophagous insects than grasses or herbs, and may this not be due to better air and a freer circulation, to a more equable temperature, perhaps of a higher average, and thus lead insects to eat more? May not the plump bodies of the larger silkworms, as the larval Attaci, the Ceratocampids, and especially the Cochlidiæ (Limacodes), be in some way due to their strictly arboreal environment?[1]

When the ancestors of the present groups became fairly established under these changed conditions, becoming high-feeders, and rarely wandering to low herbaceous plants, we should have a condition of things akin to geographical isolation. The species would gradually tend to become segregated. The females would more and more tend to deposit their eggs on the bark or leaves of trees, gradually deserting annual herbs.

For example, the females of the Attaci and their allies, as well as the Cochlidiæ, may have at first had larger wings and smaller bodies, or been more active during flight than their descendants. Their present heavy, thick bodies and sluggish habits are evidently secondary and adaptive, and these features were induced perhaps by the habit of the females ovipositing directly upon leaving their cocoon, and cocoon-spinning moths are perhaps as a rule more sluggish and heavy-bodied than those which enter the earth to transform, as witness the Ceratocampidæ compared with the cocoon-spinning silkworm (*B. mori*) and the Attaci. Spinning their cocoons among the leaves, at a period in the earth's history when there was no alternation of winter and summer, and probably only times of drought, as in the dry season of the tropics at the present day, the females may have gradually formed the habit of depositing their eggs immediately after exclusion and on the leaves of the trees forming their larval abode. The females thus scarcely used their

[1] The fat overgrown slug-worms (Limacodes) may be compared to the over-fed, high-bred pig, which eats voraciously, has little need of rooting, and takes but little exercise. Where, as in cave Arthropods, there is a deficiency of food, we have a constant tendency to slimness, to an attenuation of the body. This is seen in the blind cave animals, such as the blind crayfish, blind beetles, blind Cæcidotæa, etc., compared with their allies which live under normal conditions. (See the author's memoir on the Cave Fauna of North America, etc., Mem. Nat. Acad. Sciences, IV, 24, 1889.)

wings, while (as in *Callosamia promethea*) the males with their larger wings, lighter bodies, broadly pectinated antennæ, and consequently far keener sense of smell, could fly to a greater or less distance in search of their mates.[1] The principle of segregation[2] so well worked out by Mr. Gulick, to which Mr. Romanes' theory of physiological selection is a closely allied factor, if not covering the same ground, would soon be in operation, and the tendency to breed only among themselves, rather than with the low-feeders, would more and more assert itself, until, as at present, arboreal moths, as a rule, almost, if not wholly, oviposit exclusively on the leaves or bark of trees.

Coming now to the origin of humps, fixed or movable, and of spines, the change from herbaceous to arboreal feeding-grounds doubtless affected not only the shape of the body, causing it in many cases to be thick and fleshy, but also led to a hypertrophy of the piliferous warts common to all Lepidopterous larvæ. The change was probably not necessarily due to the stimulus of the visits and attacks of parasitic insects, because the low-feeders are, if anything, at the present day at least more subject to injury from them than arboreal caterpillars. The cause was probably more pervasive and a result of a change of the environment, such as is seen in the growth of thorns on desert plants, or the knees of the cypress and other water plants, or the aerial roots of orchids and other epiphytes; and that they may have originated with comparative suddenness seems probable when we bear in mind the aerial roots of corn artificially produced in the lifetime of a single individual; though it should be taken into account that plants are far more plastic than animals.

If the reader will look at the recapitulations we have given at the end of the detailed life-histories of certain Notodontians, it will

[1] The secondary sexual characters so marked in Bombyces are perhaps the result of their peculiar arboreal habits; so also the apterous tendency of Orgyia and a few other forms, especially the arboreal Psychidæ (*Œceticus* and *Thyridopteryx*) as well as *Anisopteryx* and *Hibernia*. It may be questioned whether any wingless female Lepidoptera live on herbaceous plants. Contrast with them the grass-feeding species of Noctuidæ as those of *Agrotis*, *Leucania*, etc.

[2] In fact nearly the whole group of insects is an example on a vast scale of the principles of segregation, geographical isolation and physiological selection. As soon as the ancestors of insects acquired wings, their *milieu* was changed. The air rather than the earth became their habitat; the acquisition of wings introduced them to a new world of existence and free from the attacks of creeping enemies and other adverse conditions to which the terrestrial Myriapods and Arachnids were subjected; the winged insects living a part of their lives, and the most important part, above the surface of the soil, multiplied prodigiously, the number of species being estimated by millions when we take into account the fossil as well as the living forms.

be seen that not only are there different adaptive characters in the larval, pupal and imaginal stages, but that the larva itself in its different stages is wonderfully adapted to different surroundings.

1. At first some, indeed most, species live socially on the under side of the leaves, near where they were born, and thus concealed from observation. Many have glandular hairs, while the tubercles are more or less uniform.

2. Toward the end of Stage II, and in Stage III, they feed in exposed situations on the upper side of the leaves, and at the same time appears the showy style of ornamentation both as regards colors, hairs and tubercles, approximating to that of the mature caterpillar, whose life apparently is conditioned by its bright colors and bizarre trappings.

The smooth-bodied, green larvæ of Nadata and Lophodonta, etc., are the primary forms. Their shape, coloration and retired habits ally them biologically to the larvæ of the European *Panolis piniperda*, and other smooth-bodied, green caterpillars with reddish or yellowish stripes, which feed on trees. These smooth larvæ are however, rare and exceptional.

But now owing to a change in the environment, there arose a tendency to the hypertrophy of the normal piliferous warts, and in the actual life-history of the caterpillar the tendency manifests itself in the third stage of larval life. We are inclined to believe (1) that the hypertrophy of certain of the tubercles was effected in a comparatively sudden period, in consequence of a comparatively sudden change from herbs to trees, and (2) in response to a sudden exigency ; (3) that the spines and stiff, dense spinulated hairs were immediately useful in preventing the attacks of parasitic insects, while (4) the poison-glands at the base of the tubercles (in the Attaci, etc.) served to render them distasteful to birds ; (5) the bright colors serving as danger-signals.

The Lamarckian factors (1) of change (both direct and indirect) in the *milieu*, (2) need, and (3) habit, and the now generally adopted principle that a change of function induces change in organs[1] and in some or many cases actually induces the hypertrophy and specialization of what otherwise would be indifferent parts or organs ;

[1] R. Marey : Le transformisme et la physiologie expérimentale, Cours du Collége de France. Revue scientifique, 2d Série, IV, 818. (Function makes the organ, especially in the osseous and muscular systems.)

See also A. Dohrn : Der Ursprung der Wirbelthiere und das Princip des Functionswechsels, Leipzig, 1875.

these factors are all-important in the evolution of the colors, ornaments and outgrowths from the cuticle of caterpillars.[1]

The following table is an attempt at a classification of some of the structures arising from the various modifications of the primitive piliferous warts or tubercles common to nearly all, if not all, smooth-bodied, lepidopterous larvæ. As is well known, the term "hair" does not properly apply to the bristles or hair-like structures of worms and Arthropoda, as morphologically they are not the homologues of the hairs of mammals, but arise, as Newport first showed, through a modification and hypertrophy of the nuclei of certain cells of the cuticle. Hence the word *seta*, as suggested by Lankester, is most applicable.

A. Tubercles.

a. Simple and minute, due to a slight thickening of the hypodermis and a decided thickening of the overlying cuticle; the hypodermis contains a large unicellular gland either for the secretion of the seta (or for the production of poison).

1. Minute piliferous warts. (Most Tineid, Tortricid and Noctuid larvæ.)
2. Enlarged smooth tubercles, bearing a single seta. (Many Geometrid and Bombycine larvæ.)
3. Enlarged, spherical tubercles, bearing a number of setæ, either radiated or subverticillate. (Arctians, Lithosians, Zygænidæ, including some Glaucopinæ.)
4. High, movable, smooth tubercles, having a terrifying function. (*Schizura*, *Janassa*, *Notodonta*, *Nerice*.)
5. Low and broad, rudimentary, replacing the "caudal horn." (Chœrocampa, the European *Pheosia dictæa* and *dictæoides*.)

b. More or less spinulose or spiny (disappearing in some Sphinges after stage I).

1. Long and slender, usually situated on top of the eighth abdominal segment, with microscopic spinules in stage I. (Most Sphingidæ and *Sesia*.)

[1] It is possible that the close resemblance of the warts, projections and spines of certain arboreal caterpillars, which so closely mimic the spines, leaf-scars and projections of the branches or twigs or plants, has been brought about in a way analogous to the production of spots and lines on the body of caterpillars. Darwinians attribute this to the action of "protective mimicry," but this expression rather expresses the result of a series of causes to which we have endeavored to call attention. The effect of dark and light shades, and the light and shade in producing the stripes and bars of caterpillars are comparatively direct and manifest, but how can thorns and other projections on trees and shrubs affect caterpillars directly? Given the origination by hypertrophy of warts and spines, and it is then easy to see that by natural selection caterpillars may have finally become adapted so as to mimic similar vegetable growths. Our object is to endeavor to explain the causes of the primary growth and development of such projections, *i. e.*, to lay the foundation for the action of natural selection.

2. Smooth, subspherical warts. (Zygænidæ, *e. g.*, Chalcosia, East Indies); or elongated but still smooth. (*Attacus atlas* and a species from southwestern territories U. S. A.)
3. Subspherical or clavate, spiny tubercles of many Attaci; the spinules usually short.
4. Spinulated spines or elongated tubercles of Ceratocampidæ and Hemilucini. (*H. io* and *H. maia*, etc.)
5. Spike-like hairs or spines. (*Samia cynthia*, Anisota, East Indian Hypsa, Anagnia.)
6. Antler-like spines. (Early stages of *Heterocampa guttivitta.*)

B. SETÆ ("hairs," bristles, etc.).

1. Simple, fine, short or long, microscopic or macroscopic setæ, tapering hairs, scattered or dense, often forming pencils. (Many Bombyces, Zygænidæ, Noctuo-bombyces, Apatelæ.)
2. Glandular hairs, truncate, spindle-shaped or forked at the end and secreting a more or less viscid fluid. (Many in stages I and II of Notodontians, many butterfly larvæ, and in the last stages of Pterophoridæ.)
3. Long, spindle-shaped hairs of Apatelodes, *Apatela americana*, figured in Harris Corr., Pl. III, fig. 2, also Packard's Guide, fig. 236, and the European *Tinolius eburneigutta* Walk.
4. Flattened, triangular hairs in the tufts or on the sides of the body of *Gastropacha americana*, or flattened, spindle-shaped scales in the European *G. quercifolia.*
5. Spinulated or barbed hairs. (Most Glaucopides, etc., Arctians, Lithosians and Liparidæ and many other Bombyces.)

C. PSEUDO-TUBERCLES.

1. The filamental anal legs (stemapoda) of Cerura and *Heterocampa marthesia.*
2. The long, suranal spine of Platyptericidæ.

THE USUAL POSITION OF THE MORE SPECIALIZED WARTS, HUMPS OR HORNS.

Everybody has noticed that the horn characteristic of larval Sesiæ and Sphinges is uniformly situated on the back of the eighth abdominal segment and no other, and that when it is absent, as in Chœrocampa, etc., it is replaced by a small, low and flattened tubercle, the segment itself being somewhat swollen. The larval Agaristidæ (Alypia, Eudryas, Copidryas, Psychomorpha, etc.) have a prominent, gibbous hump on this segment, or at least this segment is more or less prominent and humped, not only in this family, but also in certain smooth-bodied Noctuidæ, as Amphipyra, and *Olygia versicolor*, etc.

In many Notodontidæ the first abdominal segment bears a conspicuous hump, sometimes forked, often ending in a seta.

In the larval Ceratocampidæ, either the prothoracic segment or the second and third thoracic segments bear high conspicuous horns and spines. They may be roughly classified as follows:

Prothoracic segment.—With a large, subspherical tubercle on each side bearing numerous radiating hairs (Lasiocampidæ of first stage), or pencils of hairs (Parorgyia); two antlers (*H. guttivitta*)

Second thoracic segment.—Two high, slender spines. First stage of *Anisota senatoria*, *A. stigma* and *Dryocampa rubicunda.*

Third thoracic segment.—Two spinulose pappose flaps, *Empretia stimulea.*

First, second and third thoracic segments.—Each with a pair of high spines, *Citheronia regalis* and *Eacles imperialis.*

Second and third thoracic segments.—Each with a pair of long horns, *Sphingicampa bicolor.*

First and third thoracic segments.—In stage I of the European *Aglia tau* (Poulton).

First abdominal segment.—Movable tubercle in Schizura and Janassa.

Eighth abdominal segment.—The caudal horn of Sesia and most Sphingidæ, Pheosia and Endromis, *Bombyx mori* and other species, Sphingicampa, Eacles, Citheronia, and *Aglia tau* (stage I).

So far as I am aware, no one has suggested why these horns and high tubercles and often pencils of hairs are restricted to these particular segments. As a partial explanation of the reason, it may be stated that the presence of these high tubercles, etc., is correlated with the absence of abdominal legs on the segments bearing the former. It will also be noticed that in walking the apodous segments of the caterpillar are more elevated and prominent than those to which the legs are appended. They tend to bend or hump up, particularly the first and the eighth abdominal, the ninth segment being reduced to a minimum and the tenth simply represented by the suranal and paranal plates, together with the last pair of legs.

As is well known the loopers, or geometrid worms, while walking, elevate or bend up the part of the body situated between the last thoracic and first pair of abdominal legs, which are appended to the seventh uromere. Now, in the larva of *Nematocampa filamentaria*, which bears two pairs of remarkable filamental tubercles, rolled up at the end, it is certainly very suggestive that these are situated on top of the loop made by the caterpillar's body during progression, the first pair arising from the second, and the hinder pair from the fourth abdominal segment.

It seems, therefore, that the humps or horns arise from the most prominent portions of the body, at the point where the body is most exposed to external stimuli; and the force of this is especially seen in the conspicuous position of those tubercles which are voluntarily made to nod or so move as to frighten away other creatures. Perhaps the tendency of these segments to loop or hump-up has had a relation of cause and effect in inducing the hypertrophy of the dermal tissues entering into the composition of the tubercles or horns.

Analogous positions are in the vertebrates utilized, as in spiny, osseous fishes, or the sharks, the horned Amphibia, or horned reptiles and horned mammals. The prominence of the foundation parts, from which the tubercles arise, may lead to a determination of the blood toward such places and thus in well-fed or over-fed (possibly under-fed individuals) induce a tendency to hypertrophy which once set up in early generations led to the production of incipient humps which became more developed as they proved useful and became preserved in this or that form by natural selection. On the other hand, the hypertrophy of certain piliferous warts would tend to cause an arrest of development or a tendency to atrophy in the piliferous warts of adjoining segments. And in like manner may the simple setæ have become hypertrophied on account of their great utility as deterrent organs, and become wonderfully modified in this and that direction in such and such forms, until they became in recent geological times the common and normal inheritance, not only of scattered species but of certain genera in scattered families, and even of entire families.

It is to be observed, as one will see by referring to the special larval histories and the recapitulations which we have appended, that, as in the species of Schizura, the evolution or hypertrophy of the movable or nutant tubercles begins in the third stage, at about the time when the young caterpillars leave their common birthplace on the under side of the leaf and seek more conspicuous feeding grounds on the outer edge or on the upper side of the leaf, where they are exposed to the visits of ichneumons, or Tachinæ, or carnivorous Hemiptera, or to the onset of open-mouthed insectivorous birds. At the same time the bright colors, spots and stripes, the very peculiar V-shaped silver or yellowish-white mark characteristic of the species of Schizura,—these are perhaps danger-signals, though later in life the brown shades and green tints, so like the green leaf with its serrated, blotched, sere-patched edges, would often deceive the most observant of birds.

In regard to the nutant or movable tubercles, it may be observed that a slight motion of these appendages may suffice to scare off an approaching ichneumon or Tachina. If most insects have, as supposed by Exner and by Plateau, more imperfect vision than has formerly been attributed to them, so that they are extremely near-sighted and only clearly perceive bodies when in motion, then even slight movements of these tubercles, while the caterpillar itself was immobile, would probably be sufficient to frighten a parasitic insect and deter it from laying its eggs on the caterpillar.

PARTIAL LIFE-HISTORY OF ICHTHYURA INCLUSA HUBN. (CLOSTERA AMERICANA HARRIS).

For the opportunity of examining five alcoholic examples of the first stage of this larva, I am indebted to Professor Riley; those of the last stage I have collected from the poplar. Mr. H. Edwards (Papilio, iii, 24) briefly describes the second stage, and adds that it "feeds in companies until after the second moult; the larvæ then separate and act independently of each other."

First stage.—Length, 3–4 mm. The head is blackish brown, rounded, but little wider than the body, and provided with scattered, long, stiff, tapering bristles. The body is regularly cylindrical, and does not differ essentially in shape from the full-fed larva. There is a well developed prothoracic or cervical shield, on the front edge of which are four piliferous warts, and the bristles arising from them are longer than the body is thick; the warts on the hinder edge bear much shorter hairs. The shield is not large, but is very distinct, forming a blackish, chitinous plate. On each side of the same segment are two distinct piliferous warts. On the second and third thoracic segments is a transverse straight row of ten piliferous warts which, like all the others are dark, and contrast with the pale flesh ground-color of the body. Of the ten piliferous warts, the two median dorsal ones are much smaller than the others, the two subdorsal ones on each side being twice as large, and those on the second segment bearing each a single long hair; the pair of setæ on the inner of the four warts being nearly twice as long as the body is thick. The hairs on the third thoracic segment are pale gray, like those on all the posterior segments except the eighth to tenth. On the abdominal segments the four piliferous warts are on segments 1–5, arranged in a semicircle rather than a trapezoid, but on segments 6–8 form a trapezoid, the two anterior warts being paler and smaller than those behind, with the marked exception of the pair on the first and eighth abdominal segments, where they are about twice as large, and surrounded at the base by a deep reddish patch.

The suranal plate is also very distinct, blackish, and bears about eight or ten prominent piliferous warts, but the hairs are fine and short. The thoracic legs are black, the abdominal legs with a black chitinous scale on the outside near the end. The spiracles are round and remarkably small. All the abdominal feet possess ten crochets, and no bulbous hairs are present, all tapering to the end, but the skin is covered with numerous fine, microscopic, short tapering hairs. The body is faintly striped on each side with three interrupted dark red lines. It will thus be seen that the dorsal twin tubercles on the first and eighth abdominal segments, and the mode of coloration of the last stage, are already indicated in Stage I.

Second stage.—Length (after the first moult), 18 mm. Mr. Edwards' description, judging by the great length of the larvæ, probably applies to the end of the stage, just before the second moult. His description is as follows:—"Head black, shining, with double fovea in front. Second (first thoracic) edged in front with bright yellow. Body black, with a series of bright yellow longitudinal stripes, those of the dorsum being the most distinct; four and eleven (first and eighth abdominal) have small black tubercles in the centre. All the segments bear small, jet-black, piliferous tubercles. The hairs of the body are all sordid white. Anal segment black. Under side dull yellow. Feet black at the tips."

Final, or fifth stage.—Length, 38 mm. In the mature larva the cervical shield is divided into two separate halves, but the head is still black and rounded, while the piliferous warts on the first and eighth abdominal segments have become twinned, papilliform, hirsute, dark, prominent (probably slightly movable) tubercles. The body is finely striped, longitudinally, with yellow (this being the ground color) and dark lines, and is provided with short, pale hairs, about one-third as long as the body is thick. Besides the black head, the two black twin tubercles, and the black suranal plate, there are two rows of black slashes along the sides of the body, one subdorsal and the other lateral. The thoracic legs are black at the ends, and the abdominal legs are dotted with black at the extreme tip.

Recapitulation.—The changes from the first to the last stages are not so marked as usual in this family, and this appears to be due to the fact that the mature larvæ, though brightly colored, spotted and banded, live more or less in tents, out of sight, the young larvæ apparently also adopting a partial life in tents.

1. In Stage I the cervical shield is well developed, and in Stage V, or the last stage, is divided into halves.

2. The dorsal tubercles on the first and eighth uromeres are separate, while in the last stage they are closely contiguous and very prominent, while the piliferous warts on the mature larva are nearly obsolete.

3. Stage I already shows traces of longitudinal lines.

4. The markings (both colorational and structural) of the last stage appear at the end of Stage II, and are probably still more emphasized in Stage III.

Dr. Harris, in his "Treatise," quite fully describes the habits of this tent-inhabiting caterpillar, remarking, "When young they sometimes fold up one side of a leaf for a nest, and eat the other half." He also fully describes the tent made by the social mature larvæ, which we have also observed on the poplar, "made of a single leaf folded or curled at the sides, and lined with a thin web of silk." He also states that "the caterpillars go out to feed upon the leaves near to their nests." It thus appears that from early larval life the caterpillars live in much the same way as the fully grown larvæ, dwelling in tents, and, unlike most Notodontians, continuing to live socially in "swarms of twenty or more," until they disperse, preparatory to pupation. While feeding exposed, they are probably not eaten by birds, as their colors and markings serve as "danger signals."

LIFE-HISTORY OF DATANA INTEGERRIMA G. AND R.

The following notes were written out from an examination of greatly enlarged drawings, made by Mr. Bridgham at Providence. The figure of the fourth stage agrees with Mr. Beutenmüller's description of the fourth stage of *Datana integerrima.* The food plant is the walnut. As is well known, these larvæ feed in large conspicuous clusters, being social through larval life.

First stage.—Length, when 24 hours old, 5 mm., July 24. In this larva the head is very large, entirely black and hairy, being nearly twice as wide as the end of the body. The body is brick-red, with a faint subdorsal and lateral yellowish stripe along the body, and a diffuse spiracular yellowish line. There is a distinct small, black prothoracic shield, transversely oblong, from which arise about twenty black hairs, slightly clavate, two or three of them as long as the segment is thick. A distinct, black suranal plate is present; it is entire and rather large, though not so wide as the tenth abdominal segment. The piliferous warts are minute, and the dorsal and lateral glandular hairs arising from them are more or less club-shaped, some of them markedly so, and not quite so long as the body is thick. The thoracic legs are black; the middle abdominal legs are concolorous with the body; the plantæ dusky; the anal legs are about half as thick as the others, and black at the end.

In another specimen of this stage, of the same length, which is just about exuviating (July 23), the body being very long and the head small in proportion to the body, the suranal plate is divided into two oval lanceolate black plates, the small ends pointing towards the head. Otherwise the body is marked as in the above described specimen, except that there are black spots at the base of the middle abdominal legs. The hairs are not represented as so clavate as in the other specimen. It is possible that the latter is in the second stage, but if so, the suranal plate would not probably be so large and entire.

Third stage. — Length, 7 mm. (probably not of the normal length, owing to confinement), July 30. About ready to moult, as the prothoracic segment is somewhat swollen. The black prothoracic plate still persists, and the hairs arising from it are about twice as long as those elsewhere, but the black suranal plate has disappeared; the anal legs are still slight, and the body beyond the sixth abdominal segment is upraised. The reddish color has deepened, and the yellowish lines are more distinct, while the spiracular line, enclosing the distinct black spiracles, is pale lilac; the middle abdominal legs do not appear to be spotted.

Fourth stage.—Length, 10 mm., August 13 (evidently under-fed and unnaturally small). The head is large, as wide as the body in front; the cervical shield still persists, as do the clavate hairs! The color has now changed to a dark reddish brown, above and beneath, with six longitudinal gray stripes seen from above, and four seen sidewise; the additional stripe is the infra-spiracular one, while the spiracular one has moved up, the spiracles being situated between them.

Fifth stage.—Length 28 mm. Aug. 29th. Very different from the fourth stage, the color being still darker, while only two grayish lines are seen from above, and two lines when the larva is seen from the side. The two dorsal and the supra-spiracular lines have disappeared. The body is now clothed with numerous soft fine gray hairs, many of which are nearly twice as long as the body. The anal legs are still smaller than in the preceding stage.

Recapitulation.—1. In this species the larvæ of the first four stages apparently have clavate glandular hairs, an unusually late persistence.

2. The body is reddish in the three first stages, but becomes dark in the fourth, while in *D. ministra* the body is reddish in the fourth, its larva being less precocious than in this species.

3. The loss of two of the longitudinal stripes in stage V is noteworthy, and the habits of the larva should be noted by the future observer to learn the probable cause of such a change; also why in *D. ministra*, and perhaps in other species, there is such a decided change in the general color and stripes in the last as compared with the penultimate stage.

4. The black suranal plate seems in stage I to be entire, and to divide in two at the end of the stage, not being present in the third stage. It is to be hoped that those who may hereafter rear the species of *Datana*, will preserve specimens of the earlier stages in alcohol for future study.

LIFE-HISTORY OF APATELODES TORREFACTA (ABB. AND SM.)

The following notes are based on the sketches and notes made for me by Mr. J. Bridgham, who kindly preserved for me in alcohol specimens of the two later stages, from which with the aid of his excellent drawings the following description of those two stages were drawn up. It appears that there are six larval stages.

The eggs were laid on the wild cherry June 22, and hatched July 9. They are much flattened, resembling a very shallow inverted plate, with sloping sides. The surface appears as if covered with overlapping rings, each enclosing a circle of five, six, and sometimes seven spines. Diameter $1\frac{1}{2}$ mm.

Larva, first stage.—Length 4 mm. Head and body pale greenish-white; head moderately large; body covered thickly with long white hairs, which arise in irregular and scattering tufts from four dorsal and three lateral tubercles; the hairs arising from the thoracic are rather longer than those from the abdominal segments.

Second stage.—Length 6 mm., July 16. Much as in the first stage, the hairs a little denser, and the head and body still whitish, with no dark spots.

Third stage.—Length 11 mm., July 25. Color of the head and body the same, but the woolly white hairs on the thoracic segments appear to be thick and matted. Now appears along the back of each abdominal segment a conspicuous black dash, and from the eighth abdominal segment arises a long slender tapering black pencil which projects backwards.

Fourth stage.—Length 20 mm., Aug. 3. The head is yellowish white, but the body slightly pale gray. From the second and third thoracic, and eighth abdominal segments arises a black pencil, each about the same length as the others, viz., about twice as long as the thickness of the body; the anterior pencil points forward, the two others backwards. The interrupted black dorsal stripe is as before.

Fifth stage.—Length 27 mm., Aug. 7. This and the last stage (described from alcoholic specimens as well as from Mr. Bridgham's colored drawings). Head normal, rounded, the sides and top somewhat swollen, the median suture somewhat depressed; of a peculiar white-flesh color. Prothoracic segment without a pencil or a lateral black patch; second thoracic segment with two contiguous rounded tubercles from which arise two long pencils whose hairs blend together to form a common median deep ochreous pencil inclined forwards becoming black at the distal third. Third thoracic segment with a similar pencil inclined backwards. A similar median pencil on the eighth abdominal segment. There is now a dorsal row of six long median black stripes on abdominal segments 2 to 7. Between these spots arise a pair of dorsal pencils composed of curious long spindle-shaped flexible black hairs, pale at the base, which taper from near the end to a sharp point. The pencils consist of three to four hairs arising from a pair of small warts one close to, but on each side of the median line, and situated just behind each dark dorsal dash. On the sides of each segment from the second thoracic to the ninth abdominal segment is a black patch, more or less oblong and jagged on the upper edge. The sutures between the segments are not black. The under side of the body is blackish. At the base of the abdominal legs is a black ring, and another near the planta, and a longitudinal black strip down the outside of the leg.

Sixth stage.—Length 35 mm., Aug. 11. The hairs concealing the body are now uniformly white (Harris referring to the living larva, says "of a beautiful white color"), having entirely changed their color. The dorsal black lines are now more connected; the three long pencils are pale at base, and black towards the tip. The lateral black spots send two points upwards, and the sutures are now black. The head is stained with black on the vertex, and along the sutures and around the mouth-parts. The thoracic and abdominal legs are black, but the plantæ of the abdominal feet are pale. Most of the hairs are dark on the distal half, but pale at the basal half, and from the black lateral spots arise from two to four spindle-shaped black hairs; also several others which stand out from the mass of dull gray hairs, arising from minute tubercles along the sides of the body. The legs are hirsute, and the body is black beneath.

Recapitulation.—1. No glandular hairs, and in stage I, the body is already covered with long woolly soft hairs.

2. In the third stage appear the dorsal black stripe, and a single black pencil on the eighth uromere (abdominal segment).

3. The two other black thoracic pencils appear in stage IV.

4. The hairs become yellow, and the pencils bicolored, while the lateral black spots appear in stage V.

5. The last stage (VI) is signalized by an entire change in color from ochre yellow to white.

Length of egg state sixteen to seventeen days; of first larval stage seven days; stage II, nine days; stage III, eight to nine days; stage IV, four days; stage V, four days; stage VI, nine days (Harris); prepupal stage three days (Harris); pupal stage?

Harris states that it does not spin a cocoon, but probably enters the earth.

Dr. Lintner[1] has described quite fully the larva of the other spe-

[1]Entomological Contributions, III, 130.

cies (*A. angelica* Grote) which feeds on the ash and syringa, transforming to the pupa state Sept. 14. His larva seems to differ in the "numerous fine black linings, among which may be traced two forming a vascular stripe, and two similar lateral stripes on each side." Lintner also speaks of "four dorsal white lines, posteriorly black" on the prothoracic segment, and also of "short stiff red hairs on the sides of the second and third thoracic segments, and indeed it is evident that the larvæ of the two species differ considerably in markings. Our larva, on the other hand, appears to be identical with that described by Harris (Correspondence, 307) under the name of *Astasia torrefacta?* Sm. and Abb., the two last stages of which he describes. He found it on the burdock, and says that it "eats leaves of willow well," and further on states that he found one "on a leaf of *Prunus virginiana*."

This conspicuous hairy caterpillar, which evidently feeds exposed on the leaves, seems to be somewhat omnivorous in its tastes and sometimes feeds on herbaceous plants, as the burdock. Hence it apparently belongs to the same category of hairy pencilled white-and-black-spotted and tufted caterpillars as those of Halesidota, those of the Liparidæ, and certain species of Noctuidæ, as *Charadra deridens*, etc. It is noteworthy as being in this respect exceptional among Notodontians.

PARTIAL LIFE-HISTORY OF PHEOSIA RIMOSA PACK.

The larvæ described below were observed at Brunswick, Me., Aug. 17, feeding on the aspen; the last stage was assumed Aug. 25. It will be particularly interesting to observe the first stage of this larva, and to see whether the horn is well developed.

Third stage.—Length 11 mm. Head very large and full, wider than the body; the vertex somewhat divided and produced into two very slightly marked lobes; the head is somewhat narrower above than below. The eighth abdominal segment is somewhat swollen, and bears a large blood-red horn, which is rather obtuse at tip. The suranal plate is much rounded, and smooth on the upper side. The anal legs are much smaller than the four other pairs, which are rather large. The thoracic legs are stout and brown in color. The lateral ridge is prominent and of a yellowish hue; beneath this ridge there is a lateral conspicuous brown stripe extending upon the legs. The spiracles are brown. The body is glaucous green, of the same hue as the under side of the aspen leaves, with yellowish sutures.

Fourth stage.—Length 15 mm. The larva is now reddish-brown all over the body, except the head, which is dull amber-green. The horn is retractile, and smooth, not stiff and rough as in many Smerinthi, for which it might be mistaken.

Mature larva.—Length 40 mm. Now all the characters of the larva are assumed. The body is of a peculiar pearly hue, with a porcelain-like polish, the head being of the same tint as the body. The head is smooth, not quite so wide as the prothoracic segment, which is much smaller than the somewhat swollen second thoracic segment. All the segments are slightly swollen in the middle. The eighth abdominal segment is swollen dorsally, and is surmounted by a high rather stiff well developed horn, which is not granulated, but somewhat annulated ; it is black, this tint extending as a black lateral line reaching below and behind the spiracle. The suranal plate is of peculiar shape, being long, crescentic, and bearing a small knob in front, the surface of the whole plate being coarsely granulated, rust-red, becoming greenish in front. The thoracic feet are deep amber-red. Of the abdominal feet the first four pairs are large and thick, conical, while the anal pair are very small, with a rust-red callous spot externally. On the under side of the abdominal segments is an irregular greenish median line.

This remarkable larva recalls those of the Sphingidæ, and I confess when I first saw it, I was uncertain whether to regard it as a Sphingid or not. The horn is slightly retractile, and thus being movable, must add to its efficiency as a terrifying appendage, while the black streak on the sides heightens the effect of the horn. The spiracles also are so large and conspicuous that it is possible that they may add to a visage not altogether prepossessing to those insects or birds which may desire to be too intimate with it. Many years ago, when a boy, I found this larva on the balm of Gilead poplar, and well remember the peculiar porcelain polish and lilac tints of the glaucous green skin, and the prominent horn. Mr. Lintner (Ent. Contr., iv, 76) has given an interesting account of this caterpillar which he found both on the aspen and the willow, and he also at first, as he says, mistook it for some Sphinx larva. He remarks that the pupa has "a rather long bifid anal spine." Dr. Lintner thinks that this species is identical with the European *dictœa*, and such was the opinion of Professor Zeller. I have no means at present of confirming or disproving this view, except to say that in the figures of the British larva of *dictœa* in Buckler's work published by the Ray Society (his fig. 1*b*, Pl. xxxv) the stripe is present on the eighth abdominal segment, while the large horn of our form is represented by only a hump. In one of Buckler's figures the hump of the green variety is almost obsolete, and the black line is wanting. In Buckler's figures of the allied *dictœoides* there is only a hump. Judging by the figures none of the British species seem identical with ours. In Duponchel and Guénée's Iconographie et Histoire Naturelle des Chenilles, t. II, the larva is very well figured, but there is no horn, not even a marked lateral black line, and the hump is not particularly well developed. (Compare Mr. Meske's remarks in the forthcoming fifth Report U. S. Entomological Commission, under poplar insects, where our larva is figured.) We have not seen other figures of the European caterpillar.

REMARKS ON THE LARVA OF NOTODONTA STRAGULA AND NERICE BIDENTATA.

A knowledge of the early stages of these forms, also of Lophodonta and of Nadata is much to be desired.

Mature larva of Notodonta stragula.—The head is rather square on the sides, narrowing above, and scarcely bilobed above; it is of the same general shape as in Schizura and Janassa. In this species instead of a single hump on the first abdominal segment, there is a large high soft movable hump on the second, and which nods backward, besides one a little stouter and shorter on the third. The humps are simple, with no traces of a fork, or of bristles, and they are both brownish, of the hue of a dead dry leaf. The very prominent hump on the eighth abdominal segment bears two slight low tubercles, but no bristles. The anal legs are long and slender, but the planta is well provided with crochets.

It is interesting to notice that in the European forms—and in Europe there are more species than in North America—there is a tendency among the species, which vary in the number of dorsal humps, to fill up the gap between the genus Notodonta and Nerice. In fact the latter genus exists in northeastern Asia,[1] and this fact adds another point of resemblance between the fauna of northeastern America and northeastern Asia.

In the European *N. ziczac* there are, judging by Buckler's figures, as in our species, but three humps; in *N. tritophus* there are four, while the larva of *N. dromedarius* most nearly approaches Nerice in

[1] *Nerice davidi* Oberthur, from the north of China.

having five humps; four on the four basal abdominal segments and one on the eighth.

Larva of Nerice bidentata.—This form, judging by the figure and description of Mr. C. L. Marlatt,[1] is an exaggeration of that of the European *N. dromedarius*, as each abdominal segment from the first to the ninth bears a large fleshy two-toothed hump, the three largest on segment 3 to 5. Thus the outline of the back is serrate, and perhaps mimics the serrate edge of the leaf of the elm on which it feeds. The body is greenish, with the upper half of the sides washed with white, with crimson spots and bands, the tip of the dorsal protuberances being also crimson.

Mr. Marlatt does not state whether the dorsal tubercles are movable, or whether the caterpillar is protected by mimicking the outlines or the colors of the leaf of its food plant. Further observations are needed on this point.

LIFE-HISTORY OF EDEMA ALBIFRONS (ABBOT AND SMITH).

For the description of the early stages of this caterpillar I have not full notes drawn up from living specimens, but have to depend on alcoholic examples of the different stages and the excellent colored sketches of Mr. Bridgham, so that this notice is in part provisional, as we have yet to see the eggs, although this is one of the commonest caterpillars on the oak.

First stage; larva just hatched.—Length 5–6 mm., Aug. 24. Just before the first moult the body is moderately thick and of a pale yellowish tint; the head is brown, not deep amber, as in the subsequent stages. The anal legs are decidedly smaller than the other abdominal legs and somewhat uplifted, or rather extended horizontally. They are slightly retractile and probably bear a few hooks. The large dorsal hump on the eighth abdominal segment, so characteristic of the genus Edema, is already well developed, so that the chief generic characters of the caterpillar appear at birth. The hairs are minute, short, sparse and very slightly thickened at the end, all of the same length and arising from minute, microscopic warts. The dark dorsal line is only faintly indicated; the lateral dark brown line well marked, most distinct on the prothoracic segment, interrupted at the sutures, and faded out on the eighth

[1] Trans. 20th and 21st Annual Meetings of the Kansas Academy of Science, 1887–88, xi, 1889, 110.

abdominal segment. The large hump on this last named segment is large and high, but scarcely differs in tint from the rest of the body, though slightly darker. On each side of the ninth segment is a large black comma-shaped spot, the point directed forward and downward, while behind them is a median black dot. There is a broad yellowish spiracular lateral band ; above it a pale dirty white band, edged above by the lateral, or rather subdorsal black line ; the under side of the body, including both the thoracic and abdominal legs is whitish. The anal legs bear about six hooks.

Second stage, after the first moult.—Length 6–8 mm. Aug. 27. The head is still very large in proportion to the body. The hump on the eighth abdominal segment is larger, more pronounced and orange-yellow, sometimes red ; the head is dull amber. The dorsal line is now distinct, and the subdorsal line is triplicated on the two anterior thoracic segments and duplicated on the eighth abdominal. Behind the dorsal hump there are two instead of one median black dots, one placed behind the other, and two black spots are added on the side of the body near the base of the anal legs, *i.e.*, two on the ninth and two on the tenth segments. On the pro- and mesothoracic segments are two parallel short, sinuous blackish-red lines. The spiracular band and under side of the body as in the previous stage, but deeper straw-yellow. The anal legs have a longitudinal reddish stripe on the outside or are reddish near the tip. The hairs are longer and slenderer than before, taper a little, but are docked at the tip, and arise from warts, those on the back arranged in a trapezoid.

Third stage, after the second moult.—Length 20 mm., Sept. 6. The general shape of the body of the mature larva, with its large smooth dorsal hump and peculiar shining banded skin are now assumed ; the specific characters having apparently now appeared, though we have none of the other species (*albicosta* and *packardii*) with which to compare it. The head is still large, wider than the body, which does not yet grow smaller towards the head as it does in the fully grown larva. The body is now richly and very conspicuously banded so that already in this stage the caterpillar becomes a very showy object. How it is regarded by birds and ichneumons remains to be observed. The narrow thread-like dorsal line and the lateral line are now enclosed in a broad dull whitish gray band bordered on each side by a faint dark line. There is a subdorsal straw-yellow broad band. The spiracular deep straw-yellow band is bordered below by a double blackish-red broken line. The dorsal hump is bright coral-red, so bright and conspicuous as to suggest that when the end of the body is suddenly moved at the presence of an ichneumon the movements of the bright red mass may frighten away the unwelcome visitor. The black spots and slashes on the ninth and tenth segments have increased in number. The two median reddish-black dots of the second stage have coalesced and formed a long stripe, flanked on each side by a shorter stripe, and an outer dot on the ninth segment. On each side of the ninth and tenth segments are two blackish spots.

Fourth stage, after the third moult.—Length 30 mm. The markings and colors are the same as in stage V, but the larva at this period only differs from the third stage in being longer in proportion; though with a greater number of black lines and spots as described under the fifth, or last stage.

Fifth and last stage.—Sept. 12. Length 40–50 mm. The body now increases in width from the prothoracic segment to the eighth abdominal, the head being much rounded, but a little wider than the prothoracic segment and more pitchy red. The arrangement of the markings is mainly as in the third and fourth stages, but the straw-yellow bands are now deep orange, often almost coral red. The number of blackish lines have increased; there are five instead of three dorsal lines, the outer line on each side being the heaviest and most continuous, and scarcely broken at the sutures. The black spots and slashes on the sides at the base of the abdominal legs are more distinct and numerous than before, as are the black spots on the eighth, ninth and tenth segments, behind the dorsal hump. On the hinder edge of the eighth segment are eleven black spots, varying in size and shape. On the ninth segment are three sublinear dorsal and two oblong black lateral spots, and on the tenth segment are three dorsal coarse black dots, and on each side a black dot and oblong black spot. The supra-anal plate is distinct, crescent-shaped and deep honey-yellow like the anal legs. There is a median ventral interrupted black line, also indicated in the third stage.

In this genus, then, we have functional anal legs, armed with hooks, the end of the body not being more or less permanently uplifted or extended horizontally. Instead of this deterrent, or terrifying feature, we have the showy coral-red hump and the bright black and red bands on a shining glistening skin (already indicated as early as the third stage) which may be danger signals to birds, to whom this caterpillar may be distasteful.

LIFE-HISTORY OF DASYLOPHIA ANGUINA (ABBOT AND SMITH), PL. III.

I received a few of the eggs of this moth from Miss Emily L. Morton of Newburg, N. Y. The young hatched July 25th, and were fed on locust leaves.

Egg.—Shape of a flattened spheroid, the upper pole somewhat concave, a little broader at the base than at the top. The shell is very thin and transparent, so that the larva with its yellowish head and red lines can be distinctly seen through it. The surface is covered with polygonal areas, which are not very distinct, though as much so on the upper pole as on the sides. The areas vary somewhat in shape, size, and distance apart, the interspaces being rather broad, and there are no beads like those on the surface of the eggs of Schizura. Diameter, 1 mm.

Larva of first stage, just after hatching.—July 25. Length 3–4 mm. The head is very large, nearly twice as wide as the body behind the middle, rounded, and with a fine narrow black stripe along the hinder edge; it is honey-yellow, with scattered black hairs. Body moderately slender, gradually diminishing in width to the end, the anal legs being long and slender, larger than in the young of Schizura. They are forked, long and slender, the terminal third evaginating, and nearly as large at the end as at the base, and held lifted up together with the two preceding segments, at an angle of about 45°. The claws are entirely absent, the tip being soft, retractile and extensile, and the leg itself being provided with 12–13 stiff dark acute setæ. They differ but slightly from those of the fully-fed caterpillar. The end of the leg is retracted by three slender retractor muscles, one being single, the two others united near their insertion into the retractile portion.

The other abdominal legs are provided with a semicircle of ten hooks each, the inner two hooks of one set being very short. All the legs, both thoracic and abdominal, are dull greenish. The body is deep pea-green, the surface shining. The first abdominal segment shining red, with two slender, papilliform, non-piliferous subdorsal deep red tubercles, situated in or just below the subdorsal lines. There are two similar but much smaller piliferous red warts on the eighth segment. Body behind the head with five red, or reddish-black lines; the single dorsal and the two subdorsal lines narrow, nearly continuous, scarcely broken. The lateral line is slightly interrupted like the others at the sutures. Below the spiracles is a much interrupted line of heavier dark red, somewhat curved or sinuous slashes, situated at the base of the legs, becoming less distinct behind the fourth pair of abdominal legs.

The hairs are stiff and black, mostly thick and clavate, and pale at the extreme tip. Those on the head are slightly knobbed. On the prothoracic segment is a chitinous plate or shield from which arise four of these hairs, of which two are about one-third longer than those of the meso- and metathoracic segment; they are about as long as the body is thick; those on the second, third and fourth abdominal segments are larger and longer, more distinctly clavate than those elsewhere; they are smooth, black, but clear and colorless at the extreme tip.

Second stage, after first moult.—Length, 6–7 mm., July 28th. The head is now more distinctly amber-colored and smaller in proportion than before. Body pale green, the dark brown stripes, especially the dorsal one, being more distinct; the dorsal line is continuous, the two lateral ones somewhat broken. The hairs are black, not so much club-shaped as before. The markings show little change from the first stage, but the reddish first abdominal segment has grown paler. The tubercles on the eighth abdominal segment have each lost their single hair.

Third stage, after second moult.—Aug. 5th. Length, 15 mm. The larva has now dropped the club-shaped setæ, or "glandular hairs," all the hairs being minute, tapering, and very short, while the lateral humps on the eighth abdominal segment are decidedly larger than before and marked with two parallel reddish-brown lines, so that in respect to these humps the characters of the fully-grown larva are nearly assumed, while the tubercles on the first abdominal segment are still slightly larger in proportion than in the mature larva.

The head is of moderate size, but little wider than the body, rounded and orange-reddish. The body is smooth and shining, straw-yellow, the line blackish; the dorsal black line ends on the smooth black knob on the eighth segment. The three lateral black lines are more or less interrupted, situated in a broad whitish band, the middle line being the faintest, which encloses on the first abdominal segment a jet-black tubercle. Low down is an infra-spiracular row of twelve black spots situated at the base of the legs, when present. There are four black spots on the front part of the suranal plate, while the double reddish-black slashes on the lateral humps of the eighth abdominal segment are more pronounced than in the earlier stages. The extensile, uplifted anal legs are black at the tips.

Fourth stage, after third moult.—Aug. 10–11. Length, 22–24 mm. In this stage the larva only differs from the preceding one in the deeper, more distinct colors of the body and its markings, while the body itself is larger and thicker. The black tubercles on the first abdominal segment are slightly smaller than before.

Fifth stage, fully-fed larva.—Length, 55 mm. Differs from the fourth stage in the rather thicker body, slightly shorter anal legs, and the smaller first abdominal black dorsal tubercles; while the black spots on the eighth abdominal segment are more pronounced. One found by Mr. Bridgham, Sept. 6, on the wild indigo.

Recapitulation.—1. The larva hatches with the generic characters already established: viz., with the long slender retractile anal legs, unprovided with hooks, and with the pair of hairless dorsal tubercles on the first abdominal segment.

2. The two dorsal tubercles on the eighth abdominal segment lose the hairs at the first moult and begin to assume the shape and coloration seen at the last stage.

3. The glandular hairs disappear with the second moult.

4. In the third stage the coloration and markings of the species begin to appear, the body changing from pea-green to straw-yellow, the skin smooth and shining, and the lines and spots blackish, while the reddish tint of the first abdominal segment, characteristic of the first stage, is discarded.

It is probable, though further field work is needed to prove it, that by the third stage the caterpillar is exposed to the same dangers and escapes them in the same way as the larva in its final stage. Observations as to the position of the larva while feeding on the locust or wild indigo leaf are needed in order to show how the reddish head, shining straw-yellow body and blackish stripes and markings assimulate it to its habitat; also whether ichneumons are repelled by the movements of the anal legs, and whether such motions of the end of the body are sufficient to drive away ichneumons and Tachinæ from its otherwise unprotected, smooth body.

These remarks will also apply, though less strongly, to the caterpillar of *Edema albifrons*, which has similar shape and coloration, though its anal legs are not retractile, nor so long and slender and hence not so well calculated to frighten away unwelcome insects.

Experiments should also be made to ascertain whether the two larvæ in question are distasteful or not to birds.

The earliest stages of Dasylophia are very different from those of Edema, the latter apparently lacking the clavate hairs and the tubercles of the former genus.

It may be here observed that although many insects, according to the recent views of Exner and Plateau, may not distinctly perceive the outlines of bodies, yet all insects doubtless see objects in motion. Hence any ichneumon or Tachina, or the carnivorous beetles or bugs, may be frightened away by the sight of a moving or nodding tubercle like those on many Notodontians, and still more by the movements of the filamental or even the slightly elongated legs of other forms, or by the upturned abdomens of Datana caterpillars.

LIFE-HISTORY OF ŒDEMASIA CONCINNA (ABBOT AND SMITH).

As is well known the caterpillars of this species are common and conspicuous, feeding in clusters in a very exposed manner on apple leaves. Harris (Treatise, 425) observed the eggs laid in clusters on the under side of a leaf and the habits of the larvæ, which "when first hatched eat only the substance of the under side of the leaf, leaving the skin of the upper side and all the veins untouched; but as they grow larger and stronger, they devour whole leaves from the point to the stalk, and go from leaf to leaf down the twigs and branches." When full-grown, Harris adds: "They rest close together on the twigs, when not eating, and sometimes entirely cover the small twigs and ends of the branches." We have observed this habit, which proves the almost entire immunity enjoyed by this caterpillar from the attacks of birds.

Second stage.—Length 6 mm. Head reddish-amber, not dark coral-red as in the mature larva; angular on the sides, with two thick, stout, rather large black tubercles on the vertex, bearing a hair; there are also five or six piliferous warts on each side of the head. Body with large piliferous warts, those on the prothoracic and first abdominal segments much larger (about three times) than the others, those on the prothoracic a little slenderer than those on the first, abdominal segment; those on the eighth segment broader at the base, and rather larger than those on the first abdominal segment; those on the mesothoracic slightly larger than those on the metathoracic; those on the second abdominal very slightly larger than those on abdominal segments 3 to 6, the latter slightly decreasing in size from before backwards, and all considerably smaller than those on the ninth and tenth abdominal segments. All the tubercles, except those on the head, bear slender hairs which are about one-third as long as the body is thick, and which are broad and flattened at the end, which is abruptly truncate. All the tubercles on the body are of the same color as the body, which is of a general mottled reddish hue, with no distinct traces of longitudinal bands, except along the base of the legs; the skin is minutely dotted with white specks and the small lateral black piliferous warts.

The only bright spots are the light straw-yellow bases of the dorsal tubercles on the second and third thoracic segments, besides a pair of latero-dorsal oblique bright yellow patches on the seventh abdominal segment and a small bright yellow spot on each side of the base of the tenth segment. All the legs, both thoracic and abdominal, are concolorous with the body. The anal legs are normal, but smaller than the others, with numerous hooks, and are held slightly uplifted.

Third stage.—Length 9 mm. The body is rather stouter than in the previous stage. The head is black, and all the tubercles on the head and body, together with the thoracic legs, and the scale on the outside of the end of the abdominal legs are now black. All the tubercles end in a hair, now acute and simple, while the tubercles themselves are higher and more pronounced than before. There are traces of a subdorsal and two lateral lines (these are effaced by the alcohol).

Fourth stage.—Length 13 mm. The head is still black, with the two large black tubercles present, though smaller in proportion than before. All the tubercles on the body are much as in the last stage in their relative size and shape; those of the third thoracic segments are of the same size and height, the pair on the first abdominal segment being longer and larger than the others, and those on the eighth abdominal segment have not increased proportionately in size, but are still nearly twice as large as those on the seventh segment. The body is still reddish, with (in the alcoholic specimen) traces of three or four reddish lines on each side, which are bordered more or less regularly with whitish.

Fifth and last stage.—Length 23–24 mm. Some notable changes have occurred in the coloration, while the shining black spines are much larger and more imposing than in the earlier stages ; all these changes adapting the caterpillar more completely to its exposed mode of life.

The head is now deep coral-red, smooth, with no traces of the tubercles characteristic of the previous stages, the vertex being smooth and simply bilobed. The two prothoracic dorsal spines instead of being larger than the other thoracic spines, as in Stage II, are much smaller, being only about one-fourth as long or as high as the mesothoracic pair ; the latter are a little thicker, but shorter than those on the third thoracic segment. Those on the first abdominal segment are very long, rather slender, and arise from a deep coral-red, soft swollen hump, whose soft red swollen sides descend so as to embrace the spiracle. The dorsal spines of the second abdominal segment are of the same size as those on the third thoracic segment, those of the following segments decreasing in size to those of the seventh segment, while those on the eighth are slightly larger than those on the tenth segment.

The suranal plate is rounded lozenge-shaped, with a row of four large piliferous warts extending across the middle, while around the hinder edge are four smaller ones. On each side of the black dorsal line are seven wavy black lines alternating with white ones, so that the caterpillar is very conspicuously banded and spotted. The small black tubercles on the side of the body all bear a single hair. The anal legs are normal, about a third smaller than the other abdominal legs, and with numerous hooks. The end of the body is often uplifted.

Until we know more of the exact structure and markings of the first stage, it would be premature to attempt to fully recapitulate the leading points in the ontogeny of this curious larva.

What we have taken to belong to the second stage of *concinna*, and whose exact coloration we failed to note when collected, shows that even probably when hatched from the egg the larva is provided with its full complement of spines, and even more, there being two on the head, which are lost in the last stage. Without specimens of the other species for comparison, we cannot properly interpret the nature of the singular ornamentation of this larva, so unlike that of any other Notodontian of the American or European fauna.

To recapitulate, it is to be noticed that:—

1. The head is deep dull amber in stage II, becoming black in stages III and IV, and deep coral-red in the last stage. The head

is angular or squarish in the early stages, bearing on the vertex a pair of tubercles which disappear at the final moult. Of what use these tubercles are in the early stages, and why if useful at that period of the insect's life they are not retained in the last stage, is difficult to understand, though the smooth, shining dark coral-red head may and doubtless does make the creature more conspicuous.

2. The glandular hairs in the second stage are as usual enlarged at the end, being flattened and suddenly truncated.

3. A swollen coral-red dorsal hump arises in the last stage on the first abdominal segment, bearing two very long black blunt spines, which can be moved by the larva so as to terrify its enemies.

4. The great dorsal spines along the entire body, and the large lateral ones, like elongated hob-nails, have in general grown larger from the second to the last stage, rendering the creature probably still more distasteful and repulsive to birds and less open to attack from parasitic insects.

5. It is worthy of notice that in this genus the dorsal tubercles and spines are separated widely, while in Schizura those of the first and eighth abdominal segments grow together and form a single more or less movable terrifying spine. Janassa is intermediate, the tubercles on the hump being in pairs.

6. On account of these unique characteristics and its system of conspicuous markings and noticeable appendages which all unite in giving warning to birds that it is inedible, and the entire absence of protective mimicry, this larva occupies an unique place in the Notodontian group. In Schizura we have a mixture of two properties; the larva is both disguised so as to resemble a part of a brown spotted green leaf, and has a movable detergent spine on the back. In Edema the larva is so gayly colored as to at once indicate to birds that it is distasteful, but there are no deterrent spines or bristles. It is obvious that experiments should be made by feeding Edema, Œdemasia and Dasylophia larvæ to birds in order to see if they would be rejected or not.

The young, at least after the first moult, are so spiny that it is difficult to say from what existing form this caterpillar may have descended.

LIFE-HISTORY OF SCHIZURA IPOMEÆ DOUBLEDAY (CŒLODASYS BIGUTTATUS PACK.) PLATE IV.

The eggs were kindly sent me by Miss Emily L. Morton, who obtained them at Newburg, N. Y., from a female *Schizura ipomeæ*

(*Cœlodasys biguttata* Pack.) of the normal form mated with a male of the variety *C. cinereofrons* Pack. Miss Morton informed me that a male of the normal *C. biguttata* was also attracted. The eggs were laid July 11 and hatched July 17; the first moult occurred July 19–24; the second on August 1–2; the third Aug. 6–7; the fourth August 16–18; the date of the last moult not noted, but about four or five days later.

Egg.—1 mm. in diameter. Perfectly hemispherical in shape, with the surface marked on the sides and near the base with minute polygonal areas which toward the top become gradually smaller, with minute beads at the angles; the top of the egg is smooth.

First stage; larva just hatched.—Length 2–3 mm. It shows an approach to the characters of the fully-fed larva in the uplifted small anal legs, and the tubercles on the segments, though those characteristic of the last stage are not specialized.

The head is enormous in proportion to the size and width of the body, being twice as wide as the thoracic segments; it is well rounded, rather short antero-posteriorly; full and rounded on the vertex, rounded not angulated above, and in color dark amber.

The prothoracic segment is wider than the succeeding ones, with two very large dorsal piliferous tubercles, situated far apart, while those on the meso- and metathoracic segments are minute and situated not so near together as those on the abdominal segments. The tubercles on the first, third, eighth and ninth abdominal segments are larger than those on the other segments. They are all darker than the body, and dull amber-brown in color.

The body in general is greenish-yellow, with a pale reddish band around the prothoracic segment, and around the first, third, and eighth abdominal segments. The hairs are in most cases about twice as long as the body is thick. On the head are a few scattered simple hairs pointed at the end. Those on the segments behind the head are in general clavate at the tip. Those of the two large prothoracic tubercles and of the larger warts on the eighth and ninth abdominal segments are nearly twice as long as most of the others, and are slightly bulbous at tip. Those on the meso- and metathoracic segments are about a fourth longer than most of those on the succeeding segment to the eighth abdominal.

The larva just before the first moult is nearly twice as large as when first hatched, but it can be easily distinguished by its hairs alone, from those in the second stage.

The thoracic legs are black, the abdominal, including the anal legs, dusky. Before moulting the larva doubles in length, finally being 6 mm. long.

Second stage, after the first moult.—Observed to moult July 19–24. Length 7–8 mm. The larva is very different from the preceding stage. The head, though smaller in proportion to the rest of the body, is still much wider than the body, ending on the vertex in two conical tubercles, much as in the adult; color of the head brown, with four rows of large round pale spots, three in each row; the sides of the head and occiput pale. Prothoracic segment with two large black-tipped conical tubercles, and two much larger ones on the first and eighth abdominal segments, those on the first being larger than those on the eighth segment, and several times larger than in the first stage; there is a smaller pair on the fifth abdominal segment. Anal legs long and slender, of much the same proportions as in the fully-fed larva. Color of the body greenish, but the prothoracic and first, third, fifth and eighth abdominal segments reddish. The piliferous tubercles on the sides of the body are not so large and prominent as in stage I.

The hairs are not quite so long as the body is thick and of more uniform length all over the body than in stage I, and decidedly different in shape from those of the first stage; they are shorter, thicker, and somewhat shovel-shaped, being broad and flat at the end, and slightly notched or toothed on the edge, the flattened portion being striated; those of the head are still simple. Those of the two prothoracic tubercles are twice as long as those on the meso- and metathoracic segments, the hairs on the latter two segments and on the abdominal being somewhat shorter than the body is thick; those of the two larger tubercles on the eighth and ninth segments are a little longer than those on the smaller tubercles at the end of the body. In nearly all the hairs the shaft is, under a one-half inch Tolles objective, seen to be finely spinulated.

Third stage, after the second moult.—Observed to moult August 1–2. Length 10–11 mm., finally becoming 13–14 mm. The head, tubercles and hairs (setæ) much as before, the head retaining the same style of markings. The colors of the body, however, have changed; there is an irregular double dorsal reddish-resin line on the thoracic segments. On abdominal segments 2 to 4 is a single line, and on the same segments the dorsal tubercles are yellowish-green, as are those on segments 6 and 7. The ground color of the body is yellowish-green, irregularly marbled on the sides with resinous red. The anal and other abdominal legs are tinted with reddish. There is a lateral reddish line along the sides of the thoracic segments; a double dorsal reddish line on the seven terminal abdominal segments extending out on the uplifted anal legs (not developed in stage II, though faintly indicated). Those observed August 4th, later on in this stage, had changed a little since moulting, have assumed more of the distinctive coloring of the fully fed larva; the yellowish-green parts, especially on the thoracic segments, are now of a bright pea-green, while the silvery-white V-shaped mark on the sixth to eighth abdominal segments, so characteristic of the genus Schizura, is now very distinct. (This mark is faintly indicated in the previous stage, by two broad slightly converging whitish-yellow dashes on the seventh segment, and a median pointed whitish dash in front, but in the present stage these dashes are strengthened, united, broader, and colored more distinctly.)

A noteworthy step taken at this stage is the final consolidation of the two dorsal tubercles of the first abdominal segment, which now becomes a forked single tubercle.

Fourth stage, after the third moult.—Observed Aug. 6. Length 15–16 mm. The characters of the full-fed larva are now almost wholly assumed. The head is high and narrow, the vertex bearing two tubercles. The forked tubercle on the first abdominal segment is now larger and higher than that on the eighth segment; all are reddish, tipped with black. The body is much thicker than before and marbled, except on the pale pea-green meso- and metathoracic portions, with reddish lines and spots, which are much more numerous than before. The hairs are now entirely changed in shape, being simple and pointed like those on the head.

Fifth stage, after the fourth moult.—Observed Aug. 16–18. Length 25–27 mm. and finally 35 mm. This stage does not differ essentially from the fourth, except that the horns are a little higher. The markings and colors of the mature larva seem to be acquired in this stage.

Sixth and last stage, after the fifth moult.—Length 35 mm. The essential or specific characters may be best brought out by comparison with the fully-grown larva of *S. unicornis*. *S. ipomeœ* is larger and the hairs are longer. The head is less angular above and not so strongly marbled with the irregular network of reddish lines and has four dark lines in two pairs extending from the vertex to the base of the mandibles. The arrangement of the four double red and yellow dorsal lines between the head and the horn on the first abdominal segment is the same in the two species, but the space they occupy is wider in *S. unicornis*, while the corresponding dorsal lines of the first behind the horn and the second and third segments are firmer, less wavy than in *S. unicornis*. The horn of the first abdominal segment is higher and slenderer, not so thick at the base as in *S. unicornis*, while those on the eighth abdominal segment are much higher and more prominent. The four pairs of dorsal oblique lines of *S. unicornis* are less distinct in *S. ipomeœ* and more wavy, while the V-shaped dorsal mark just behind them is less sharp and distinct with more red interlineations in *S. ipomeœ*.

The first stage of *S. unicornis* (Fig. 1) differs but slightly from that of *S. ipomeœ*.[1] The head and body are of the same propor-

FIG. 1. *Schizura unicornis* stage I. Bridgham *del.*

tions, the prothoracic tubercles of nearly the same size, but those on the back of the meso- and metathoracic segments are larger than in *S. unicornis*. The tubercles on the abdominal segments are of nearly the same proportions, but slightly larger.

The first, third and eighth abdominal segments are bright-red in *unicornis* as in *ipomeœ*, and the colors and markings in general scarcely different from those of *ipomeœ*. The anal legs are the same in size and position in the two species, but the tubercles are on the whole larger in *ipomeœ*.

The hairs are clavate in *unicornis* and of the same proportionate length as in *ipomeœ*.

It thus appears that no genuine specific differences exist between the freshly hatched larvæ of *S. ipomeœ* and *unicornis* and most

[1] The great apparent difference between the figures of stage I of *S. ipomeœ* and *S. unicornis*, is due to the difference in their preservation, the body of *S. unicornis* having been much contracted by the alcohol.

probably *leptinoides*, though the caterpillars are so different when fully fed. On the other hand, though we do not know the earliest stages of the other species of Schizura, yet from our knowledge of those of *Dasylophia anguina*, there seems little doubt that the generic characters are quite clearly indicated in the first stage; that is, it will always be easy to separate Schizura larvæ just after hatching from those of any other genus of Notodontians, while if specimens of *S. ipomeæ* and *unicornis* of the first stage were mixed together, it would be almost impossible to safely separate them according to the species; the incipient specific characters actually existing being too slight and indecisive.

PARTIAL LIFE-HISTORY OF SCHIZURA LEPTINOIDES (GROTE).

I am indebted to Professor Riley for an opportunity of examining four alcoholic specimens representing the three earliest stages of this species. I have compared them with the equivalent stages of alcoholic specimens of *S. ipomeæ*.

First stage.—Length 4 mm. The larva of this stage is very similar to that of *S. ipomeæ*, the shape of the head, of the tubercles, dorsal and lateral, and of the peculiar paddle-shaped glandular hairs being identical. I can only perceive a difference in the slightly smaller dorsal tubercles, especially those on the eighth and ninth abdominal segments. There are probably slight differences in color, but Professor Riley's specimens are faded out from long immersion in alcohol, so that it is impossible of course to say how the two larvæ differ in color until the two forms have been compared in the living state.

Second stage.—Length 7 mm. Of the same size as *S. ipomeæ* of the same stage. The tubercles do not differ in shape or in size. The specific differences (besides those of color, about which I cannot ascertain) are that the two vertical lobes of the head are more acute than in *S. ipomeæ*, while the surface seems to be less distinctly marked. Moreover, the paddle-shaped glandular setæ are decidedly shorter. By these marks alone, alcoholic specimens of the larvæ of the two species of the present stage can be easily separated.

Third stage.—Length 11 mm. The same differences obtain as in the preceding stages. The vertical lobes of the head are more acute in *S. leptinoides* than in *S. ipomeæ*, while the setæ, now less flattened at the end, are in shape like those of the third stage of

S. ipomeæ, but are decidedly shorter. The dorsal and other tubercles are just as in *S. ipomeæ*. It is probable that other specific distinctions are to be sought for in this style of coloration. Indeed, as may be seen in alcoholic specimens, the head of *S. leptinoides* is simply rough on the surface and uniformly resinous, while in *S. ipomeæ* of this stage the surface in front and on the sides are divided into whitish areas bounded by brown lines. The coloration in general is much alike in the two species. The dorsal band along the thoracic segments and the V-shaped whitish-yellow mark on the sixth and seventh segments are nearly as in the third stage of *S. ipomeæ*.

SUMMARY OF THE STEPS IN THE ASSUMPTION OF THE GENERIC OR ADAPTIVE, *i. e.*, PROTECTIVE CHARACTERS, OF THREE SPECIES OF SCHIZURA.

The supergeneric features of the partly elevated, uplifted anal legs, and the difference in the size of the tubercles appears at the time of hatching.

1. The head becomes marked much as in the adult in the second stage.

2. The tubercles begin to be differentiated in the second stage, when the prothoracic tubercles are much smaller than in the first.

3. The dorsal tubercles of the first abdominal segment, originally separate, become united at the base in the third, and form a single high-forked tubercle in the fourth stage.

4. The glandular hairs differ generically in the second stage from those in the first. The flattened glandular hairs are present in the first and second, and disappear in the fourth stage.

5. The V-shaped dorsal mark on the sixth and seventh abdominal segments appears at the end of the third stage and is due to the coalescence of three separate, whitish-yellow spots.

6. The pea-green color of the meso- and metathoracic segments appears at the end of the third stage.

It thus appears that the mimetic colorational features, being those which especially enable the larva to escape observation, appear shortly before the creature is half-grown, these changes occurring at the end of the third stage, while the movable terrifying tubercle of the first abdominal segment becomes developed at the same time.

When feeding on the edge of a leaf, the Schizuræ exactly imitate a portion of the fresh-green, serrated edge of a leaf including a sere, brown, withered spot, the angular, serrate outline of the back corresponding to the serrate outline of the edge of the leaf. And as the leaves only become spotted with withered dead portions by the end of summer, so the single-brooded caterpillars do not, in the northern states, develop so as to exhibit their protective coloration until late in the summer, *i. e.*, by the middle and last of August.

A feature of some significance is the large size of the prothoracic tubercles in the larva of the first stage of *S. ipomeœ*, which in successive stages becomes reduced to a size no greater than those of the other thoracic segments. Is this a case of inheritance and survival from such a larva as that of *Heterocampa guttivitta* (Walk.?)? In this caterpillar, when mature, the only tubercles on the body are the separate high twin bright-red warts on the prothoracic segment.

THE LIFE-HISTORY OF JANASSA LIGNICOLOR, WALK.

This caterpillar has been already well described in all its five stages by Mr. H. G. Dyar in "Entomologica Americana" (v, 91, May, 1889). The points of special interest, noticed by Mr. Dyar, are: (1) That only five eggs in the case observed were deposited on the same plant; (2) the larvæ feed singly and during stages I and II they "eat only the upper portion of the leaf, and their yellowish-brown color well simulates its withered appearance; (3) subsequently, they devour the entire leaf, with the exception of the largest veins and rest on its edge, where they might be mistaken for a curled and discolored portion."

Of the structural features and shape, as compared with the last stage of the first stage, Mr. Dyar gives no detailed account, except referring to a "hump on joint 5," *i. e.*, the first abdominal segment.

In the second stage the head is said to be "slightly notched on top." In stage III the important observation is made that "the markings of the mature larva now begin to be assumed." This is in accordance with what appears to be the rule in this group, *i. e.*, that when the larvæ reach stage III they feed more conspicuously, and then begin to arise the special protective shape and colors of the last stage and also the terrifying movable warts or spines, if present at all.

As regards the second stage of this larva, the following notes on some alcoholic specimens, kindly loaned me by Professor Riley and collected by Mr. Bruner in Nebraska, may be of interest.

Second stage.—Length 6–7 mm. Head large, deeply indented on the vertex, each lobe bearing near the end a piliferous wart. The two dorsal piliferous tubercles, on each thoracic segment, are nearly of the same size, but those of the prothoracic pair are considerably larger than the mesothoracic, and the latter are larger than the metathoracic pair. The tubercles on the first abdominal segments are a little larger than those on the prothoracic segment. Those on the eighth abdominal segment are as large at the base, but not so high as those on the first abdominal segment; and those on the ninth segment are quite large, being about two-thirds as large as those on the eighth abdominal segment. All the setæ arising from the dorsal and lateral tubercles are decidedly clavate at the end.

Compared with *Schizura ipomeæ* of the same stage and size, the head of Janassa is seen to be larger, and the lobes above more pointed. The shape and proportions of the thoracic and abdominal segments are nearly the same, but the paddle-shaped setæ are shorter, while the body, generally, is stouter. At this stage, the two larvæ appear to be scarcely generically distinct.

Last stage.—Mr. Dyar has quite fully described this stage, but there are some structural features to which we would call attention. The head is distinctly bilobed, with no warts, but a bristle on each side of the vertex. The markings of the head have been well described by Mr. Dyar. From the first abdominal segment arises a large, double tubercle, undoubtedly movable as in Schizura and serving to frighten away parasitic insects. From the hump arise two dark, smooth tubercles, which are directed forwards and give rise each to a bristle.

On the eighth abdominal segment, where the spiracles are nearly twice as large as the others on the abdomen, is a decided hump, bearing two small, piliferous warts. The anal legs and end of the body are much as in Schizura, being raised at times.

The larva closely approaches those of the species of Schizura, having essentially the same style of coloration and the same arrangement of terrifying humps and tubercles, but not the peculiar V-shaped dorsal marks of Schizura. The markings of the moths are quite different, and while the two genera are quite distinct, they are more closely allied than any other two genera of the group.

LIFE-HISTORY OF CECRITA (HETEROCAMPA) GUTTIVITTA (WALK.).

The eggs and earliest stage of this very interesting form have yet to be observed and described. My single example of the mature larva was compared with specimens with the above names in Professor Riley's collection, and agree with Doubleday's figures 3 and 4 and description in the *Entomologist*, Jan., 1841.

Third stage?—Length 15 mm. Beaten from a red maple in Maine, Aug. 15. The head is very large, considerably wider than the body, and seen sidewise, very large, with the vertex prolonged into two well marked lobes which rise high above the body; it is deep dull amber in color.

From the prothoracic segment two enormous dorsal, chitinous

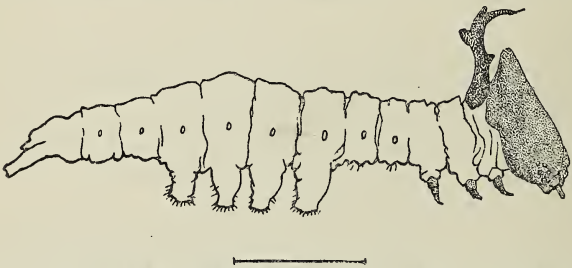


FIG. 2. Young larva of *Heterocampa guttivitta*, stage III? Bridgham *del.*

antlers, as long as the diameter of the sixth segment, arch over the top of the head; they each have three short branches, or tines: a sharp one in front near the middle, and two larger blunt ones behind on the distal half, the tip ending in a hair. The body is smooth, not tuberculated; the markings of the adult are but faintly indicated, and indeed any addition of tubercles or spines or markings would be quite useless and add nothing to the bizarre and forbidding appearance of this young caterpillar.

The ninth and tenth abdominal segments are elongated and distinctly indicated. The anal legs are very long and slender, the reversible ends being drawn in by two retractor muscles with about six to eight hooks, and about as long as the eighth segment is thick.

The last stage.—Length 30 mm. The head is still high, bilobed, narrowing towards the vertex, with two black lines in front extending from each side of the clypeus and ending on the vertex near the tubercles, and another behind, one on each side, extending posteriorly from the antennæ and mandibles half way up the back side of the head.

The antlers of the early stage are now replaced by two conical rounded polished knobs, each bearing a minute bristle, and from them on the inside two parallel lines extend backward.

The anal legs are shorter than in the early stage, being about as long as the well rounded supra-anal plate. Doubleday probably gives the characteristic attitude of this caterpillar when not walking, its legs being moderately elevated.

I add a fuller description of this larva when fully grown.

H. guttivitta; mature larva.—Head high, narrowing from below to the vertex, which is very slightly bilobed. Two black lines ascend from the antennæ and approach each other on the vertex, the space between the lines slightly roseate; outside the head is light uniform brown with a slight greenish and lilac tinge; the clypeus is small, while the median suture of the epicranium in front is very distinct. On the prothoracic segment behind the vertex are two contiguous, thick, conspicuous, large, conical, bright red tubercles, dark at the tip; there are no other humps, and none at the end of the body, which is thickest at and a little behind the middle, the body tapering gradually to the long anal legs which fork widely and are longer than the others, but are constantly used. Supra-anal plate unusually small. Color of a peculiar brownish-green dotted with black points and specks, with a white spot between the prothoracic tubercles. Body above finely marbled with dark brown, with a broken pale flesh-colored line; beginning on the mesothoracic segment, and on the first to third abdominal segments suddenly expanding into a large, broad, sub-lozenge-shaped spot, suddenly succeeded, over the segment bearing the first pair of abdominal legs, by a rounded spot. On the top of the fifth segment begins another dorsal patch of the same color which widens and extends down the sides of the third segment from the end. Along the middle of this patch are two parallel dark lines; and two broader dark lines of speckles begin on the fourth segment from the end of the body, converging and uniting on the second segment from the end forming on the last two segments a broad median dorsal line. Thoracic legs reddish; abdominal legs reddish flesh color. Anal legs slender, reddish. Length 35 mm. On the oak at Providence, Oct. 9.

To recapitulate:

1. The pair of prothoracic antlers of the early stage of this larva is certainly the most unique and unexpected feature to be found among Lepidopterous larvæ and the object evidently is to render the creature frightful to its assailants.

2. The rest of the body is without tubercles and markings, the latter of which appear in the later stages and are such as to completely adapt it to a maple leaf, late in summer or in the autumn when portions begin to wither and to turn brown. Hence the horns, if present, would then only serve to attract attention to it, and thus they are modified into much less prominent tubercles. It should be observed that in the larva of *H. astarte*, which has the same general colors and markings as *H. guttivitta*, and is thus protected, the prothoracic tubercles are absent.

How to account for the appearance of such enormous horns may be impossible even after we have become acquainted with the early stages of all the allied species, though it should be borne in mind that the young of *Citheronia regalis* and *Eacles imperialis*, as well as Anisota, have nearly as large spines when first hatched.

LIFE-HISTORY OF LOCHMÆUS MANTEO DOUBLEDAY (HETEROCAMPA SUBALBICANS GROTE).

From the inspection of the figure by Doubleday of the larva of *Lochmœus manteo* Doubleday, I feel sure that *Heterocampa subalbicans* Grote is a synonym. Indeed it has been referred with a doubt by Mr. Grote to his species. I am indebted to Professor Riley for an opportunity of examining and describing a series in alcohol of the larvæ in all the five stages (No. 2759 from box 12, 155) and have myself collected the caterpillar in its last two stages, while Professor Riley has given me a blown specimen, and the opportunity of examining his own series.

First stage.—Length 4–6 mm. The head is very large, nearly twice as wide as the body, and flattened in front, the outline seen from in front being somewhat six-sided. There are 6–7 minute piliferous warts, the black setæ arising from them being unusually large and stiff, and tapering at the end; around the base of the warts are brown discolorations, and the row of warts on each side of the median line, together with the outer row, are connected by an irregular, faint, brownish band.

The body narrows in width to the end. The dorsal and lateral tubercles are well developed, the dorsal ones being quite high, but on the whole rather small and all of the same shape ; those on the prothoracic and first abdominal segments are of about the same size, and only a little larger than those on the second and third segments ; the two dorsal ones on the eighth abdominal segment are of the same size as those on the first abdominal segment, but are nearer together and with somewhat larger bases. The ninth and tenth segments are rather long, with well developed tubercles. The supra-anal plate is well developed, being rounded, not so long as broad, bearing on the edge eight hairs, of which the two posterior ones are bristle-like and black ; near the middle of the plate are two black dorsal bristles. The paranal lobes are large and full, each bearing an excrementiferous bristle. The anal legs are long and slender, being as long as the ninth segment, and are slightly retractile. The four anterior pairs of abdominal legs bear on the planta from sixteen to eighteen crochets. The setæ arising from the dorsal and lateral tubercles are long and large, and though apparently tubular, taper, some to a point, while others are slightly docked, but they do not, as usual, end in a broad clear tip. But along the extreme lower side of the first and second and seventh and eighth abdominal segments, is a series of singular battledoor-like setæ, a pair to each of the segments named, and arising from the lowest tubercle on the side of the segment. These battledoor hairs, which are modified secretory setæ, are very short, only from one-third to one-half as long as the other setæ, and have a slender pedicel enlarging into an elongate bulbous expansion, the surface of which is striated or wrinkled longitudinally, while the tip appears under a half-inch objective to be clear. There is also a pair of remarkable foliaceous oval appendages at the end of the thoracic legs, which we have not seen in the few other larvæ whose feet we have specially examined. These are described and figured in our succeeding paper on the External Structure of Caterpillars.[1]

The colors being well preserved in the alcoholic specimens examined may be described, in the absence of the living. The head is amber mixed with resinous. The body is whitish above ; the tubercles and their bases pale straw-yellow, as are the anal region and anal legs ; the setæ are brownish and there are pinkish stains at the base of the prothoracic, and first and eighth abdominal dorsal tubercles. Hence it seems that in the first stage of this species the mode of coloration of the final stage (5) is already indicated.

[1] These Proceedings, XXV, 1890.

Second stage.—Length 10–11 mm. The head is now proportionately smaller than before, the dark spots more exaggerated, and the twin dorsal tubercles on the prothoracic and first and eighth abdominal segments, while not much larger than the others, are much darker, reddish-brown, with pink stains around their bases, and thus contrast with the others which are yellow. The two double dorsal pink lines, connecting the prothoracic and first abdominal tubercles, also the four short lines in front of and behind the tubercles, on the eighth segment, are now distinct, also the subdorsal, white lateral band on the outer side of the dorsal tubercles; while the subspiracular, narrow, pale-yellow line is distinct. The stigmata on the eighth abdominal segment is twice as large as the others. The hairs are very long, black and tapering. I cannot see any battledoor setæ in this stage. The anal legs are provided with crochets.

Third stage.—Length 12–15 mm. The characters of the final stage now appear. The head has changed its shape and style of markings to that of the last stage; it is flatter in front, with a lateral brown line edged with white, while the large, conspicuous, dark spots have disappeared, and the color of the head is dull opaque amber. The four red, parallel, dorsal lines on the second and third thoracic, and seventh and eighth abdominal segments are now distinct. All the dorsal tubercles, except those on the prothoracic, and first and eighth abdominal segments have much diminished in size, while the others have remained stationary.

Fourth stage.—Length 18 mm. The piliferous warts in general are smaller than in stage III, and those on the prothoracic and first and eighth abdominal segments are smaller than before. The eighth abdominal segment is slightly humped, and the anal legs are normal, though about one-half as thick as those in front. The body is green, with a broad subdorsal and two narrow lateral yellow lines as in the last stage, the lower being the infra-spiracular line. The sides of the three thoracic segments are dotted with reddish-pink, and there is a reddish streak on the outside of the anal legs. The subdorsal yellow lines diverge on the prothoracic segment, and along the next two segments succeeding are edged within with pink-red lines. Behind the two dorsal tubercles on the first abdominal segment they are much farther apart, extending to the supra-anal plate and are whitish-yellow, narrowly bordered with deep, straw-yellow and enclose a narrow, yellow dorsal line. (This line in the next stage extends to the prothoracic segment.)

Fifth and last stage.—Length 30–32 mm. It differs in the dorsal piliferous warts on the first thoracic and first and eighth abdominal segments being smaller than in the fourth stage, being now no larger than those on the other segments, and the hump on the eighth segment has almost disappeared. There is, as in the fourth stage, a conspicuous red dash on each side of the third abdominal segment, and the other lines are as described in the fourth stage.

RECAPITULATION.

1. Head large, with dark spots and connected lines in stages I and II.

2. The spots disappear, and the peculiar lateral dark line edged with white, characteristic of the final stage, appears in stage III.

3. The piliferous tubercles on first thoracic, and first and eighth abdominal segments attain their maximum in stage II; the tendency after this stage is to return to a simple, smooth body, without excessive ornamentation, or any decided change in coloration.

4. In stage III, all the other tubercles diminish in size.

5. The style of coloration of stage V is indicated in stage II.

6. In stage IV, the tubercles almost reach their minimum, becoming still smaller in the final stage.

7. The few tenant hairs present in the first stage are battledoor-shaped.

It is interesting to notice, in reviewing the life-history of this species, the strong tendency shown after the second stage to a diminution in size of the tubercles, so that by the fourth stage the body becomes smooth and free from all projections, humps and spines, and thus more noctuiform. At the same time the yellow and whitish stripes and pink blotches become indicated at an earlier stage than usual, as if the aim were to adapt the caterpillar to the ribs and parallel greenish and yellowish lines or shades of the leaf on which it feeds.

THE MATURE LARVA OF HETEROCAMPA PULVEREA G. & R.

From the examination of blown larvæ in Professor Riley's collection, I am enabled to make the following observations: it is congeneric with that of *H. subalbicans*. The anal legs of *H. pulverea* are like those of *H. subalbicans,* but the larva differs in being smoother, *i. e.*, having smaller dorsal tubercles. The head is produced towards the vertex and is narrower than in *H. subalbicans.*

There is a black line, with a wider purple band beyond, a yellow dorsal line and two lateral ones, the lines edged with purple dots, with which the body is elsewhere scattered (these lines are confused and diffuse in the largest, mature specimens). Along the back is a pair of deep red lines (sometimes nearly obsolete) much as in *H. subalbicans*, converging on the prothoracic segment, parallel and very near each other on the mesothoracic, thence very widely diverging on the second abdominal and approximating on the suture between the fourth and fifth abdominal segments. Length 35 mm. Before the final moult the front edge in the middle of the prothoracic segment is turned up and stained with yellow, with two red dots, the remains of the red line.

LIFE-HISTORY OF HETEROCAMPA UNICOLOR PACK.

Thanks to Professor Popenoe,[1] we now have an account of the transformations of this species, whose eggs are, as usual in this group, hemispherical and " laid in close groups of from fifteen to seventy-five, upon the under side of the leaf of the sycamore." It appears that the "newly hatched larvæ for a time feed in company upon the leaf-pulp," and in the first stage when disturbed fall or spring off and hang suspended by a silken thread. It is to be noticed that the larva "forms a loosely woven silken cocoon under or among the leaves and other rubbish upon the ground." There appears in the pupa to be no well-developed cremaster with curved setæ.

While the different stages are not specially described, only stages I, II and V being figured and briefly noticed, the following facts are apparent:

First stage.—Length 5 mm. Anal legs much longer than in the last stage, being as long as abdominal segments 7–10, or one-fourth as long as the body. From the prothoracic segment arise two very long, blunt tubercles, nearly as long as the body is thick.

Second stage.—Length 9 mm. The anal legs are still longer than before, but the prothoracic spines are much less than one-half shorter than before, while the back of the body is now reddish.

Last stage.—In a blown full-grown larva received from Professor Riley, the body is cylindrical, smooth, and the head is small and

[1] First Annual Report of the Kansas Experiment Station, for 1888, Rept. Dept. Hort. and Ent., p. 35. The illustrations were drawn by Mr. C. L. Marlatt.

rounded, with no traces of warts on the head, which is slightly bilobed. The prothoracic and first and eighth abdominal segments are normal, *with no piliferous tubercles*, not even on the segments specially named. The anal legs are long and slender, but no longer than the body is thick.

The body is green, of the hue of the leaf on which it feeds; along the back is a broad whitish-yellow band edged with reddish. There are no subdorsal or lateral lines or other marks.

RECAPITULATION.

1. In stages I and II, we have the high prothoracic tubercles like those of *H. marthesia* in its third stage (the earlier stages of this species being unknown).

2. There are no subdorsal or lateral lines in the last stage, and as in *marthesia*, the movements of the anal legs must serve to deter its enemies from attacking it, being otherwise protected by its color which is like the leaf on which it feeds.

It is evident that by their larval characters this species and *marthesia* are closely and generically allied.

LIFE-HISTORY OF HETEROCAMPA MARTHESIA CRAMER (L. TESSELLA PACK.).

The eggs and two earliest stages of this unusually interesting form have not yet been observed. The following notes are drawn up from alcoholic specimens in an excellent state of preservation; I think there is little doubt but that the earliest stage I have is the third.

Third stage.—Length of body 15, of the "tails" or stemapoda 6–7 mm. The head is regularly triangular seen from in front, the vertex being high, pointed and slightly bilobed. The body is long and slender. On the prothoracic segment are two high slender but very broad-based fleshy tubercles, which are probably movable, and about as large as the thoracic legs, or one-half as long as the body is thick seen from the side; they rise high over the body, being very prominent, and each ending in a stiff dark bristle. There are no other tubercles on the body. The segments are deeply wrinkled transversely over the back, as in the final stage. The head is provided with the lateral yellow stripe of the larva of the last stage, and the body has the distinct broad straw-yellow slightly interrupted dorsal band of the last stage.

The anal legs are very long and slender closely resembling those of Cerura, about four times as long as the body is thick; reddish beneath and at the tips, with a pale broad ring before the tip.

Fourth stage.—Length of body 22, of the "tails" 8–9 mm.; length just before moulting 28; of the "tails" 10 mm.

Larva much as in the third stage; the prothoracic tubercles as before, but slightly smaller in proportion to the body. The anal or filamental legs are as before, with the color and pale ring as in the stage III, the flagellum or everted portion nearly as long as the sheath, which is red at the end.

Fifth and last stage.—Length 40–42 mm.; furcula 4–5 mm. I have already briefly described the last stage of this caterpillar.[1]

A great change has occurred in the prothoracic tubercles which are now two low, flattened, inconspicuous warts on the upturned or flaring edge of the segment. The anal legs are much shorter in proportion and not so long as the body is thick, being about one-third as long in proportion as in the third and fourth stages.

This caterpillar we have observed when disturbed to send out from near the head a copious shower of spray, or vapor, being in this respect like that of Cerura, so carefully worked out by Mr. E. B. Poulton. The opening of the median prothoracic gland is exactly like what we have observed in *Cerura borealis.* It is a transverse slit situated in the median line of the body, between two transverse folds directly behind the head, but yet a little way behind the front edge of the segment. It has slightly developed lips.

The points of interest in the partial ontogeny known to us are:

1. The presence of filamental anal legs exactly homologous with those of Cerura, and nearly as long, and the fact that they are much longer in the early stages than in the final one; which seems to suggest strongly the view that this genus has directly descended from Cerura-like forms; and that the very long lashes were of more use to the ancestors of the present species than to the form we now have. It will be remembered that *H. marthesia* ranges as far south as Brazil, and that it may have originated in South America and spread northward; it is also possible that it had a set of enemies, probably ichneumons, which it has not had to contend with in temperate North America, and that the filaments have begun to diminish in size from partial disuse. On the other hand, the

[1] American Naturalist, Oct., 1884, 1044.

spraying apparatus lodged in the first segment next to the head seems to function in undiminished vigor. Experiments like those made by Mr. Poulton, on the fluid secreted by Cerura, should be conducted with the present insect.

2. The second point is the complete reduction in size of the two high prothoracic spine-like tubercles, which takes place at the last exuviation.

3. The head compared with that of Cerura is not retractile, the prothoracic segment being of the normal size.

From what we now know of the larvæ of the genus Heterocampa of Grote's catalogue, the species whose larvæ are known may be grouped into the following order, though it may be found when we know more of the first three species, that *guttivitta* should be assigned to a separate genus (Cecrita of Walker).

Group I. { *astarte.* *obliqua.* *trouvelotii.* *guttivitta.*

II. { *manteo.* *pulverea.*

III. { *unicolor.* *marthesia.*

Whether these divisions correspond to generic groups remains to be seen after further examination of the imaginal characters.

LIFE-HISTORY OF CERURA BOREALIS BOISD.

The following account of the ontogeny of this species (identified from Professor French's description) has been drawn up in part from alcoholic specimens and in part from greatly enlarged and most carefully executed drawings by Mr. J. Bridgham. The different stages occurred at Providence on the wild cherry in September. Hellins states that the eggs of *C. vinula* are 1.6 to almost 2 mm. in diameter, and that the larva at its first moult is not more than 7 mm. long. Possibly the first stage was not observed by Mr. Bridgham, and the following description should apply to the second.

First stage.—Length in all 15 mm. Sept. 4. Head only as wide as the body behind the middle. The filamental anal legs, or stemapods,[1] as we may designate them, are now more than slightly half as long as the body. The horn-like tubercles on the prothoracic segment are slightly longer than in the second stage. The head and body are dark reddish brown above, the filamental anal legs with two broad pale, greenish rings. All the other abdominal legs are green; the green patch extends from the under side of the first abdominal segment back over the third to eighth pair of spiracles, and underneath to the end of the body.

Second stage.—Length of body 14, of stemapods, 7–8, and of flagella 3 mm. Sept. 11. The head is rough and warty, the small warts bearing fine hairs. On the front towards the vertex are four papilliform piliferous warts of the same size and shape as those on the prothoracic projections, and concolorous with the dark brown head. These spines are represented in the other species (*C. occidentalis*) from the willow, only by very minute warts, bearing long tapering bristles. The prothoracic segment is very wide and large; the well defined cervical shield very broad, and ending on each side in a large stout tuberculated horn, bearing about twelve piliferous papilliform tubercles, there being a rude whorl of spines in the middle of the horn, the others growing out at the end. There are four coarse piliferous warts on the hinder edge of the cervical shield.

Along the body are scattered coarse piliferous warts, the dorsal four being arranged in a trapezoid. The stemapods are coarsely spined (more so than in *C. occidentalis*).

A peculiarity of the genus is the pair of very long papilliform paranal tubercles, situated under the supra-anal plate, and ending in two long, stiff, sharp bristles.[2] The supra-anal plate is long

[1] The term "tails" or caudal filaments is too vague for these highly modified anal legs; hence we propose the term *stemapoda* or stemapods, for those of Cerura and Heterocampa. The derivation is Gr. στημα, filament, πούς, ποδός, leg or foot. Mr. J. Hellins referring to these organs in Buckler's "Larvæ of the British Butterflies and Moths" (Roy. Soc., II, 138) remarks "but now through Dr. T. A. Chapman's good teaching, I regard them as dorsal appendages, somewhat after the fashion of the anal spines of the larvæ of the Satyridæ." This I am satisfied is an error. After repeated comparisons of the filamental anal legs of Cerura with those of *Heterocampa marthesia*, and comparing these with the greatly elongated anal legs of young *H. unicolor* as figured by Popenoe, and taking into account the structures and homologies of the supra-anal and paranal flaps, one can scarcely doubt that those of Cerura are modified anal legs.

[2] The use of these I find explained by Mr. Hellins in his description of the larva of *C. bifida* in Buckler's Larvæ of British Butterflies and Moths, II, p. 142, as follows: "At the tip of the anal flap are two sharp points, and another pair underneath, which are used to throw the pellets of frass to a distance." Similar dung-forks are very generally present in geometrid larvæ; the paranal papilliform tubercles being well developed, though we have not seen them in use.

and narrow, well rounded, and the surface is provided with high papilliform piliferous warts.

In this species the head and the prothoracic horns *above and beneath* are reddish-brown, the latter in *C. occidentalis* being yellowish beneath, the two species by this mark being easily separated.

The body is now more green on the sides, the green hue encroaching on the back and nearly meeting on the third thoracic segment. Only the fourth abdominal segment is wholly dark seen from above, and the green approximates high up on the sides of the sixth and seventh segments.

Third stage.—Sept. 17. Length of body 19 and of stemapods 12 mm. The body is now much thicker than before. The head is now smooth, with no traces of piliferous warts or of hairs representing them. The head is now larger in proportion to the body, and paler red, spotted with still paler patches. The prothoracic segment is still large and broad, but the lateral projections are much shorter, and now the tubercles of the preceding stages are represented by sunken pits from the bottom of which arise small hairs. The hairs on the body are minute, only being visible with a lens. The supra-anal plate is smooth, the papilliform tubercles much thicker and shorter in proportion than before, and the bristles arising from them slenderer and more flexible. The spinules on the stemapods are much slenderer and smaller than before, but it is to be noticed that by this time, they are *larger on the under side*, *i. e.*, that side now almost constantly held up and thus more exposed to external stimuli, than those on the upper sides of the filaments.

The colors of the body are nearly the same as in stage II, but the brown is tinged with lilac and reddish, with greenish patches on the upper side of the second to fifth abdominal segments.

Fourth stage.—Sept. 16. Length of body 26, of stemapods 15–16 mm. The larva is still much paler in hue than before, with more decided lilac blotches on the back. The thoracic dorsal hump is now very marked, while the lateral projections of the prothoracic segment have nearly disappeared. The front edge of this segment is vermilion red.

PARTIAL HISTORY OF CERURA OCCIDENTALIS LINTNER.

This incomplete history is introduced in order to supplement the foregoing notes. The specimens occurred on the willow in Maine.

Second stage.—Length of body 11; of stemapods 8 mm. It differs from the foregoing species of the same stage in wanting the frontal tubercles of the head, which is paler, and in the longer and slenderer prothoracic horns, the latter having smaller spines; it is also yellow beneath. The spines on the stemapods are finer. There is more yellow on the sides of the body, the yellow extending along the sides of the stemapods.

Third stage.—Length of body 15; of stemapods, 4 mm. It differs from the third stage of *Cerura borealis* in the longer cervical shield and the shorter horns, so that the shield is more normal in shape, being as usual in many caterpillars. The piliferous warts over the body are a little larger, while the dorsal reddish saddle-like spots are more definitely lined with deep red.

LIFE-HISTORY OF CERURA CINEREA WALK.

Although Messrs. H. Edwards and S. L. Elliot (Papilio, III, 130) have well described the larva of this species, which lives on the willow, I have been able to compare some very well preserved alcoholic specimens of the mature and young caterpillars (kindly loaned by Professor Riley) with similar stages of the two foregoing species.

Second stage.—Length without the filamental legs, 12 mm.; of the latter, 7 mm. It is at once distinguished from the larvæ of *C. occidentalis* and *C. borealis* of the same size by the larger bristles, the warts bearing them being scarcely larger, but the bristles themselves being two or three times as large. The head is as usual in the genus, as are the two lateral prothoracic "horns," and the cervical shield from which they arise. The "horns" are as in *C. occidentalis*, being spined in the same manner, and pale yellowish beneath. A large reddish triangular dorsal patch extends backwards from the horns, the apex resting on the second thoracic segment. The back is discolored from the third thoracic segment to the end of the supra-anal plate, not so decidedly reddish as in my specimens of the two other species previously described.

Mature larva.—Length, without the "tails," 38 mm.; of the filamental legs, 15 mm. The head is small, being one-half as wide as the body, reddish, but darker on the sides.

The prothoracic horns in this stage are reduced to smooth projecting tubercles of the usual size which are blackish above and pale below. Body pale green. From the horns a lilac-red, nearly equilaterally triangular spot edged with yellow, extends backwards its apex resting on the hinder edge of the second thoracic segment. An oval lilac-red spot edged with yellow on the hind edge of the third thoracic segment separated by the suture from a similar spot on the first abdominal segment, but which is three or four times as large. A transversely sub-elliptical similar spot on the second abdominal segment twice as large as the one in front, succeeded by a much wider one on abdominal segments 3 and 4 ; that on the fifth segment is of the same size as that on the second. On the sixth abdominal segment is a transversely oblong spot. (These spots were all connected in Edwards' and Elliot's specimens.) Along the back of segments 7 to 10 is an elongated dumb-bell-shaped spot, the contraction in the middle of the spot occurring on the back of the eighth segment ; the spot terminates on the end of the suranal plate, which is squarely docked at the end.

The stemapods, or anal filamental legs, are reddish at the base above and beneath, with two pale rings beyond the middle ; the flagellum being reddish-lilac. There is a lilac-red spot at the base of the thoracic and abdominal legs, one near the origin of each leg, and one on the sides of abdominal segments 7–9 ; besides these reddish lilac dots are elsewhere scattered over the sides of the body. The paranal lobes and the excrementiferous bristles are well developed.

This species differs from *C. borealis* and *occidentalis* in the less connected and narrower dorsal lilac-red patches, and in the end of the suranal plate being squarer, that of *C. occidentalis* being somewhat rounded behind. It is more nearly allied to *C. occidentalis* than to *C. borealis.*

Pupa.—In the absence of those of the other species for comparison it can only be observed that the end of the body is perfectly rounded and obtuse, with no trace of a cremaster. It is evident that in this genus, owing to the fact that the pupa is enclosed in a dense perfect cocoon, with no chance of its falling out, the cremaster by disuse has completely disappeared : and it is not improbable that the abolition may have occurred with comparative suddenness.

RECAPITULATION OF THE MORE STRIKING FEATURES IN THE ONTOGENY AND STRUCTURE OF CERURÆ.

1. The larva hatches with fully developed stemapoda (filamental legs), indicating that the genus, so peculiar in this respect, has descended with little modification from some preëxistent type, and not directly from a Platypteryx-like form.

2. On the other hand the prothoracic "horns" are larger in the earliest than in the latest stages.

3. The head is smaller in proportion to the body than usual, owing to the great width of the prothoracic segment.

4. The body is all brown above in the first stage, beginning to turn green in the second, and in the third becoming nearly as in the last stage. Thus the colors are more diversified, with more green in the fourth and fifth stages, rendering the now more exposed larva more adapted for protection by the resemblance of its markings to the yellow and red spots on the green leaves of its food plant, which appear early in autumn.

5. The dorsal hump on the third thoracic segment does not seem to appear until the last stage.

6. The filamental legs retain their shape from the first to the last stage, but if anything are a little shorter in the last. On the other hand the spinules in the third stage become larger on the under side than before, the filaments being held curved up more than before, so that the offensive spines on the under side in response to external stimuli have developed more rapidly than those on the upper side.

7. Novel structures are the very long and well developed supra-anal plate, and the pair of coproliferous spines (or dung-forks) arising from the paranal lobes, and available for tossing away the pellets of excrement. These seem to be peculiar to the genus.

GROUPING OF NOTODONTIAN LARVÆ ACCORDING TO THEIR AFFINITIES AND ALSO THEIR ADAPTATION TO ARBOREAL LIFE.

As is well known the larvæ of this family vary greatly in form and ornamentation for a group of such moderate numbers; and the following synopsis has been prepared in order to show this great variety in as graphic a manner as possible.

1. Body smooth, moderately hairy. *Ichthyura*, *Datana*.

2. Very hairy, the body almost totally concealed. *Apatelodes*.

3. Body smooth, hairless, with red and yellow spots. *Gluphisia*, *Seirodonta*.

4. Body smooth, hairless; with no humps or tubercles, of a noctuid shape; anal legs never elevated; color green, with yellow lines, the latter sometimes edged with reddish; feeding less conspicuously than any others of the family. *Nadata*, *Lophodonta*.

5. Body smooth, polished; a single hump, surmounted by a horn on the eighth abdominal segment. *Pheosia*.

6. Back 2–8-humped, serrate, body smooth, not brightly striped. *Notodonta*, *Nerice*.

7. Body smooth, gayly striped, eighth abdominal segment gibbous. *Edema*, *Dasylophia*.

8. Body with stout spines and with spiny tubercles on first and eighth abdominal segments. *Œdemasia*.

9. Body smooth, with nutant tubercles on first and eighth abdominal segments ; end of body uplifted. Colors green with brown patches simulating dead blotches on leaves. *Hyparpax*, *Schizura*, and *Janassa*.

10. Body smooth, tapering ; anal legs normal, with two prothoracic tubercles, enormous in early stages. *Cecrita guttivitta*.

11. Body smooth, striped ; anal legs normal. *Lochmœus manteo*.

12. Body with two dorsal prothoracic tubercles ; anal legs filamental ; each ending in an eversible flagellum. *Heterocampa marthesia*.

13. Body with two lateral prothoracic tubercles ; anal legs filamental, each ending in an eversible flagellum. *Cerura*.

14. Body doubly humped on the abdominal segments ; filamental anal legs. The Old World genus *Stauropus*.

So far as I have gone in the examination of the structure of the moths, this succession of genera roughly corresponds with the usual classification of the family. Judging by the moths alone, Ichthyura with Datana stands at one end of the series and Cerura at the other.

Perhaps Cerura has generally been placed at the end of the group because of its fancied resemblance to the larva of Drepana, but this is deceptive, because the long caudal filament of the latter genus is simply a hypertrophy of the suranal plate, and the anal legs themselves are atrophied, while in Cerura they are enormously hypertrophied, probably owing to their active use as deterrent appendages.

SUMMARY.

One would suppose that the two genera Nadata and Lophodonta, with the Old World genera Pterostoma, Ptilophora, Drymonia, Microdonta, and Lophopteryx[1] (of the two species *L. cucullina*

[1]The first larval stages of the following genera are still unknown and the author would be much indebted for eggs or alcoholic specimens of the larvæ of the first and later stages :—Ellida, Nadata, Lophodonta, Gluphisia, Hyparpax, Pheosia, Notodonta, Œdemasia, Nerice, Janassa, Lochmæus, and Heterocampa.

which is humped on the eighth abdominal segment, connects with the plain-bodied *L. carmelita* and the above mentioned group, Pheosia, Leiocampa) should properly by their smooth, noctuiform shape stand at the bottom of the family, as being nearest related to the primitive form of the group. But until we know more of the earliest stages, it is best to suspend our judgment.

1. The more prominent tubercles, and spines or bristles arising from them, are hypertrophied piliferous warts, the warts with the seta or hair which they bear being common to all caterpillars.

2. The hypertrophy or enlargement was probably primarily due to a change of station from herbs to trees, involving better air, a more equable temperature, perhaps a different and better food.

3. The enlarged and specialized tubercles developed more rapidly on certain segments than others, especially the more prominent segments, because the nutritive fluids would tend to more freely supply parts most exposed to external stimuli.

4. The stimuli were in great part due to the visits of insects and birds, resulting in a mimicry of the spines and projections on the trees; the colors (lines and spots) were due to light or shade; with the general result of protective mimicry, or adaptation to tree-life.

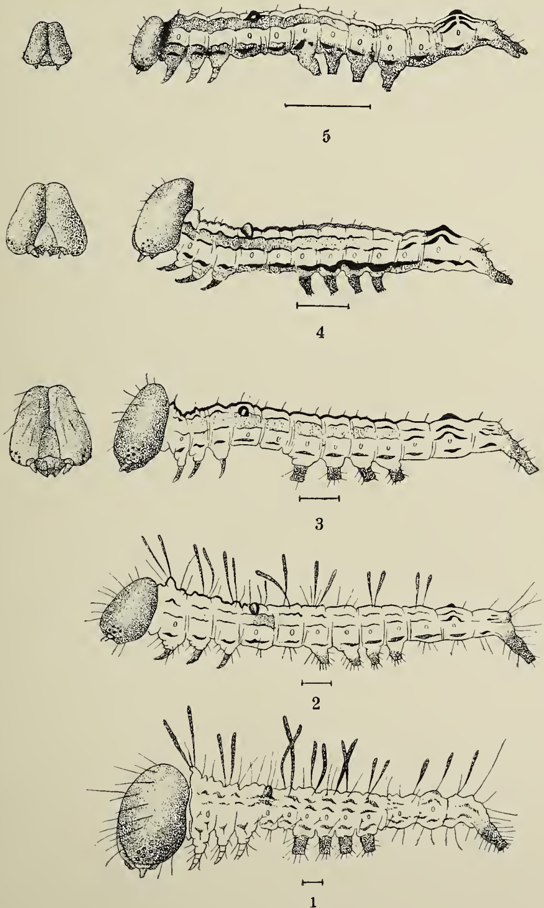
5. As the result of some unknown factor some of the hypodermic cells at the base of the spines became in certain forms specialized so as to secrete a poisonous fluid.

6. After such primitive forms, members of different families, had become established on trees, a process of arboreal segregation or isolation would set in, and intercrossing with low-feeders would cease.

7. Heredity, or the unknown factors of which heredity is the result, would go on uninterruptedly; the result being a succession of generations perfectly adapted to arboreal life.

8. Finally the conservative agency of natural selection would operate, constantly tending towards the preservation of the new varieties, species and genera, and would not cease to act, in a given direction, so long as the environment remained the same.

9. Thus in order to account for the origin of a species, genus, family, order, or even a class, the first steps, causing the origination of variations, were in the beginning due to the primary (direct and indirect) factors of evolution (Neolamarckism), and the final stages were due to the secondary factors, segregation and natural selection (Darwinism).



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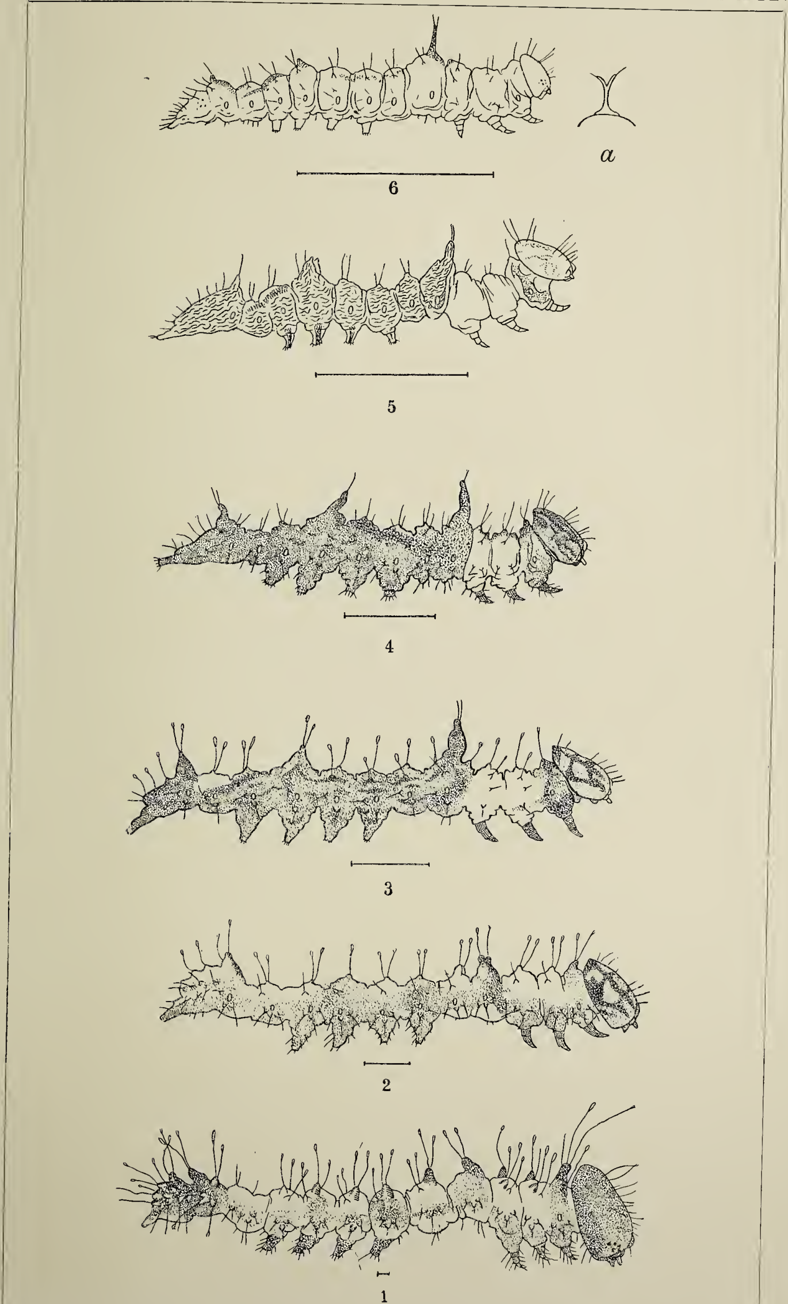
The larval stages of Dasylophia arguina.



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The larval stages of Schizura ipomeæ.

EXPLANATION OF PLATE III.

Larva of *Dasylophia anguina* Abb. and Smith; its five stages. Drawn by Mr. Joseph Bridgham.

PLATE IV.

Larva of *Schizura ipomeæ* Doubleday; its six stages. Drawn by Mr. Joseph Bridgham.

General Meeting, February 19, 1890.

The President, Prof. F. W. Putnam, in the chair.

Mr. Samuel Garman read a paper on "Some Recent Discoveries in Caves."

Prof. W. O. Crosby described a "Large Granite Bowlder from Madison, New Hampshire."

General Meeting, March 5, 1890.

The Curator, Prof. A. Hyatt, in the chair.

Prof. W. O. Crosby made a communication on a "Peculiar Case of Decomposed Granite from Blandford, Mass."

Dr. J. Walter Fewkes read a paper "On Some New Marine Animals from the Coast of California."

Mr. S. H. Scudder called attention to observations which he had made on the peculiar position assumed by a butterfly in its hibernation.

General Meeting, March 19, 1890.

The President, Prof. F. W. Putnam, in the chair.

Dr. H. V. Wilson read a paper "On the Formation of the Alimentary Canal and the Lateral Line in Teleosts."

Photographs of the spinning work of spiders were exhibited by

Mr. Horace P. Chandler, and remarks on the same were made by Mr. J. H. Emerton. Mr. Emerton also showed models of the spinning work of some of the common spiders.

Mr. Chandler showed photographs of a large bowlder which is found near Halifax, Nova Scotia.

General Meeting, April 2, 1890.

The President, Prof. F. W. Putnam, in the chair.

The Society first took up the special business of the evening, the consideration of the following recommendation of the Council:

At the last meeting of the Council, it was voted to recommend to the Society, at its meeting of April 2, the following resolution:—

" *Voted*, That in pursuance of the policy recorded in the vote of March 28, 1888, and adhering to the conditions therein required, the Society authorizes the Council, as soon as one-third of the final sum required for the establishment of its Natural History Garden and Aquaria has been raised, to proceed with the establishment of the Aquarium at City Point, in accordance with the plans laid down in the letter to the Park Commissioners of Dec. 31, 1889."

Mr. S. H. Scudder moved that the above recommendation and vote be approved by the Society. The motion was seconded by Professor Hyatt and unanimously carried.

The following paper was then read:

PHYSIOGNOMY OF THE AMERICAN TERTIARY HEMIPTERA.

BY SAMUEL H. SCUDDER.

When, in 1853, Heer had completed his classical work on the tertiary insects of Europe by the elaboration of the Hemiptera of Oeningen, Radoboj and Aix, he published in advance a summary statement of the nature of this tertiary hemipterous fauna and its relation to the existing faunas of Europe. Having just completed a similar study of the hitherto unknown tertiary hemipterous fauna of North America, comprising a number of species exactly double that of the European fossils then known to Heer, it is perhaps worth while to offer some observations on the nature of this fauna and of its broad relations, on the one hand to the existing hemipterous fauna of America and, on the other, to the tertiary fauna of Europe, which in the nearly forty years since Heer wrote has been more than doubled. It is the more desirable, as it is the first opportunity that has occurred of making a comparison in any order of hexapod insects in which the numbers in the strata of each continent are to be counted by hundreds.

The whole number of species, indeed, does not greatly differ in the two countries, but it should always be kept in mind that there are two independent sources of supply in Europe, one the rock strata proper, the other the amber deposits of the Baltic and of Sicily, which latter America does not possess, or rather does not yet divulge. In Europe, twenty-eight per cent of the total tertiary fauna is made up from amber inclusions, and the total is thereby raised as much above the number of American forms as it would be below it, were they to be excluded. The following table, in which also the relative number of species of each of the two great suborders appears, will make this evident.

TABLE I. TABLE OF KNOWN FOSSIL HEMIPTERA.

NUMBER OF SPECIES OF HEMIPTERA.	AMERICAN.	EUROPEAN.		
	IN STRATA.	IN ALL.	IN STRATA.	IN AMBER.
Homoptera.	112	102	56	46
Heteroptera.	154	201	162	39
Totals.	266	303	218	85

I presume it cannot be far wrong to state that the homopterous fauna of any given region of considerable extent in the north temperate zone is to the heteropterous fauna as about one to three; or, in other words, that about twenty-five per cent of the hemipterous fauna is homopterous. These figures are the result of the comparisons of several faunal lists. In Mr. Uhler's "List of the Hemiptera of the United States west of the Mississippi" (the geographical area of our tertiary fossils), the Homoptera hold a still more insignificant place, forming scarcely more than thirteen per cent of the whole. In tropical countries a very different proportion obtains, the Homoptera holding or nearly holding their own beside the Heteroptera, and subtropical countries or those which feel the direct influence of their proximity show an intermediate position. Thus, in Berg's "Enumeration of the Argentine Hemiptera," the proportion of the Homoptera to the whole is almost exactly thirty per cent. Now, it is precisely this proportion, 40 : 93, or thirty per cent, which Heer found the fossil Homoptera to hold in his first essay on the fossil Hemiptera of Oeningen and Radoboj; and a careful enumeration of the fossil Hemiptera of Europe to-day gives the Homoptera thirty-four per cent of the whole fauna; or, if those from the amber (which greatly heighten the proportion of Homoptera) be excluded, and we reckon those of the rocks only, the Homoptera have twenty-seven per cent. On the other hand, if we take only the fauna of the oligocene of Europe, including the amber, the proportion of the Homoptera amounts to forty-one per cent. This clearly indicates an approach to tropical relations the further back we go. Our own tertiary fauna is almost exclusively oligocene and has been found in a multitude of minor points to show distinct tropical characteristics, and it therefore becomes of peculiar interest to learn the numerical relation herein of the Homoptera to the Heteroptera; now here, much as in the oligocene of Europe, we find the Homoptera claiming forty per cent of the whole hemipterous fauna. The significance of these figures can hardly be doubted.

Before passing to a separate consideration of the two suborders, it may be well to make a single statement or two applicable to both.

1. The general facies of the hemipterous fauna is American, and distinctly more southern than its geographical position would indicate.

2. All the species are extinct, and though the localities at which they have been found are few, many of them near together and all or nearly all presumably oligocene, yet there is scarcely an instance where the same species occurs in two localities.

3. No species are identical with any European tertiary forms.

4. So, too, a very considerable number of genera are extinct,

often including numerous species. This is partly to be accounted for by a very striking feature, of which details will be given later, viz., the occurrence of peculiar characteristics running through all or nearly all the genera of entire families and distinguishing them from living types. Germar observed something akin to this when he remarked of the amber (oligocene) Hemiptera that many species had a relatively long beak.

5. Existing genera which are represented in the American tertiaries are mostly American, not infrequently subtropical or tropical American, and where found also in the Old World are mostly those which are common to the north temperate zone. A warmer climate than at present is distinctly indicated.

6. There are no extinct families.

7. The appearance of the same families and even of the same groups of genera in the European and American tertiaries is common, but of the same restricted genus very rare. It is more common when the American species are compared with the oligocene species of Europe than when the comparison is made with the European tertiary species at large.

With these preliminary statements we may pass to a separate consideration of the two great divisions of Hemiptera: the Homoptera and the Heteroptera.

The variety of forms referable to the families of Homoptera, that have been found in the American rocks, is not a little surprising, and it includes some remarkable forms. All the families are represented excepting the Stridulantia, and this exception is the more noticeable because the presence of this family has been signalized in several instances in the European tertiary rocks, and species believed to belong here have even been found in mesozoic deposits. Yet two families, Coccidæ and Psyllidæ, occur with us and have not yet been found in European rocks, though Coccidæ are known from the Baltic amber. In all we find represented six families, thirteen subfamilies, fifty-five genera, and one hundred and twelve species in the four hundred specimens that have been examined.

The families Coccidæ and Psyllidæ, however, are very feebly represented by a few examples only. The great bulk of fossil Homoptera, both in Europe and America, belonging to the four families Aphides, Fulgorina, Jassides and Cercopidæ; in each of these, with the possible exception of the Jassides, the variety and abundance of forms are greater in America than in Europe, even including the types from amber, while a comparison of the rock deposits alone would show a vast preponderance on the American side. In the number of individuals the Cercopidæ easily hold the first rank, and this appears to be true in Europe as in America; next follow the Aphides, for which in variety of type and in interest America far excels. The Jassides appear to present relatively the least interest, but the absence from American deposits of one whole division of that family, the Membracida, is rather surprising in view of their presence (though rarely) in European deposits and their relative abundance in America to-day.

The following tabular enumeration of the species and genera occurring in European and American tertiaries may serve to present in a clearer light the agreements and disparities between them. It should be remarked, however, that the European list is drawn from miscellaneous sources and includes all those genera and species which have been merely *indicated* as occurring in certain deposits and might fairly be considerably reduced. It should not be overlooked, moreover, that it includes all the amber forms.

TABLE II. SUMMARY LIST OF KNOWN FOSSIL HOMOPTERA.

FAMILIES.	AMERICA.		EUROPE.	
	GENERA.	SPECIES.	GENERA.	SPECIES.
Coccidæ	1	1	6	9
Aphides	15	32	4	20
Psyllidæ	2	2	0	0
Fulgorina	16	29	7	18
Jassides	11	21	9	24
Cercopidæ	10	27	4	24
Stridulantia	0	0	1	7
Totals.	55	112	31	102

If we exclude the amber forms and compare the fauna of the rocks only, we shall reach a very different result, as the following table will show.

TABLE III. TABLE OF FOSSIL HOMOPTERA FROM ROCK DEPOSITS.

FAMILIES.	AMERICA.		EUROPE.	
	GENERA.	SPECIES.	GENERA.	SPECIES.
Coccidæ	1	1	0	0
Aphides	15	32	3	8
Psyllidæ	2	2	0	0
Fulgorina	16	29	3	3
Jassides	11	21	8	18
Cercopidæ	10	27	4	21
Stridulantia	0	0	1	6
Totals.	55	112	19	56

This table shows clearly how poorly the Aphides and Fulgorina are preserved in the European as compared with the American rocks.

It has been necessary to establish a large number of new generic groups to contain the American forms, which perhaps would not have been the case to the same extent had a really good selection of existing tropical American types been accessible; for the affinities of nearly the whole homopterous fauna of our tertiaries are plainly subtropical. It is curious to see how highly developed some apparently extinct types were in that day; the family groups were quite as trenchant as now, and while we find in some, as in Aphides, marked departures from modern structure, it in no way appears to affect the family characters or to mark any approach toward the neighboring groups. Some genera now apparently extinct seem to have attained a high degree of differentiation, as witness Aphidopsis among the Aphides, Diaplegma among the Fulgorina, Palecphora, Lithecphora and Palaphrodes among the Cercopidæ; of all of these there were several species, and more than occur in any other generic group excepting Agallia among the Jassides, which is equal to the least prolific. As a general rule, it is also in just these genera that the individuals are the most abundant, notably among the Cercopidæ, which as a family is almost twice as numerous as all the others together, though among these larger families the least well provided with generic distinctions; for the three genera, Palecphora, Lithecphora and Palaphrodes, with their fifteen species, not only outnumber in specific types the other seven genera of Cercopidæ (twelve species), but they contain more than nine-tenths of the individuals of this family which have passed under my eyes.

A few points of special interest may be found on examining some of the separate families. Thus one would hardly suppose that objects of such extreme delicacy and minute size as plant lice would be found in a fossil state. Yet they are by no means infrequent, and have even been found in the secondary deposits of England; for in Brodie's work two objects which appear to be wingless forms are figured, and besides these another winged plant louse of a diminutive size, showing the characteristic venation of the group; while in the tertiary rocks a considerable number of species have been found; most of these have been referred to Aphis (twelve species) and Lachnus (eight), and so belong, like the bulk of living species, to the subfamily Aphidinæ. But the Pemphiginæ are represented by a Pemphigus from Oeningen, and the Schizoneurinæ by a Schizoneura from amber. Besides occurring in these localities, they have also been found at Radoboj, Aix, and Ain in Europe, and we can now add several localities in our own country.

That they are not scarce in amber is shown by Menge's collection which in 1856 included fifty-six specimens. But these are few compared with the number from Florissant where more than one hundred specimens have been found, about seventy of them determinable, though in the other American localities, Green River, in Wyoming, and Quesnel, in British Columbia, only two or three specimens have occurred. Indeed, by the publication of the American forms the number of known fossil species is doubled.

There are some remarkable features about the Florissant forms. The mass of them belong, as is the case with those from the European tertiary rocks, to the Aphidinæ proper. But both here and in the Schizoneurinæ to which the remainder appertain, we are met by two remarkable facts: one that the variation in the neuration of the wings is very much greater than occurs among the genera of living Aphidinæ and Schizoneurinæ, and greater also than occurs in the known tertiary forms of Europe, requiring the establishment of a large number of genera to represent this variation; and, second, that at the same time there is one feature of their neuration in which, without an exception, they uniformly agree, and differ, not only from the modern types, but from the European tertiary insects. This feature is the great length and slenderness of the stigmatic cell, due to the removal of the base of the stigmatic vein to the middle (or to before the middle, sometimes even to the base) of the long and slender stigma and its slight curvature ; and it is a fact of particular interest in this connection that in the only wing we know from the secondary rocks precisely this feature occurs, as illustrated in Brodie's work (see pl. 4, fig. 3). So, too, the cubital space is largely coriaceous, so that the postcostal vein may be considered as exceedingly broad and merging eventually without the intervening lack of opacity, into the stigma proper. As a general rule, the wings are also very long and narrow, and the legs exceedingly long. In all these characteristics the American plant lice appear as a rule to differ from the forms so far described from the European tertiaries.

The single winged species figured by Berendt from amber, however, shows precisely this character as far as the length of the stigmatic cell is concerned, which is about two-fifths the length of the wing. It will be interesting to know whether the other species of the Baltic amber will show a similar departure from the condition of the stigmatic cell in modern types. Not a single one of the Florissant forms can be referred to an existing genus.

The Fulgorina are fairly well represented in tertiary deposits and by a considerable variety of forms, all the subfamilies being represented except the Tropiduchida, Derbida and Lophopida; and what is curious, each of the subfamilies is represented both in European and American strata, excepting only the Issida confined to Europe and the Achilida found only in America, each by a single species, the one in Radoboj, the other at Florissant. America is far richer than Europe both in the number and diversity of its fulgorine fauna, but especially in the diversity. About half the European species have been referred to Cixius alone, and Diaplegma, a genus of Cixiida, is the most abundant American type.

With only a single exception, all the fossil species of Jassides that have been recognized in tertiary deposits of any kind have been drawn from the subfamily Jassida as Stål separates them. This is equally true when we extend the ground to America which possesses half as many species as Europe, and as already stated is the more remarkable here since the Membracida are now such a prevailing type in North America. Again, the vast proportion of forms in both worlds belongs to the series allied to Jassus and Bythoscopus and not to that of which Tettigonia is the type, so that the resemblance of the tertiary fauna in the two worlds is not slight, though rarely the same genera appear to be preserved.

If the number of individuals be regarded, the Cercopidæ were the prevailing type of Homoptera in tertiary times. At Florissant they appear to form three-fourths of the whole bulk. As compared with the Fulgorina they were there slightly less numerous in species and genera, but five times as numerous in individuals. Most of the extinct forms have been referred by authors, and especially by Germar and Heer, to the existing genera Cercopis and Aphrophora, but these references were so far incorrect that in several instances they belonged to the alternate subfamily and not to that to which they were referred. As to our own species, some of them are gigantic, nearly all large, and by far the greater part of them allied to types now found only in the tropics of the New World; and yet I have been unable in any instance to refer them to existing genera, though doubtless some of them will be found so referable.

Passing now to the Heteroptera, which form the larger part of the Hemiptera both recent and fossil, we find that of the twenty families into which the known fossil species may be divided, only five are remarkable for the abundance of their representation in the existing fauna. These are the Reduviidæ, Capsidæ, Lygæidæ, Coreidæ, and Pentatomidæ, and these same families are also well represented among the fossils, containing together about four-fifths of the total heteropterous fauna. Indeed the only other family which can be regarded as at all abundant in tertiary times is the Physapodes, the known species surpassing those of the Reduviidæ. Of these six families, the Lygæidæ were then the most abundant, containing a little more than twenty-five per cent of the whole, followed hard by the Pentatomidæ with a little less than twenty-five per cent; the Coreidæ come next with fifteen per cent, followed at nearly similar distance by the Capsidæ with nine per cent. The Physapodes have seven per cent and the Reduviidæ only four and a half, mainly because America is so strangely poor in this group, having indeed but a couple of species, the only groups at all common in America being the four with the highest percentages; here the relative percentages in the two worlds are very different, as will appear from the following table, the Lygæidæ having thirty-three per cent of the whole American fauna against nineteen and a half per cent in Europe ; the Pentatomidæ twenty-four per cent in America against twenty-five and a half per cent in Europe, these two striking contrasts combining to give the Lygæidæ the total preponderance, hitherto enjoyed by the Pentatomidæ ; the Coreidæ twenty-two per cent in America against nine and a half per cent in Europe ; and the Capsidæ nine per cent in America against ten per cent in Europe.

TABLE IV. SUMMARY LIST OF KNOWN FOSSIL HETEROPTERA.

FAMILIES.	NORTH AMERICA.		EUROPE.	
	GENERA.	SPECIES.	GENERA.	SPECIES.
Corixidæ	2	3	1	2
Notonectidæ	1	1	1	3
Nepidæ	0	0	2	4
Belostomatidæ	0	0	1	2
Naucoridæ	0	0	2	2
Galgulidæ	1	1	1	1
Saldidæ	0	0	1	1
Veliidæ	2	2	1	1
Hydrobatidæ	2	3	2	2
Limnobatidæ	0	0	2	2
Reduviidæ	2	2	7	14
Nabidæ	0	0	2	7
Aradidæ	0	0	1	5
Tingididæ	3	3	4	5
Acanthiidæ	1	1	0	0
Capsidæ	7	13	13	20
Physapodes	3	3	4	21
Lygæidæ	26	51	6	39
Coreidæ	14	34	12	19
Pentatomidæ	16	37	14	51
Totals,	80	154	77	201

Of the other smaller families, the only ones which surpass more than five known fossil species in all are the Nabidæ with seven species and the Tingididæ with eight ; of these there have been found in America no Nabidæ whatever, and the smaller half of the Tingididæ. Other families not found in America are the Nepidæ, Belostomatidæ, Naucoridæ, Saldidæ, Limnobatidæ and Aradidæ, all but the Saldidæ having more than one species in Europe. On the other hand the only family found in America and not in Europe is the Acanthiidæ with a single species. The remaining smaller families represented on both continents vary in their numbers from one to three in America and from one to four in Europe.

If, however, we omit from this enumeration the forms which have been found in amber, and thus compare those of the rocks only, as in the following table, we shall meet with somewhat different results.

TABLE V. TABLE OF FOSSIL HETEROPTERA FROM ROCK DEPOSITS.

FAMILIES.	NORTH AMERICA.		EUROPE.	
	GENERA.	SPECIES.	GENERA.	SPECIES.
Corixidæ	2	3	1	2
Notonectidæ	1	1	1	3
Nepidæ	0	0	2	3
Belostomatidæ	0	0	1	2
Naucoridæ	0	0	2	2
Galgulidæ	1	1	1	1
Saldidæ	0	0	0	0
Veliidæ	2	2	1	1
Hydrobatidæ	2	3	0	0
Limnobatidæ	0	0	1	1
Reduviidæ	2	2	6	12
Nabidæ	0	0	2	5
Aradidæ	0	0	1	2
Tingididæ	3	3	3	4
Acanthiidæ	1	1	0	0
Capsidæ	7	13	1	1
Physapodes	3	3	4	18
Lygæidæ	26	51	6	37
Coreidæ	14	34	11	18
Pentatomidæ	16	37	14	50
Totals	80	154	58	162

The principal change which may be noted here is the almost total extinction of the Capsidæ in the European representation, which shows but a single species; the Saldidæ and Hydrobatidæ do not appear and the Aradidæ are notably reduced. The greatest contrasts between the European and American rocks, with an almost equal total number of species, are seen in the Capsidæ which have eight per cent of the total fauna in America, six-tenths per cent in Europe, and the Coreidæ with twenty-two per cent in America and eleven per cent in Europe. These are the only cases of striking contrasts in which the American fauna is the richer; the others are the Reduviidæ, one and three-tenths per cent for America, seven and four-tenths per cent for Europe; the Nabidæ, none for America, three per cent for Europe; and the Physapodes two per cent for America, eleven per cent for Europe. The contrasted balance of the Lygæidæ and Pentatomidæ is well seen, America having thirty-three per cent of Lygæidæ and twenty-four per cent of Pentatomidæ, Europe twenty-three per cent of the former and thirty-one per cent of the latter.

Very little change appears in the smaller families (a relatively small number of which occur in amber), except in the entire absence of any representatives of Hydrobatidæ and Saldidæ, the former occurring in America. It is also surprising to see how little the larger families (with a single exception) are affected by the new table, amber having but the meagrest possible contribution to offer to the Pentatomidæ, Coreidæ, Lygæidæ, and Physapodes, while the single exception noted above, of the Capsidæ, is a startling one, amber furnishing nineteen of the twenty European tertiary species.

It may be worth while to extend some of these comparisons in a different direction,—that of existing American faunas. There are, I believe, but three opportunities for such comparison: first, Mr. Uhler's "Check-list of the North American Heteroptera" (1886), which includes all species known at the time, including the Mexican and West Indian; second, the same writer's valuable "List of the Hemiptera of the region west of the Mississippi" (1876), which represents particularly the geographical region of our tertiary fossil Heteroptera; and third, Mr. Distant's contribution to the "Biologia Centrali Americana" (1880-89), which has a decidedly more southern aspect than Uhler's general list. Distant's work has progressed only through the larger families, and indeed at this writing the supplement to the first volume is not complete, and accordingly in what follows I have omitted all consideration of this, to make the comparisons more equable. For the same reason, in order to use the last work at all, I have instituted comparisons only between the families there elaborated, and have used the family groups in the same sense as there, except only that I have regarded the Pyrrhocoridæ as a group of Lygæidæ.

These four families are indeed the very ones and, as will be seen, the only ones which assume any importance in the American tertiaries, and a comparison of their interrelation as to number can be shown succinctly by the following table which exhibits the relative percentage of representation of each of these families in the different regions and times as represented in the published lists, the only available ones, and which may be supposed to represent, not the numbers but the relations, with tolerable accuracy.

TABLE VI. RELATIVE VALUE OF CERTAIN HETEROPTERA IN SPECIFIED DISTRICTS.

FAMILIES.	AMER. TERTIARY.	UHLER, WEST. LIST.	UHLER, GEN. LIST	DISTANT, CENTR. AMER.
Capsidæ	9.6	11	25	27.3
Lygæidæ	37.8	31.4	19.2	17.7
Coreidæ	25.1	23.1	21.6	21.7
Pentatomidæ	27.4	34.5	34.1	33.2
Totals.	99.9	100.	99.9	99.9

The correspondence of the numbers in the last two columns is even less remarkable than the disturbance of the relative percentages of the Capsidæ and Lygæidæ of the western list when compared with those of the American and Central American forms; the merest indication of such an overturn is shown in the comparison of the nearer American and the more distant Central American lists; but the overturn is still more complete and in the same direction when we compare the existing and the fossil faunas of the west. The relative representation, then, of the four principal families of the tertiary Heteroptera of the western half of our continent agrees conspicuously better with the relative representation of the existing fauna of the same geographical region, than with that of other regions of the same world. Either the physical conditions of the region in question have remained in the same relative contrast to those of the other regions under comparison since oligocene times, or the present heteropterous fauna of the west shows a decided relation to that which existed on the same ground in tertiary times, or both.

As in the Homoptera, and for the same general reasons, it has been found imperative to establish in the Heteroptera a large number of new generic groups, to treat them on the same principles that guide the zoölogist. Characteristics of structure in antagonism to those prevalent in the same groups to-day run throughout large divisions or even families, and must be taken into account, if we are to do justice to the facts. Bringing these thus into prominence will serve the useful purpose of stimulating inquiry into their meaning and origin, which the data at present at hand seem inadequate to explain. Many of these extinct types attained a high degree of differentiation, a large number of the genera being represented by a half dozen or more species each, some of them at the time very abundant in individuals.

A few words may be added concerning certain of the families. With the exception of a Miris, reported over half a century ago from Aix and never yet described, all the European fossil Capsidæ known up to the present time are from amber. Thus Gravenhorst long ago referred half a dozen species from amber to Miris and Capsus, and Germar later described as many as thirteen species of Phytocoris from the same deposits. These genera were then used in a far broader sense than now, and the figures of Germar show at once that several genera are to be found among them. If we were to base our judgment on the comparisons with the modern species which Gravenhorst and Germar in nearly every case instituted, we should reach the conclusion that the group Capsina alone had been found, and that no less than half the divisions which Reuter founded in this subfamily were present, and a large number of genera. Thus we find the Plagiognatharia, the Oncotylaria, Cyllocoraria, Capsaria, Phytocoraria and the Loparia, a dozen genera in all, and there is at least one other genus among the species figured by Germar, unaccompanied by comparisons with modern types.

In America we have four of these divisions represented, viz.: Cyllocoraria, Capsaria, Phytocoraria and Loparia; while Bryocoraria, not recognized in amber, is also represented. In all, there are thirteen species, and all come from Florissant.

It thus appears that we may recognize among the fossils every one of the divisions instituted by Reuter that have any considerable present development of species, excepting only the Miraria, and to cover the possibilities of this also there are two species of Miris not referred to modern genera, one mentioned by Gravenhorst from amber and one by Curtis at Aix. It may also be noticed that the assemblage of fossil forms shows as a whole a leaning toward American types, more noticeable, however, among the American than the European forms, the more striking being in the development of the Loparia and Bryocoraria. Not too much stress, however, should here be placed upon these considerations, as a reexamination of the amber types is necessary before positive conclusions can be drawn, and the affinities of several of the Florissant forms is vague at the best.

The family Lygæidæ has been recognized in the secondary rocks by somewhat obscure fragments, in England and Germany, but in tertiary deposits the family is comparatively abundant and widespread. Curiously enough, only two species have been recorded from amber, and in Menge's collection the family was represented by but one. Three-fourths of the known European species are those described by Heer, who referred them to few genera. It is difficult to place the larger number of those which have been recorded, but, to judge in part by the living species with which some of them are compared, it is plain that the Myodochina should claim about one-half of them and the Lygæina the larger part of the remainder, the others being distributable among the Cymina, Blissina, and Heterogastrina. In all, there are thirty-seven species credited to six genera.

In our own country, the numbers are largely in excess of this, fifty-one species being recognized, showing this family to have been one of the more important among tertiary Heteroptera. The disposition of these in their respective subfamilies has been effected only by their evident affinities in general structure with existing members of these subfamilies, not by a demonstration of those definite characters (mostly relating to the position of the stigmata) upon which these subfamilies were founded, as that would be impossible. The result shows no small resemblance to the characteristics of the European tertiary fauna, the prevailing type being the Myodochina and the next the Lygæina, but beyond this the resemblance fails to extend greatly, the prevailing subfamily having nearly seventy-three per cent of the whole, while in Europe it claims scarcely more than fifty per cent; and again the Lygæina has less than sixteen per cent of the whole, while in Europe it has about thirty-five per cent; further, none of the other subfamilies which appear in Europe are found at all in America, our other groups being Geocorina, Oxycarenina, and Pyrrhocorina, and these find no place in Europe. But perhaps the most remarkable result of the investigation of the American forms is the large number of new generic types found to be necessary in the Myodochina, where out of the twenty-one genera, only four (with but five species together) are regarded as identical with existing types. A remarkable feature to be noticed in them—not embracing all the species, but certainly most of them—is the brevity of the antennæ, rarely half as long as the body, and usually much shorter than that. They are extraordinary, too, for their general resemblance as a whole to subtropical types. The members of the first group, the Myodocharia, seem to form, with few exceptions, a type apart, in which the posterior lobe of the thorax does not broaden from behind forward, being as a whole narrower, or at least no broader, than the anterior lobe when the latter has ampliated sides, the opposite being ordinarily the case in modern types. With a single exception or two they all come from Florissant.

The members of the large family Coreidæ do not appear to have been recovered from the rocks in any great variety of forms and from amber but a single species is known. The Coreina and Alydinæ appear to have been far the most abundant among the subfamilies, the former prevailing in Europe, the latter in America, where much the greater number of all the species, and genera as well, belong to the Alydinæ,—a somewhat remarkable fact in view of their relatively slight importance to-day. The Corizida were next in importance, a few species being found both in Europe and America. The other subfamilies represented are the Pseudophlœina, occurring only in America, and in a single genus, which appears however, to have been very common; and the Berytina, found only in Europe, and the only subfamily represented in amber. Excepting one Corizus, all the American species that have been found have occurred only at Florissant. None of the European fossil Coreina at all resemble in any particular manner the forms we find at Florissant, where all the species but one have to be referred to extinct genera and the one exception may require a similar reference when better known. There are, however, but four genera with nine species. In all, the antennæ are brief and have the joints beyond the basal of more than usual equality.

Although compared to the other Coreidæ the subfamily Alydinæ is to-day but poorly represented in America, whether in temperate or tropical regions, this was not the case in tertiary times; for it was fairly well furnished with genera and species and as for numbers in individuals no group of Heteroptera could compare with it. Most of the genera are extinct types and belong to the division of Micrelytraria in the immediate vicinity of Protenor and Darmistus, with slender and unarmed hind femora, but also as a general rule with distinctly and profusely though delicately spined hind tibiæ. One genus, Rhepocoris, contains the bulk of all, and of the four or five species belonging to it, nearly all the specimens obtained belong to two closely allied forms, possibly to be regarded as only one. In Europe, but three fossil Alydinæ have been recognized, and these have all been referred to the division Alydaria.

The family Pentatomidæ has always held the first place among Heteroptera in tertiary deposits, but now its place must be disputed by the Lygæidæ. This is due not only, though principally, to the exceptional abundance of Lygæidæ at Florissant, but also to the rather meagre proportion of the subfamily Pentatomida, as will appear below. In European deposits only a single species is known from amber, while fifty have been exhumed from the rock deposits. They represent only four of the nine subfamilies, and the great majority belong to the two subfamilies Cydnida and Pentatomida, the former with sixteen species referred to four genera, the latter with twenty-five species referred to six genera. The other subfamilies represented are the Scutellerina with five species of two genera, both at Oeningen, and the Acanthosomina with four species of two genera, both at Radoboj. The American forms represent only the subfamilies Cydnida and Pentatomida, but in reverse proportion to what appears in Europe, the Cydnida being very well represented by twenty-four species of six genera, nearly all of them by a number of individuals and one by a great many, the Pentatomida on the contrary by only thirteen species of ten genera, and of each of these species more than a single example has rarely been found. While therefore the prevalent subfamilies are the same on the two continents, one has scarcely half as many representatives in America as in Europe, while the other has half as many more in America as in Europe.

A very striking peculiarity is found in the American Pentatomidæ as a whole, whether Cydnida or Pentatomida. In living forms the vast majority have a long scutellum reaching beyond the middle of the abdomen, and have the tip produced forming a parallel-sided apical lobe. In the American tertiary forms, so far as yet known with only a single exception, no such apical lobe exists, but the scutellum ends with an angular apex, sometimes a little rounded, but the sides perfectly straight and entire, at least in the apical half; besides which, or perhaps partly as a consequence, the scutellum does not reach further than, sometimes does not attain, the middle of the abdomen. It has seemed necessary therefore to establish a considerable number of new generic groups to embrace these remarkable forms. To judge from the illustrations given by Heer, the same thing would seem to be true of at least a few of the European tertiary Pentatomida, especially of those from Radoboj, and it would be very desirable to institute direct comparisons between specimens from the two continents.

In the general remarks under the Heteroptera as a whole, attention was called to the close relation which existed between the proportional abundance (in the number of specific forms) of the four principal families of Heteroptera in tertiary times and the same in the existing fauna of the selfsame region. A further illustration, but even more exaggerated, appears by using the same guides in comparing the relative numbers of the Cydnida and Pentatomida, the only two subfamilies of Pentatomidæ known to exist in our tertiary deposits and so capable of comparison. In Distant's work, the Cydnida number about one-sixth of the total number of Cydnida and Pentatomida; in Uhler's general list one-seventh; in his western list one-fourth; while the increasing number thus shown in the region where the fossils occur is vastly exaggerated in their relative representation in the rocks, this being two-thirds of the whole.

Prof. F. W. Putnam then gave an account of explorations of the Indian burial-place at Winthrop, Mass., and showed some of the specimens found during the day.

Dr. J. Walter Fewkes called the attention of the Society to a new method of printing colored cuts in the text especially adapted to works on natural history.

The following names were presented for Associate Membership:

Dr. John S. Flagg, Dr. Selah Merrill, Mrs. Charles H. Ramsay, Messrs. C. J. Maynard, W. E. Sheldon, John A. Thompson, George F. Topliff, and Dr. H. V. Wilson.

General Meeting, April 16, 1890.

Mr. Samuel Wells in the chair.

The following papers were read:

NOTE ON THE VALUE OF SALIFEROUS DEPOSITS AS EVIDENCE OF FORMER CLIMATAL CONDITIONS.

BY N. S. SHALER.

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For some years I have been incidentally engaged seeking evidence which might be of value in determining the conditions of climate in former geological periods. The facts already in the possession of geologic science enable us to assert that the strata formed in certain periods in particular portions of the earth were accumulated during times of greater rainfall than now exist in the same lands. Such peculiarities of climate are attested not only by the existence of sediments which indicate large precipitation through the presence of rapidly accumulated fragmental materials, but the organic remains, such as those accumulated in Carboniferous strata, are also of value in the determination. Proofs of arid climate are not so well afforded by the character of the materials deposited or the fossils remains which they enclose. For some time it indeed seemed to me almost hopeless to seek for facts which would serve to establish the existence of arid periods in the past history of various countries. At length, however, it became evident that the phenomena of salt deposits afford a kind of evidence of great value in this determination. I hope in the near future to present in some detail the assemblage of evidence which may be drawn from this store. In the present writing, I propose briefly to set forth the general results of the inquiry.

Salt deposits are divisible into two groups: in the first of these divisions the saline material is held in solution in water which is contained in sedimentary beds formed on old sea bottoms. In this case the presence of salt is attributable to the imprisoning in the interstices of the strata of the marine waters in which the beds were formed. As T. Sterry Hunt and others have shown, this embedded sea water may, under favorable circumstances, remain confined in the strata for an indefinite period. The presence of such marine waters manifestly affords no evidence as to the former conditions of climate in the time when and in the region where the materials were accumulated. The other smaller but economically more important group of saliferous deposits consist in the accumulations of salt and the other mineral substances contained in waters which have been more or less completely evaporated. Such deposits in all cases appear in the form of rock salts either in the pure state or more or less commingled with other sedimentary materials. It is evident that, wherever such accumulations occurred, the climate at the time of their formation must have been of a peculiar arid nature, that is, the measure of evaporation in the given field must have considerably exceeded that of the rainfall.

The various deposits of rock salt are evidently divisible as regards the circumstances of their formation into two groups to which we may give the name of marine lagoon deposits and dead sea deposits. The former class of accumulations are found along seashores where the neighboring land has a rainfall less than the evaporation and where the physical conditions of the shore favor the enclosure of considerable areas by coast barriers. From time to time the sea waters obtain access to these embayed areas and are evaporated to the point where they precipitate their dissolved materials. It appears possible, in many cases, to discriminate the deposits formed under such circumstances and those accumulated in the dead seas. The marine character of the neighboring contemporary sediments, the shape of the basins and perhaps the chemical nature of the precipitates may afford data which will enable us to determine the particular conditions of the accumulation, and thus to ascertain whether or no it was formed along a seashore. It appears to me also possible in most cases where the physical conditions of the deposits are well revealed to separate the dead sea deposits from those which were accumulated along the shores. From the general geology of the district it is, in many cases, possible to determine in a direct manner whether the accumulation took place in an interior or coastal basin. The character of the deposits and the nature of the fossils in contemporaneous strata will also afford evidence on this point. Still further the chemical nature of the bed may serve to show whether the precipitated materials were drawn from marine waters or from the substances brought in from the neighboring lands by tributary rivers.

To utilize the data afforded by salt deposits in determining the existence of arid conditions in various countries in various ages, it has been found necessary to plat on a series of world maps the accumulations which have been formed in the several divisions of geological time, taking first those now forming and in succession those which were accumulated at each stage in the geological development of the continents. Although this task is but begun, it is evident that the final result will afford some important conclusions concerning the ancient climates. Thus in the field about the great lakes of North America we have extensive accumulations of rock salts formed during the Silurian period. These accumulations of the Salina period were immediately preceded by deposits of the Niagara and were succeeded by those of Lower Helderberg age. The Niagara rocks afford abundant evidence showing that this region was covered by marine waters of considerable warmth. The abundant development of corals appears to indicate that the region was visited by a warm current coming from the south. Warm oceanic waters in a region of this high latitude must have led to an abundant precipitation on the neighboring more northerly shores. We are, therefore, entitled to believe that the land conditions in this district were those of a humid nature. On the other hand, the very thick deposits of rock salts which were accumulated immediately after the close of the Niagara beds appear to indicate that in a sudden manner the climatal conditions of this region were greatly changed, an arid state of the atmosphere replacing the humid conditions which had previously existed. Again, in passing to the Lower Helderberg, we find after the period of the Waterlime, evidence that the seas returned to something like their previous conditions of temperature. It appears legitimate to suppose that this alteration in climatal conditions may have been at least in part due to the presence or absence of the ancient gulf stream in the waters of this vicinity. Such a stream, flowing against the southern borders of the Laurentian land area, would, it appears to me, have inevitably produced a warm sea and a humid climate of the neighboring shore. If the current were for a time withdrawn from this field, as by subsidence of the isthmian district of America permitting the tide to flow into the Pacific, this portion of the continent would be likely to enter upon a period of aridity. A yet more striking instance of important climatal change is indicated by the presence of extensive salt deposits in Eastern Louisiana immediately contiguous to the shores of the Gulf of Mexico. The precise age of this southern salt deposit is not well determined. It appears, however, probable that it was formed in comparatively recent geological time. It should be observed that this field is now the seat of the most considerable rainfall which occurs in the eastern half of North America, north of the 25th parallel. In any condition of the climatic equations it seems impossible to suppose that rock salts could be accumulated in this portion of that shore of the Gulf of Mexico while the Gulf Stream had free access to its area. The geographic and geological position of this formation appears to exclude the supposition that it was deposited in a dead sea. The general character of the strata and all the other circumstances of its existence, seem to indicate that it is a coast-line deposit. It therefore becomes necessary to suppose that it was accumulated along an old seashore, and we are justified in arranging our suppositions as to the conditions of the sea in this region in such manner as will account for the occurrence of the deposit.

The salt deposits of England, Germany, and other portions of the earth afford similar evidence as to the existence of arid periods in various stages of the earth's history in which they occur, regions which are now characterized by an abundant rainfall.

From the facts already noticed it appears probable that in many instances the arid periods in which saliferous deposits were accumulated occurred in the geologic ages, when we have evidence of extensive precipitation in the same field, at a period not remote from the time of desiccation. Thus, in Europe, the Trias contains extensive salt deposits, though other portions of the section indicate by their composition an abundant precipitation and by their organic remains a tolerably warm climate.

Although not yet in the form to warrant extended discussion, these facts clearly indicate sudden climatal revolutions at various stages in the past.

Although I have spoken of ordinary salt deposits alone, it is evident that accumulations of other materials ordinarily precipitated by evaporation, require attention. While indications of value may be derived from deposits such as the Stassfurt salts they are of less value than those secured from strata of more soluble materials. It should also be noticed that the negative evidence concerning saliferous accumulations is of very little value, for the reason that deposits of salt are peculiarly liable to destruction by the process of solution. Wherever they are exposed to the surface the process of removal is likely to be rapid. It is interesting to note that whenever a glacial sheet comes in contact with salt deposits, the erosion of the material must be singularly effective. It seems to me not improbable that a portion of the area of certain lakes may have been excavated in this manner by glacial ice. Even where the masses of saline matter remain buried at considerable depths below the surface, the passage of rainwater through the materials is apt to lead to their removal. The greater part of the known salt deposits yield spring waters which are slowly removing the material. In this way a large part of the saline matter which has once existed in the strata in the form of rock salt has probably gone away to the sea. Owing to its less soluble nature, lime and perhaps some of the other precipitates which have gone down in desiccation basins may remain to attest the existence of arid conditions after the rock salt has disappeared.

The extent to which the ancient saline deposits have been removed from the rocks may, in certain instances at least, afford valuable evidence as to the position of the given deposits with reference to the sea level since the time of their formation. Although this matter is apart from the subject of this paper, I venture to give a few instances bearing on the point. In northern Florida and the neighboring portions of the southern states, the bored wells indicate that although the beds for nearly a thousand feet below the sea level are of marine origin, they have been drained of the salt water originally stored in their interstices. It is difficult to account for this removal of the waters of construction from the strata except by the supposition that the region has, since its formation, been elevated to a considerable height above the sea. We therefore gain from the evidence in this district an important clew as to the former height of the continent in this field. It is, however, clear that we cannot, save in particular instances, expect to find the saline materials removed from strata which have been formed beneath the sea and afterwards elevated above its level, for in the Palæozoic rocks of the Mississippi valley, particularly those in the region of the upper Ohio, we observe that the marine waters buried in the rocks at the time of their construction, are still retained in the strata, their retention being due to the very dense nature of the beds which overlie the layers in which the salt water is preserved.

GLACIAL STUDIES BEARING ON THE ANTIQUITY OF MAN.

BY FRANK LEVERETT.

[ABSTRACT.]

THE paper called attention to the complexity of glacial problems whose solution has a more or less direct bearing upon the antiqnity of man, and showed the necessity of long and careful observations upon various classes of phenomena by experts in the study of each class before a decision concerning the antiquity of man can be reached by geologists.

As yet, scarcely any estimates upon the date and duration of the glacial period have been carried to a degree of accuracy sufficient to make it possible for conclusions of a high order to be drawn. Recent estimates indicate that the glacial period is less remote than was supposed by the earlier geologists. These estimates are based upon geological instead of astronomical data, and the tendency is to rely upon the former rather than upon the latter. Even careful estimates like those of Professor Gilbert on the falls of Niagara and Prof. N. H. Winchell on the falls of St. Anthony are not enough to fix with certainty the date of the close of the glacial period, as they themselves admit and even urge. Additional estimates and other methods of reckoning age besides by recession of falls must be brought into use to corroborate or to correct the results of this method. Evidence of age based on erosion seems to be the most reliable but it requires an expert of rare skill to interpret it.

Since paleoliths have been found in both the newer and older drift it is important to determine their relative ages, a proceeding which will involve careful study in many lines; and not only the relative ages of the older and newer drifts but of the different portions of the newer drift should be determined. The great number of moraines in the newer drift suggests the lapse of a long period of time in their formations, and there is evidence that the line indicating the margin of the newer drift may not consist of a single

moraine but include moraines of various ages. This is sh wn by the position of the Kettle moraine of Wisconsin, which, though one of the later moraines of the newer drift-sheet, is at the very border of the newer drift and in part of its course reaches even beyond the older drift; also by the overriding of moraines in the East White river lobe of Indiana and the Scioto lobe of Ohio. There are hypothetical reasons based upon altitude and amount of precipitation, in addition to conclusions drawn from the distribution of the moraines east from the Georgian Bay and Lake Erie and from difference in surface erosion and other phenomena, which lead me to consider the outer portion of the newer drift of the eastern United States to be newer than that of the interior. The fullest possible tracing and correlation of moraines is therefore necessary to determine the order of succession and relative age of sheets of drift in widely separated districts. Because two moraines hold the same relative position in separate series, it does not follow that they are of the same age. If the implement-bearing gravels at Loveland, Ohio, were derived from the outer moraine of the newer drift in that state, and the Trenton gravels from the outer moraine of the newer drift in New Jersey, it cannot be safely asserted that they are of the same age. The gravels at Trenton may be, for aught we know, as new as the gravels at Little Falls, Minnesota.

The relation between certain silts in the Mississippi basin and on the Atlantic coast has not yet been ascertained. Those on the Atlantic coast have been included by Mr. McGee in the Quaternary but are considered by him much older than the terminal moraine of New Jersey and Pennsylvania. Those in the interior are later than the older drift sheet. Implements have been found beneath the silt both in the interior and on the coastal plain, and since these are among the oldest of discovered traces of man's workmanship considerable importance attaches to the accurate determination of the age of the silts which overlie them.

THE SANBORN BOWLDER.

BY M. H. SAVILLE.

Last November, in company with Dr. J. E. Sanborn, of Rockport, and Mr. Warren Upham, I made a visit to a large granite bowlder in Rockport, Mass. This bowlder has long attracted the curiosity of those who wander along the rocky shores of Rockport, although I believe its true significance has never been fully understood until Dr. Sanborn happened to discover the ledge from which it was detached. This block has been moved by the waves in a northwesterly direction, a distance of one hundred feet on the moderately ascending smooth ledge shore of the east side of Flat Point, one of the two most extreme eastward projections of Cape Ann opposite Thacher's Island. The dimensions of this block are about 5 × 6 × 13 feet (about 15 feet maximum length) having approximately the form of a four-sided prism. It thus contains about 390 cubic feet, which at 168 pounds per cubic foot would give it a weight at least 32 tons. The base of the block in its original position, shown by the ledge from which it was broken, is about seven feet above the present level of high tide, and its base where it now lies is about fifteen feet above high tide. In its transportation the block has been turned over, so that what was formerly its upper northwest corner when in place,is now its lower northeast corner, the length of the block both before and after its transportation being approximately north to south.

The parent ledge is northeast of a dike several feet wide which runs northwest to southeast and shows a definitely banded condition due to differences in its crystalline structure, its central portion being porphyritic. After being dislodged from the ledge and passing south fifteen or twenty feet, far enough to be beyond the western side of the nearly vertical wall from which it was removed, the progress of the block across the dike and onward was up a gently inclined plane, rising about one foot in ten in the direction of the movement. This block is readily recognizable as coming from the place mentioned by comparison of its north end with the ledge from which it was broken, in respect to the form of these two corresponding surfaces, the discoloration produced by weathering, before the block was separated, and by the presence on both surfaces of an obliquely intersecting joint plane. This fracture, which is fresh in appearance and with almost unworn edges, differs from the four lateral faces of the prism, all of which follow joint planes.

At this portion of the shore, there is no barrier to obstruct the full force of the waves driven by the frequent northeast storms. At such times there is no part of the North shore where the sea beats with more relentless fury, but the block itself and even its original ledge are now elevated above the reach of the waves. The transportation of the block is certainly to be referred to wave action, for the direction in which it has been moved is at right angles with that of glacial movement as indicated by striæ in its vicinity. Glacial striæ, noted in several places about the quarries of the Rockport and Pigeon Hill Granite Companies, about three miles northwest from this locality, bear commonly south 40° east, varying from this in two or three places observed, to south 35° east and south 45° east. At one place these striæ are south 20–25° east as referred to the true meridian.

At the time when this block was thus removed, it seems probable that the land was submerged to a vertical extent of at least fifteen or perhaps twenty-five feet below the present level, allowing the full force of the waves to carry the bowlder forward by slow degrees, and eventually it was overturned in some violent storm, when it reached the place where it is now seen, far beyond the power of any further transportation by wave action, as the level of the shore exists to-day.

Such a submergence of the land is known to have existed and to have affected this part of the coast at the close of the glacial period during and shortly after the recession of the continental ice-sheet. The depression of the land which may have been caused by the ice weight was probably about twenty feet on Cape Ann, as shown by fossil shells found at Gloucester by Professor Shaler and described in the Proceedings of this Society (Vol. xi, 1868, pp. 27–30), and its amount increased northward and northwestward to 200 feet or more in Maine and to 520 feet in the St. Lawrence valley at Montreal. For these figures and also for other assistance in preparing this communication, I am indebted to Mr. Warren Upham. To those who may chance to visit this locality I would say that this bowlder is about ten minutes' walk along the shore northward from the summer resort of Land's End.

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ERRATA.

Page 209, line 10. *Dele* Plate III, fig. 1. For the figure illustrating the article see p. 225, fig. 1.

Page 274, line 2. For Plate VI, figs. 11, 19, read Plate VI, figs. 10, 11.

Page 280, line 2. For Plate VI read Plate VII.

Page 360, line 8. For of the original read from the original.

Page 361, lines 25 and 26. For in the opposite direction or east-east-south read in another direction west-west-south.

For other corrections see page 355.