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TOWN GEOLOGY

PREFACE

This little book, including the greater part of this Preface, has

shaped itself out of lectures given to the young men of the city of

Chester. But it does not deal, in its present form, with the geology

of the neighbourhood of Chester only. I have tried so to recast it,

that any townsman, at least in the manufacturing districts of England

and Scotland, may learn from it to judge, roughly perhaps, but on the

whole accurately, of the rocks and soils of his own neighbourhood.

He will find, it is true, in these pages, little or nothing about

those "Old Red Sandstones," so interesting to a Scotchman; and he

will have to bear in mind, if he belong to the coal districts of

Scotland, that the "stones in the wall" there belong to much older

rocks than those "New Red Sandstones" of which this book treats; and

that the coal measures of Scotland, with the volcanic rocks which

have disturbed them, are often very different in appearance to the

English coal measures. But he will soon learn to distinguish the

relative age of rocks by the fossils found in them, which he can now,

happily, study in many local museums; and he may be certain, for the

rest, that all rocks and soils whatsoever which he may meet have been

laid down by the agents, and according to the laws, which I have

tried to set forth in this book; and these only require, for the

learning of them, the exercise of his own observation and common

sense. I have not tried to make this a handbook of geological facts.

Such a guide (and none better) the young man will find in Sir Charles

Lyell's "Student's Elements of Geology." I have tried rather to

teach the method of geology, than its facts; to furnish the student

with a key to all geology, rough indeed and rudimentary, but sure and

sound enough, I trust, to help him to unlock most geological problems

which he may meet, in any quarter of the globe. But young men must

remember always, that neither this book, nor all the books in the

world, will make them geologists. No amount of book learning will

make a man a scientific man; nothing but patient observation, and

quiet and fair thought over what he has observed. He must go out for

himself, see for himself, compare and judge for himself, in the

field, the quarry, the cutting. He must study rocks, ores, fossils,

in the nearest museum; and thus store his head, not with words, but

with facts. He must verify--as far as he can--what he reads in

books, by his own observation; and be slow to believe anything, even

on the highest scientific authority, till he has either seen it, or

something like enough to it to make it seem to him probable, or at

least possible. So, and so only, will he become a scientific man,

and a good geologist; and acquire that habit of mind by which alone

he can judge fairly and wisely of facts of any kind whatsoever.

I say--facts of any kind whatsoever. If any of my readers should be

inclined to say to themselves: Geology may be a very pleasant study,

but I have no special fancy for it. I had rather learn something of

botany, astronomy, chemistry, or what not--I shall answer: By all

means. Learn any branch of Natural Science you will. It matters

little to me which you learn, provided you learn one at least. But

bear in mind, and settle it in your hearts, that you will learn no

branch of science soundly, so as to master it, and be able to make

use of it, unless you acquire that habit and method of mind which I

am trying to teach you in this book. I have tried to teach it you by

geology, because geology is, perhaps, the simplest and the easiest of

all physical sciences. It appeals more than any to mere common

sense. It requires fewer difficult experiments, and expensive

apparatus. It requires less previous knowledge of other sciences,

whether pure or mixed; at least in its rudimentary stages. It is

more free from long and puzzling Greek and Latin words. It is

specially, the poor man's science. But if you do not like it, study

something else. Only study that as you must study geology;

proceeding from the known to the unknown by observation and

experiment.

But here some of my readers may ask, as they have a perfect right to

ask, why I wish young men to learn Natural Science at all? What good

will the right understanding of geology, or of astronomy, or of

chemistry, or of the plants or animals which they meet--what good, I

say, will that do them?

In the first place, they need, I presume, occupation after their

hours of work. If any of them answer: "We do not want occupation,

we want amusement. Work is very dull, and we want something which

will excite our fancy, imagination, sense of humour. We want poetry,

fiction, even a good laugh or a game of play"--I shall most fully

agree with them. There is often no better medicine for a hard-worked

body and mind than a good laugh; and the man who can play most

heartily when he has a chance of playing is generally the man who can

work most heartily when he must work. But there is certainly nothing

in the study of physical science to interfere with genial hilarity;

though, indeed, some solemn persons have been wont to reprove the

members of the British Association, and specially that Red Lion Club,

where all the philosophers are expected to lash their tails and roar,

of being somewhat too fond of mere and sheer fun, after the abstruse

papers of the day are read and discussed. And as for harmless

amusement, and still more for the free exercise of the fancy and the

imagination, I know few studies to compare with Natural History; with

the search for the most beautiful and curious productions of Nature

amid her loveliest scenery, and in her freshest atmosphere. I have

known again and again working men who in the midst of smoky cities

have kept their bodies, their minds, and their hearts healthy and

pure by going out into the country at odd hours, and making

collections of fossils, plants, insects, birds, or some other objects

of natural history; and I doubt not that such will be the case with

some of my readers.

Another argument, and a very strong one, in favour of studying some

branch of Natural Science just now is this--that without it you can

hardly keep pace with the thought of the world around you.

Over and above the solid gain of a scientific habit of mind, of which

I shall speak presently, the gain of mere facts, the increased

knowledge of this planet on which we live, is very valuable just now;

valuable certainly to all who do not wish their children and their

younger brothers to know more about the universe than they do.

Natural Science is now occupying a more and more important place in

education. Oxford, Cambridge, the London University, the public

schools, one after another, are taking up the subject in earnest; so

are the middle-class schools; so I trust will all primary schools

throughout the country; and I hope that my children, at least, if not

I myself, will see the day, when ignorance of the primary laws and

facts of science will be looked on as a defect, only second to

ignorance of the primary laws of religion and morality.

I speak strongly, but deliberately. It does seem to me strange, to

use the mildest word, that people whose destiny it is to live, even

for a few short years, on this planet which we call the earth, and

who do not at all intend to live on it as hermits, shutting

themselves up in cells, and looking on death as an escape and a

deliverance, but intend to live as comfortably and wholesomely as

they can, they and their children after them--it seems strange, I

say, that such people should in general be so careless about the

constitution of this same planet, and of the laws and facts on which

depend, not merely their comfort and their wealth, but their health

and their very lives, and the health and the lives of their children

and descendants.

I know some will say, at least to themselves: "What need for us to

study science? There are plenty to do that already; and we shall be

sure sooner or later to profit by their discoveries; and meanwhile it

is not science which is needed to make mankind thrive, but simple

common sense."

I should reply, that to expect to profit by other men's discoveries

when you do not pay for them--to let others labour in the hope of

entering into their labours, is not a very noble or generous state of

mind--comparable somewhat, I should say, to that of the fatting ox,

who willingly allows the farmer to house him, till for him, feed him,

provided only he himself may lounge in his stall, and eat, and NOT be

thankful. There is one difference in the two cases, but only one--

that while the farmer can repay himself by eating the ox, the

scientific man cannot repay himself by eating you; and so never gets

paid, in most cases, at all.

But as for mankind thriving by common sense: they have not thriven

by common sense, because they have not used their common sense

according to that regulated method which is called science. In no

age, in no country, as yet, have the majority of mankind been guided,

I will not say by the love of God, and by the fear of God, but even

by sense and reason. Not sense and reason, but nonsense and

unreason, prejudice and fancy, greed and haste, have led them to such

results as were to be expected--to superstitions, persecutions, wars,

famines, pestilence, hereditary diseases, poverty, waste--waste

incalculable, and now too often irremediable--waste of life, of

labour, of capital, of raw material, of soil, of manure, of every

bounty which God has bestowed on man, till, as in the eastern

Mediterranean, whole countries, some of the finest in the world, seem

ruined for ever: and all because men will not learn nor obey those

physical laws of the universe, which (whether we be conscious of them

or not) are all around us, like walls of iron and of adamant--say

rather, like some vast machine, ruthless though beneficent, among the

wheels of which if we entangle ourselves in our rash ignorance, they

will not stop to set us free, but crush us, as they have crushed

whole nations and whole races ere now, to powder. Very terrible,

though very calm, is outraged Nature.

Though the mills of God grind slowly,

Yet they grind exceeding small;

Though He sit, and wait with patience,

With exactness grinds He all.

It is, I believe, one of the most hopeful among the many hopeful

signs of the times, that the civilised nations of Europe and America

are awakening slowly but surely to this truth. The civilised world

is learning, thank God, more and more of the importance of physical

science; year by year, thank God, it is learning to live more and

more according to those laws of physical science, which are, as the

great Lord Bacon said of old, none other than "Vox Dei in rebus

revelata"--the Word of God revealed in facts; and it is gaining by so

doing, year by year, more and more of health and wealth; of peaceful

and comfortable, even of graceful and elevating, means of life for

fresh millions.

If you want to know what the study of physical science has done for

man, look, as a single instance, at the science of Sanatory Reform;

the science which does not merely try to cure disease, and shut the

stable-door after the horse is stolen, but tries to prevent disease;

and, thank God! is succeeding beyond our highest expectations. Or

look at the actual fresh amount of employment, of subsistence, which

science has, during the last century, given to men; and judge for

yourselves whether the study of it be not one worthy of those who

wish to help themselves, and, in so doing, to help their fellow-men.

Let me quote to you a passage from an essay urging the institution of

schools of physical science for artisans, which says all I wish to

say and more:

"The discoveries of Voltaic electricity, electromagnetism, and

magnetic electricity, by Volta, OErsted, and Faraday, led to the

invention of electric telegraphy by Wheatstone and others, and to the

great manufactures of telegraph cables and telegraph wire, and of the

materials required for them. The value of the cargo of the Great

Eastern alone in the recent Bombay telegraph expedition was

calculated at three millions of pounds sterling. It also led to the

employment of thousands of operators to transmit the telegraphic

messages, and to a great increase of our commerce in nearly all its

branches by the more rapid means of communication. The discovery of

Voltaic electricity further led to the invention of electro-plating,

and to the employment of a large number of persons in that business.

The numerous experimental researches on specific heat, latent heat,

the tension of vapours, the properties of water, the mechanical

effect of heat, etc., resulted in the development of steam-engines,

and railways, and the almost endless employments depending upon their

construction and use. About a quarter of a million of persons are

employed on railways alone in Great Britain. The various original

investigations on the chemical effects of light led to the invention

of photography, and have given employment to thousands of persons who

practise that process, or manufacture and prepare the various

material and articles required in it. The discovery of chlorine by

Scheele led to the invention of the modern processes of bleaching,

and to various improvements in the dyeing of the textile fabrics, and

has given employment to a very large number of our Lancashire

operatives. The discovery of chlorine has also contributed to the

employment of thousands of printers, by enabling Esparto grass to be

bleached and formed into paper for the use of our daily press. The

numerous experimental investigations in relation to coal-gas have

been the means of extending the use of that substance, and of

increasing the employment of workmen and others connected with its

manufacture. The discovery of the alkaline metals by Davy, of

cyanide of potassium, of nickel, phosphorus, the common acids, and a

multitude of other substances, has led to the employment of a whole

army of workmen in the conversion of those substances into articles

of utility. The foregoing examples might be greatly enlarged upon,

and a great many others might be selected from the sciences of

physics and chemistry: but those mentioned will suffice. There is

not a force of Nature, nor scarcely a material substance that we

employ, which has not been the subject of several, and in some cases

of numerous, original experimental researches, many of which have

resulted, in a greater or less degree, in increasing the employment

for workmen and others." {1}

"All this may be very true. But of what practical use will physical

science be to me?"

Let me ask in return: Are none of you going to emigrate? If you

have courage and wisdom, emigrate you will, some of you, instead of

stopping here to scramble over each other's backs for the scraps,

like black-beetles in a kitchen. And if you emigrate, you will soon

find out, if you have eyes and common sense, that the vegetable

wealth of the world is no more exhausted than its mineral wealth.

Exhausted? Not half of it--I believe not a tenth of it--is yet

known. Could I show you the wealth which I have seen in a single

Tropic island, not sixty miles square--precious timbers, gums,

fruits, what not, enough to give employment and wealth to thousands

and tens of thousands, wasting for want of being known and worked--

then you would see what a man who emigrates may do, by a little sound

knowledge of botany alone.

And if not. Suppose that any one of you, learning a little sound

Natural History, should abide here in Britain to your life's end, and

observe nothing but the hedgerow plants, he would find that there is

much more to be seen in those mere hedgerow plants than he fancies

now. The microscope will reveal to him in the tissues of any wood,

of any seed, wonders which will first amuse him, then puzzle him, and

at last (I hope) awe him, as he perceives that smallness of size

interferes in no way with perfection of development, and that

"Nature," as has been well said, "is greatest in that which is

least." And more. Suppose that he went further still. Suppose that

he extended his researches somewhat to those minuter vegetable forms,

the mosses, fungi, lichens; suppose that he went a little further

still, and tried what the microscope would show him in any stagnant

pool, whether fresh water or salt, of Desmidiae, Diatoms, and all

those wondrous atomies which seem as yet to defy our classification

into plants or animals. Suppose he learnt something of this, but

nothing of aught else. Would he have gained no solid wisdom? He

would be a stupider man than I have a right to believe any of my

readers to be, if he had not gained thereby somewhat of the most

valuable of treasures--namely, that inductive habit of mind, that

power of judging fairly of facts, without which no good or lasting

work will be done, whether in physical science, in social science, in

politics, in philosophy, in philology, or in history.

But more: let me urge you to study Natural Science, on grounds which

may be to you new and unexpected--on social, I had almost said on

political, grounds.

We all know, and I trust we all love, the names of Liberty, Equality,

and Brotherhood. We feel, I trust, that these words are too

beautiful not to represent true and just ideas; and that therefore

they will come true, and be fulfilled, somewhen, somewhere, somehow.

It may be in a shape very different from that which you, or I, or any

man expects; but still they will be fulfilled.

But if they are to come true, it is we, the individual men, who must

help them to come true for the whole world, by practising them

ourselves, when and where we can. And I tell you--that in becoming

scientific men, in studying science and acquiring the scientific

habit of mind, you will find yourselves enjoying a freedom, an

equality, a brotherhood, such as you will not find elsewhere just

now.

Freedom: what do we want freedom for? For this, at least; that we

may be each and all able to think what we choose; and to say what we

choose also, provided we do not say it rudely or violently, so as to

provoke a breach of the peace. That last was Mr. Buckle's definition

of freedom of speech. That was the only limit to it which he would

allow; and I think that that is Mr. John Stuart Mill's limit also.

It is mine. And I think we have that kind of freedom in these

islands as perfectly as any men are likely to have it on this earth.

But what I complain of is, that when men have got the freedom, three

out of four of them will not use it. What?--someone will answer--Do

you suppose that I will not say what I choose, and that I dare not

speak my own mind to any man? Doubtless. But are you sure first,

that you think what you choose, or only what someone else chooses for

you? Are you sure that you make up your own mind before you speak,

or let someone else make it up for you? Your speech may be free

enough, my good friend; and Heaven forbid that it should be anything

else: but are your thoughts free likewise? Are you sure that,

though you may hate bigotry in others, you are not somewhat of a

bigot yourself? That you do not look at only one side of a question,

and that the one which pleases you? That you do not take up your

opinions at second hand, from some book or some newspaper, which

after all only reflects your own feelings, your own opinions? You

should ask yourselves that question, seriously and often: "Are my

thoughts really free?" No one values more highly than I do the

advantage of a free press. But you must remember always that a

newspaper editor, however honest or able, is no more infallible than

the Pope; that he may, just as you may, only see one side of a

question, while any question is sure to have two sides, or perhaps

three or four; and if you only see the side which suits you, day

after day, month after month, you must needs become bigoted to it.

Your thoughts must needs run in one groove. They cannot (as Mr.

Matthew Arnold would say) "play freely round" a question; and look it

all over, boldly, patiently, rationally, charitably.

And I tell you that if you, or I, or any man, want to let our

thoughts play freely round questions, and so escape from the tendency

to become bigoted and narrow-minded which there is in every human

being, then we must acquire something of that inductive habit of mind

which the study of Natural Science gives. It is, after all, as

Professor Huxley says, only common sense well regulated. But then it

is well regulated; and how precious it is, if you can but get it.

The art of seeing, the art of knowing what you see; the art of

comparing, of perceiving true likenesses and true differences, and so

of classifying and arranging what you see: the art of connecting

facts together in your own mind in chains of cause and effect, and

that accurately, patiently, calmly, without prejudice, vanity, or

temper--this is what is wanted for true freedom of mind. But

accuracy, patience, freedom from prejudice, carelessness for all

except the truth, whatever the truth may be--are not these the

virtues of a truly free spirit? Then, as I said just now, I know no

study so able to give that free habit of mind as the Study of Natural

Science.

Equality, too: whatever equality may or may not be just, or

possible; this at least, is just, and I hope possible; that every

man, every child, of every rank, should have an equal chance of

education; an equal chance of developing all that is in him by

nature; an equal chance of acquiring a fair knowledge of those facts

of the universe which specially concern him; and of having his reason

trained to judge of them. I say, whatever equal rights men may or

may not have, they have this right. Let every boy, every girl, have

an equal and sound education. If I had my way, I would give the same

education to the child of the collier and to the child of a peer. I

would see that they were taught the same things, and by the same

method. Let them all begin alike, say I. They will be handicapped

heavily enough as they go on in life, without our handicapping them

in their first race. Whatever stable they come out of, whatever

promise they show, let them all train alike, and start fair, and let

the best colt win.

Well: but there is a branch of education in which, even now, the

poor man can compete fairly against the rich; and that is, Natural

Science. In the first place, the rich, blind to their own interest,

have neglected it hitherto in their schools; so that they have not

the start of the poor man on that subject which they have on many.

In the next place, Natural Science is a subject which a man cannot

learn by paying for teachers. He must teach it himself, by patient

observation, by patient common sense. And if the poor man is not the

rich man's equal in those qualities, it must be his own fault, not

his purse's. Many shops have I seen about the world, in which fools

could buy articles more or less helpful to them; but never saw I yet

an observation-shop, nor a common-sense shop either. And if any man

says, "We must buy books:" I answer, a poor man now can obtain better

scientific books than a duke or a prince could sixty years ago,

simply because then the books did not exist. When I was a boy I

would have given much, or rather my father would have given much, if

I could have got hold of such scientific books as are to be found now

in any first-class elementary school. And if more expensive books

are needed; if a microscope or apparatus is needed; can you not get

them by the co-operative method, which has worked so well in other

matters? Can you not form yourselves into a Natural Science club,

for buying such things and lending them round among your members; and

for discussion also, the reading of scientific papers of your own

writing, the comparing of your observations, general mutual help and

mutual instructions? Such societies are becoming numerous now, and

gladly should I see one in every town. For in science, as in most

matters, "As iron sharpeneth iron, so a man sharpeneth the

countenance of his friend."

And Brotherhood: well, if you want that; if you want to mix with

men, and men, too, eminently worth mixing with, on the simple ground

that "a man's a man for a' that;" if you want to become the

acquaintances, and--if you prove worthy--the friends, of men who will

be glad to teach you all they know, and equally glad to learn from

you anything you can teach them, asking no questions about you, save,

first--Is he an honest student of Nature for her own sake? And next-

-Is he a man who will not quarrel, or otherwise behave in an

unbrotherly fashion to his fellow-students?--If you want a ground of

brotherhood with men, not merely in these islands, but in America, on

the Continent--in a word, all over the world--such as rank, wealth,

fashion, or other artificial arrangements of the world cannot give

and cannot take away; if you want to feel yourself as good as any man

in theory, because you are as good as any man in practice, except

those who are better than you in the same line, which is open to any

and every man; if you wish to have the inspiring and ennobling

feeling of being a brother in a great freemasonry which owns no

difference of rank, of creed, or of nationality--the only

freemasonry, the only International League which is likely to make

mankind (as we all hope they will be some day) one--then become men

of science. Join the freemasonry in which Hugh Miller, the poor

Cromarty stonemason, in which Michael Faraday, the poor bookbinder's

boy, became the companions and friends of the noblest and most

learned on earth, looked up to by them not as equals merely but as

teachers and guides, because philosophers and discoverers.

Do you wish to be great? Then be great with true greatness; which

is,--knowing the facts of nature, and being able to use them. Do you

wish to be strong? Then be strong with true strength; which is,

knowing the facts of nature, and being able to use them. Do you wish

to be wise? Then be wise with true wisdom; which is, knowing the

facts of nature, and being able to use them. Do you wish to be free?

Then be free with true freedom; which is again, knowing the facts of

nature, and being able to use them.

I dare say some of my readers, especially the younger ones, will

demur to that last speech of mine. Well, I hope they will not be

angry with me for saying it. I, at least, shall certainly not he

angry with them. For when I was young I was very much of what I

suspect is their opinion. I used to think one could get perfect

freedom, and social reform, and all that I wanted, by altering the

arrangements of society and legislation; by constitutions, and Acts

of Parliament; by putting society into some sort of freedom-mill, and

grinding it all down, and regenerating it so. And that something can

be done by improved arrangements, something can be done by Acts of

Parliament, I hold still, as every rational man must hold.

But as I grew older, I began to see that if things were to be got

right, the freedom-mill would do very little towards grinding them

right, however well and amazingly it was made. I began to see that

what sort of flour came out at one end of the mill, depended mainly

on what sort of grain you had put in at the other; and I began to see

that the problem was to get good grain, and then good flour would be

turned out, even by a very clumsy old-fashioned sort of mill. And

what do I mean by good grain? Good men, honest men, accurate men,

righteous men, patient men, self-restraining men, fair men, modest

men. Men who are aware of their own vast ignorance compared with the

vast amount that there is to be learned in such a universe as this.

Men who are accustomed to look at both sides of a question; who,

instead of making up their minds in haste like bigots and fanatics,

wait like wise men, for more facts, and more thought about the facts.

In one word, men who had acquired just the habit of mind which the

study of Natural Science can give, and must give; for without it

there is no use studying Natural Science; and the man who has not got

that habit of mind, if he meddles with science, will merely become a

quack and a charlatan, only fit to get his bread as a spirit-rapper,

or an inventor of infallible pills.

And when I saw that, I said to myself--I will train myself, by

Natural Science, to the truly rational, and therefore truly able and

useful, habit of mind; and more, I will, for it is my duty as an

Englishman, train every Englishman over whom I can get influence in

the same scientific habit of mind, that I may, if possible, make him,

too, a rational and an able man.

And, therefore, knowing that most of you, my readers--probably all of

you, as you ought and must if you are Britons, think much of social

and political questions---therefore, I say, I entreat you to

cultivate the scientific spirit by which alone you can judge justly

of those questions. I ask you to learn how to "conquer nature by

obeying her," as the great Lord Bacon said two hundred and fifty

years ago. For so only will you in your theories and your movements,

draw "bills which nature will honour"--to use Mr. Carlyle's famous

parable--because they are according to her unchanging laws, and not

have them returned on your hands, as too many theorists' are, with

"no effects" written across their backs.

Take my advice for yourselves, dear readers, and for your children

after you; for, believe me, I am showing you the way to true and

useful, and, therefore, to just and deserved power. I am showing you

the way to become members of what I trust will be--what I am certain

ought to be--the aristocracy of the future.

I say it deliberately, as a student of society and of history. Power

will pass more and more, if all goes healthily and well, into the

hands of scientific men; into the hands of those who have made due

use of that great heirloom which the philosophers of the seventeenth

century left for the use of future generations, and specially of the

Teutonic race.

For the rest, events seem but too likely to repeat themselves again

and again all over the world, in the same hopeless circle.

Aristocracies of mere birth decay and die, and give place to

aristocracies of mere wealth; and they again to "aristocracies of

genius," which are really aristocracies of the noisiest, of mere

scribblers and spouters, such as France is writhing under at this

moment. And when these last have blown off their steam, with mighty

roar, but without moving the engine a single yard, then they are but

too likely to give place to the worst of all aristocracies, the

aristocracy of mere "order," which means organised brute force and

military despotism. And, after that, what can come, save anarchy,

and decay, and social death?

What else?--unless there be left in the nation, in the society, as

the salt of the land, to keep it all from rotting, a sufficient

number of wise men to form a true working aristocracy, an aristocracy

of sound and rational science? If they be strong enough (and they

are growing stronger day by day over the civilised world), on them

will the future of that world mainly depend. They will rule, and

they will act--cautiously we may hope, and modestly and charitably,

because in learning true knowledge they will have learnt also their

own ignorance, and the vastness, the complexity, the mystery of

nature. But they will be able to rule, they will be able to act,

because they have taken the trouble to learn the facts and the laws

of nature. They will rule; and their rule, if they are true to

themselves, will be one of health and wealth, and peace, of prudence

and of justice. For they alone will be able to wield for the benefit

of man the brute forces of nature; because they alone will have

stooped, to "conquer nature by obeying her."

So runs my dream. I ask my young readers to help towards making that

dream a fact, by becoming (as many of them as feel the justice of my

words) honest and earnest students of Natural Science.

But now: why should I, as a clergyman, interest myself specially in

the spread of Natural Science? Am I not going out of my proper

sphere to meddle with secular matters? Am I not, indeed, going into

a sphere out of which I had better keep myself, and all over whom I

may have influence? For is not science antagonistic to religion?

and, if so, what has a clergyman to do, save to warn the young

against it, instead of attracting them towards it?

First, as to meddling with secular matters. I grudge that epithet of

"secular" to any matter whatsoever. But I do more; I deny it to

anything which God has made, even to the tiniest of insects, the most

insignificant atom of dust. To those who believe in God, and try to

see all things in God, the most minute natural phenomenon cannot be

secular. It must be divine; I say, deliberately, divine; and I can

use no less lofty word. The grain of dust is a thought of God; God's

power made it; God's wisdom gave it whatsoever properties or

qualities it may possess; God's providence has put it in the place

where it is now, and has ordained that it should be in that place at

that moment, by a train of causes and effects which reaches back to

the very creation of the universe. The grain of dust can no more go

from God's presence, or flee from God's Spirit, than you or I can.

If it go up to the physical heaven, and float (as it actually often

does) far above the clouds, in those higher strata of the atmosphere

which the aeronaut has never visited, whither the Alpine snow-peaks

do not rise, even there it will be obeying physical laws which we

term hastily laws of Nature, but which are really the laws of God:

and if it go down into the physical abyss; if it be buried fathoms,

miles, below the surface, and become an atom of some rock still in

the process of consolidation, has it escaped from God, even in the

bowels of the earth? Is it not there still obeying physical laws, of

pressure, heat, crystallisation, and so forth, which are laws of God-

-the will and mind of God concerning particles of matter? Only look

at all created things in this light--look at them as what they are,

the expressions of God's mind and will concerning this universe in

which we live--"the Word of God," as Bacon says, "revealed in facts"-

-and then you will not fear physical science; for you will be sure

that, the more you know of physical science, the more you will know

of the works and of the will of God. At least, you will be in

harmony with the teaching of the Psalmist: "The heavens," says he,

"declare the glory of God; and the firmament showeth His handiwork.

There is neither speech nor language where their voices are not heard

among them." So held the Psalmist concerning astronomy, the

knowledge of the heavenly bodies; and what he says of sun and stars

is true likewise of the flowers around our feet, of which the

greatest Christian poet of modern times has said--

To me the meanest flower that grows may give

Thoughts that do lie too deep for tears.

So, again, you will be in harmony with the teaching of St. Paul, who

told the Romans "that the invisible things of God are clearly seen

from the creation of the-world, being understood by the things that

are made, even His eternal power and Godhead;" and who told the

savages of Lycaonia that "God had not left Himself without witness,

in that He did good and sent men rain from heaven, and fruitful

seasons, filling men's hearts with food and gladness." Rain and

fruitful seasons witnessed to all men of a Father in heaven. And he

who wishes to know how truly St. Paul spoke, let him study the laws

which produce and regulate rain and fruitful seasons, what we now

call climatology, meteorology, geography of land and water. Let him

read that truly noble Christian work, Maury's "Physical Geography of

the Sea;" and see, if he be a truly rational man, how advanced

science, instead of disproving, has only corroborated St. Paul's

assertion, and how the ocean and the rain-cloud, like the sun and

stars, declare the glory of God. And if anyone undervalues the

sciences which teach us concerning stones and plants and animals, or

thinks that nothing can be learnt from them concerning God--allow one

who has been from childhood only a humble, though he trusts a

diligent student of these sciences--allow him, I say, to ask in all

reverence, but in all frankness, who it was who said, "Consider the

lilies of the field, how they grow." "Consider the birds of the air-

-and how your Heavenly Father feedeth them."

Consider them. If He has bid you do so, can you do so too much?

I know, of course, the special application which our Lord made of

these words. But I know, too, from experience, that the more you

study nature, in all her forms the more you will find that the

special application itself is deeper, wider, more literally true,

more wonderful, more tender, and if I dare use such a word, more

poetic, than the unscientific man can guess.

But let me ask you further--do you think that our Lord in that

instance, and in those many instances in which He drew his parables

and lessons from natural objects, was leading men's minds on to

dangerous ground, and pointing out to them a subject of contemplation

in the laws and processes of the natural world, and their analogy

with those of the spiritual world, the kingdom of God--a subject of

contemplation, I say, which it was not safe to contemplate too much?

I appeal to your common sense. If He who spoke these words were (as

I believe) none other than the Creator of the universe, by whom all

things were made, and without whom nothing was made that is made, do

you suppose that He would have bid you to consider His universe, had

it been dangerous for you to do so?

Do you suppose, moreover, that the universe, which He, the Truth, the

Light, the Love, has made, can be otherwise then infinitely worthy to

be considered? or that the careful, accurate, and patient

consideration of it, even to its minutest details, can be otherwise

than useful to man, and can bear witness of aught, save the mind and

character of Him who made it? And if so, can it be a work unfit for,

unworthy of, a clergyman--whose duty is to preach Him to all, and in

all ways,--to call on men to consider that physical world which, like

the spiritual world, consists, holds together, by Him, and lives and

moves and has its being in Him?

And here I must pause to answer an objection which I have heard in my

youth from many pious and virtuous people--better people in God's

sight, than I, I fear, can pretend to be.

They used to say, "This would be all very true if there were not a

curse upon the earth." And then they seemed to deduce, from the fact

of that curse, a vague notion (for it was little more) that this

world was the devil's world, and that therefore physical facts could

not be trusted, because they were disordered, and deceptive, and what

not.

Now, in justice to the Bible, and in justice to the Church of

England, I am bound to say that such a statement, or anything like

it, is contrary to the doctrines of both. It is contrary to

Scripture. According to it, the earth is not cursed. For it is said

in Gen. viii. 21, "And the Lord said, I will not again curse the

ground any more for man's sake. While the earth remaineth, seed-time

and harvest, cold and heat, summer and winter, day and night shall

not cease." According to Scripture, again, physical facts are not

disordered. The Psalmist says, "They continue this day according to

their ordinance; for all things serve Thee." And again, "Thou hast

made them fast for ever and ever. Thou hast given them a law which

cannot be broken."

So does the Bible (not to quote over again the passages which I have

already given you from St. Paul, and One greater than St. Paul)

declare the permanence of natural laws, and the trustworthiness of

natural phenomena as obedient to God. And so does the Church of

England. For she has incorporated into her services that magnificent

hymn, which our forefathers called the Song of the Three Children;

which is, as it were, the very flower and crown of the Old Testament;

the summing up of all that is true and eternal in the old Jewish

faith; as true for us as for them: as true millions of years hence

as it is now--which cries to all heaven and earth, from the skies

above our heads to the green herb beneath our feet, "O all ye works

of the Lord, bless ye the Lord; praise Him and magnify Him for ever."

On that one hymn I take my stand. That is my charter as a student of

Natural Science. As long as that is sung in an English church, I

have a right to investigate Nature boldly without stint or stay, and

to call on all who have the will, to investigate her boldly likewise,

and with Socrates of old, to follow the Logos whithersoever it leads.

The Logos. I must pause on that word. It meant at first, no doubt,

simply speech, argument, reason. In the mind of Socrates it had a

deeper meaning, at which he only dimly guessed; which was seen more

clearly by Philo and the Alexandrian Jews; which was revealed in all

its fulness to the beloved Apostle St. John, till he gathered speech

to tell men of a Logos, a Word, who was in the beginning with God,

and was God; by whom all things were made, and without Him was not

anything made that was made; and how in Him was Life, and the Life

was the light of men; and that He was none other than Jesus Christ

our Lord.

Yes, that is the truth. And to that truth no man can add, and from

it no man can take away. And as long as we believe that as long as

we believe that in His light alone can we see light--as long as we

believe that the light around us, whether physical or spiritual, is

given by Him without whom nothing is made--so long we shall not fear

to meet Light, so long we shall not fear to investigate Life; for we

shall know, however strange or novel, beautiful or awful, the

discoveries we make may be, we are only following the Word

whithersoever He may lead us; and that He can never lead us amiss

I. THE SOIL OF THE FIELD {2}

My dear readers, let me, before touching on the special subject of

this paper, say a few words on that of the whole series.

It is geology: that is, the science which explains to us the RIND of

the earth; of what it is made; how it has been made. It tells us

nothing of the mass of the earth. That is, properly speaking, an

astronomical question. If I may be allowed to liken this earth to a

fruit, then astronomy will tell us--when it knows--how the fruit

grew, and what is inside the fruit. Geology can only tell us at most

how its rind, its outer covering, grew, and of what it is composed; a

very small part, doubtless, of all that is to be known about this

planet.

But as it happens, the mere rind of this earth-fruit which has,

countless ages since, dropped, as it were, from the Bosom of God, the

Eternal Fount of Life--the mere rind of this earth-fruit, I say, is

so beautiful and so complex, that it is well worth our awful and

reverent study. It has been well said, indeed, that the history of

it, which we call geology, would be a magnificent epic poem, were

there only any human interest in it; did it deal with creatures more

like ourselves than stones, and bones, and the dead relics of plants

and beasts. Whether there be no human interest in geology; whether

man did not exist on the earth during ages which have seen enormous

geological changes, is becoming more and more an open question.

But meanwhile all must agree that there is matter enough for

interest--nay, room enough for the free use of the imagination, in a

science which tells of the growth and decay of whole mountain-ranges,

continents, oceans, whole tribes and worlds of plants and animals.

And yet it is not so much for the vastness and grandeur of those

scenes of the distant past, to which the science of geology

introduces us, that I value it as a study, and wish earnestly to

awaken you to its beauty and importance. It is because it is the

science from which you will learn most easily a sound scientific

habit of thought. I say most easily; and for these reasons. The

most important facts of geology do not require, to discover them, any

knowledge of mathematics or of chemical analysis; they may be studied

in every bank, every grot, every quarry, every railway-cutting, by

anyone who has eyes and common sense, and who chooses to copy the

late illustrious Hugh Miller, who made himself a great geologist out

of a poor stonemason. Next, its most important theories are not, or

need not be, wrapped up in obscure Latin and Greek terms. They may

be expressed in the simplest English, because they are discovered by

simple common sense. And thus geology is (or ought to be), in

popular parlance, the people's science--the science by studying

which, the man ignorant of Latin, Greek, mathematics, scientific

chemistry, can yet become--as far as his brain enables him--a truly

scientific man.

But how shall we learn science by mere common sense?

First. Always try to explain the unknown by the known. If you meet

something which you have not seen before, then think of the thing

most like it which you have seen before; and try if that which you

know explains the one will not explain the other also. Sometimes it

will; sometimes it will not. But if it will, no one has a right to

ask you to try any other explanation.

Suppose, for instance, that you found a dead bird on the top of a

cathedral tower, and were asked how you thought it had got there.

You would say, "Of course, it died up here." But if a friend said,

"Not so; it dropped from a balloon, or from the clouds;" and told you

the prettiest tale of how the bird came to so strange an end, you

would answer, "No, no; I must reason from what I know. I know that

birds haunt the cathedral tower; I know that birds die; and

therefore, let your story be as pretty as it may, my common sense

bids me take the simplest explanation, and say--it died here." In

saying that, you would be talking scientifically. You would have

made a fair and sufficient induction (as it is called) from the facts

about birds' habits and birds' deaths which you know.

But suppose that when you took the bird up you found that it was

neither a jackdaw, nor a sparrow nor a swallow, as you expected, but

a humming-bird. Then you would be adrift again. The fact of it

being a humming-bird would be a new fact which you had not taken into

account, and for which your old explanation was not sufficient; and

you would have to try a new induction--to use your common sense

afresh--saying, "I have not to explain merely how a dead bird got

here, but how a dead humming-bird."

And now, if your imaginative friend chimed in triumphantly with: "Do

you not see that I was right after all? Do you not see that it fell

from the clouds? that it was swept away hither, all the way from

South America, by some south-westerly storm, and wearied out at last,

dropped here to find rest, as in a sacred-place?" what would you

answer? "My friend, that is a beautiful imagination; but I must

treat it only as such, as long as I can explain the mystery more

simply by facts which I do know. I do not know that humming-birds

can be blown across the Atlantic alive. I do know they are actually

brought across the Atlantic dead; are stuck in ladies' hats. I know

that ladies visit the cathedral; and odd as the accident is, I prefer

to believe, till I get a better explanation, that the humming-bird

has simply dropped out of a lady's hat." There, again, you would be

speaking common sense; and using, too, sound inductive method; trying

to explain what you do not know from what you do know already.

Now, I ask of you to employ the same common sense when you read and

think of Geology.

It is very necessary to do so. For in past times men have tried to

explain the making of the world around them, its oceans, rivers,

mountains, and continents, by I know not what of fancied cataclysms

and convulsions of nature; explaining the unknown by the still more

unknown, till some of their geological theories were no more

rational, because no more founded on known facts, than that of the

New Zealand Maories, who hold that some god, when fishing, fished up

their islands out of the bottom of the ocean. But a sounder and

wiser school of geologists now reigns; the father of whom, in England

at least, is the venerable Sir Charles Lyell. He was almost the

first of Englishmen who taught us to see--what common sense tells us-

-that the laws which we see at work around us now have been most

probably at work since the creation of the world; and that whatever

changes may seem to have taken place in past ages, and in ancient

rocks, should be explained, if possible, by the changes which are

taking place now in the most recent deposits--in the soil of the

field.

And in the last forty years--since that great and sound idea has

become rooted in the minds of students, and especially of English

students, geology has thriven and developed, perhaps more than any

other science; and has led men on to discoveries far more really

astonishing and awful than all fancied convulsions and cataclysms.

I have planned this series of papers, therefore, on Sir Charles

Lyell's method. I have begun by trying to teach a little about the

part of the earth's crust which lies nearest us, which we see most

often; namely, the soil; intending, if my readers do me the honour to

read the papers which follow, to lead them downward, as it were, into

the earth; deeper and deeper in each paper, to rocks and minerals

which are probably less known to them than the soil in the fields.

Thus you will find I shall lead you, or try to lead you on,

throughout the series, from the known to the unknown, and show you

how to explain the latter by the former. Sir Charles Lyell has, I

see, in the new edition of his "Student's Elements of Geology," begun

his book with the uppermost, that is, newest, strata, or layers; and

has gone regularly downwards in the course of the book to the lowest

or earliest strata; and I shall follow his plan.

I must ask you meanwhile to remember one law or rule, which seems to

me founded on common sense; namely, that the uppermost strata are

really almost always the newest; that when two or more layers,

whether of rock or earth--or indeed two stones in the street, or two

sheets on a bed, or two books on a table--any two or more lifeless

things, in fact, lie one on the other, then the lower one was most

probably put there first, and the upper one laid down on the lower.

Does that seem to you a truism? Do I seem almost impertinent in

asking you to remember it? So much the better. I shall be saved

unnecessary trouble hereafter.

But some one may say, and will have a right to say, "Stop--the lower

thing may have been thrust under the upper one." Quite true: and

therefore I said only that the lower one was most probably put there

first. And I said "most probably," because it is most probable that

in nature we should find things done by the method which costs least

force, just as you do them. I will warrant that when you want to

hide a thing, you lay something down on it ten times for once that

you thrust it under something else. You may say, "What? When I want

to hide a paper, say, under the sofa-cover, do I not thrust it

under?"

No, you lift up the cover, and slip the paper in, and let the cover

fall on it again. And so, even in that case, the paper has got into

its place first.

Now why is this? Simply because in laying one thing on another you

only move weight. In thrusting one thing under another, you have not

only to move weight, but to overcome friction. That is why you do

it, though you are hardly aware of it: simply because so you employ

less force, and take less trouble.

And so do clays and sands and stones. They are laid down on each

other, and not thrust under each other, because thus less force is

expended in getting them into place.

There are exceptions. There are cases in which nature does try to

thrust one rock under another. But to do that she requires a force

so enormous, compared with what is employed in laying one rock on

another, that (so to speak) she continually fails; and instead of

producing a volcanic eruption, produces only an earthquake. Of that

I may speak hereafter, and may tell you, in good time, how to

distinguish rocks which have been thrust in from beneath, from rocks

which have been laid down from above, as every rock between London

and Birmingham or Exeter has been laid down. That I only assert now.

But I do not wish you to take it on trust from me. I wish to prove

it to you as I go on, or to do what is far better for you: to put

you in the way of proving it for yourself, by using your common

sense.

At the risk of seeming prolix, I must say a few more words on this

matter. I have special reasons for it. Until I can get you to "let

your thoughts play freely" round this question of the superposition

of soils and rocks, there will be no use in my going on with these

papers.

Suppose then (to argue from the known to the unknown) that you were

watching men cleaning out a pond. Atop, perhaps, they would come to

a layer of soft mud, and under that to a layer of sand. Would not

common sense tell you that the sand was there first, and that the

water had laid down the mud on the top of it? Then, perhaps, they

might come to a layer of dead leaves. Would not common sense tell

you that the leaves were there before the sand above them? Then,

perhaps, to a layer of mud again. Would not common sense tell you

that the mud was there before the leaves? And so on down to the

bottom of the pond, where, lastly, I think common sense would tell

you that the bottom of the pond was there already, before all the

layers which were laid down on it. Is not that simple common sense?

Then apply that reasoning to the soils and rocks in any spot on

earth. If you made a deep boring, and found, as you would in many

parts of this kingdom, that the boring, after passing through the

soil of the field, entered clays or loose sands, you would say the

clays were there before the soil. If it then went down into

sandstone, you would say--would you not?--that sandstone must have

been here before the clay; and however thick--even thousands of feet-

-it might be, that would make no difference to your judgment. If

next the boring came into quite different rocks; into a different

sort of sandstone and shales, and among them beds of coal, would you

not say--These coal-beds must have been here before the sandstones?

And if you found in those coal-beds dead leaves and stems of plants,

would you not say--Those plants must have been laid down here before

the layers above them, just as the dead leaves in the pond were?

If you then came to a layer of limestone, would you not say the same?

And if you found that limestone full of shells and corals, dead, but

many of them quite perfect, some of the corals plainly in the very

place in which they grew, would you not say--These creatures must

have lived down here before the coal was laid on top of them? And

if, lastly, below the limestone you came to a bottom rock quite

different again, would you not say--The bottom rock must have been

here before the rocks on the top of it?

And if that bottom rock rose up a few miles off, two thousand feet,

or any other height, into hills, what would you say then? Would you

say: "Oh, but the rock is not bottom rock; is not under the

limestone here, but higher than it. So perhaps in this part it has

made a shift, and the highlands are younger than the lowlands; for

see, they rise so much higher?" Would not that be as wise as to say

that the bottom of the pond was not there before the pond mud,

because the banks round the pond rose higher than the mud?

Now for the soil of the field.

If we can understand a little about it, what it is made of, and how

it got there, we shall perhaps be on the right road toward

understanding what all England--and, indeed, the crust of this whole

planet--is made of; and how its rocks and soils got there.

But we shall best understand how the soil in the field was made, by

reasoning, as I have said, from the known to the unknown. What do I

mean? This: On the uplands are fields in which the soil is already

made. You do not know how? Then look for a field in which the soil

is still being made. There are plenty in every lowland. Learn how

it is being made there; apply the knowledge which you learn from them

to the upland fields which are already made.

If there is, as there usually is, a river-meadow, or still better, an

aestuary, near your town, you have every advantage for seeing soil

made. Thousands of square feet of fresh-made soil spread between

your town and the sea; thousands more are in process of being made.

You will see now why I have begun with the soil in the field; because

it is the uppermost, and therefore latest, of all the layers; and

also for this reason, that, if Sir Charles Lyell's theory be true--as

it is--then the soils and rocks below the soil of the field may have

been made in the very same way in which the soil of the field is

made. If so, it is well worth our while to examine it.

You all know from whence the soil comes which has filled up, in the

course of ages, the great aestuaries below London, Stirling, Chester,

or Cambridge.

It is river mud and sand. The river, helped by tributary brooks

right and left, has brought down from the inland that enormous mass.

You know that. You know that every flood and freshet brings a fresh

load, either of fine mud or of fine sand, or possibly some of it

peaty matter out of distant hills. Here is one indisputable fact

from which to start. Let us look for another.

How does the mud get into the river? The rain carries it thither.

If you wish to learn the first elements of geology by direct

experiment, do this: The next rainy day--the harder it rains the

better--instead of sitting at home over the fire, and reading a book

about geology, put on a macintosh and thick boots, and get away, I

care not whither, provided you can find there running water. If you

have not time to get away to a hilly country, then go to the nearest

bit of turnpike road, or the nearest sloping field, and see in little

how whole continents are made, and unmade again. Watch the rain

raking and sifting with its million delicate fingers, separating the

finer particles from the coarser, dropping the latter as soon as it

can, and carrying the former downward with it toward the sea. Follow

the nearest roadside drain where it runs into a pond, and see how it

drops the pebbles the moment it enters the pond, and then the sand in

a fan-shaped heap at the nearest end; but carries the fine mud on,

and holds it suspended, to be gradually deposited at the bottom in

the still water; and say to yourself: Perhaps the sands which cover

so many inland tracts were dropped by water, very near the shore of a

lake or sea, and by rapid currents. Perhaps, again, the brick clays,

which are often mingled with these sands, were dropped, like the mud

in the pond, in deeper water farther from the shore, and certainly in

stilt water. But more. Suppose once more, then, that looking and

watching a pond being cleared out, under the lowest layer of mud, you

found--as you would find in any of those magnificent reservoirs so

common in the Lancashire hills--a layer of vegetable soil, with grass

and brushwood rooted in it. What would you say but: The pond has

not been always full. It has at some time or other been dry enough

to let a whole copse grow up inside it?

And if you found--as you will actually find along some English

shores--under the sand hills, perhaps a bed of earth with shells and

bones; under that a bed of peat; under that one of blue silt; under

that a buried forest, with the trees upright and rooted; under that

another layer of blue silt full of roots and vegetable fibre; perhaps

under that again another old land surface with trees again growing in

it; and under all the main bottom clay of the district--what would

common sense tell you? I leave you to discover for yourselves. It

certainly would not tell you that those trees were thrust in there by

a violent convulsion, or that all those layers were deposited there

in a few days, or even a few years; and you might safely indulge in

speculations about the antiquity of the aestuary, and the changes

which it has undergone, with which I will not frighten you at

present.

It will be fair reasoning to argue thus. You may not be always right

in your conclusion, but still you will be trying fairly to explain

the unknown by the known.

But have Rain and Rivers alone made the soil?

How very much they have done toward making it you will be able to

judge for yourselves, if you will read the sixth chapter of Sir

Charles Lyell's new "Elements of Geology," or the first hundred pages

of that admirable book, De la Beche's "Geological Observer;" and

last, but not least, a very clever little book called "Rain and

Rivers," by Colonel George Greenwood.

But though rain, like rivers, is a carrier of soil, it is more. It

is a maker of soil, likewise; and by it mainly the soil of an upland

field is made, whether it be carried down to the sea or not.

If you will look into any quarry you will see that however compact

the rock may be a few feet below the surface, it becomes, in almost

every case, rotten and broken up as it nears the upper soil, till you

often cannot tell where the rock ends and the soil begins.

Now this change has been produced by rain. First, mechanically, by

rain in the shape of ice. The winter rain gets into the ground, and

does by the rock what it has done by the stones of many an old

building. It sinks into the porous stone, freezes there, expands in

freezing, and splits and peels the stone with a force which is slowly

but surely crumbling the whole of Northern Europe and America to

powder.

Do you doubt me? I say nothing but what you can judge of yourselves.

The next time you go up any mountain, look at the loose broken stones

with which the top is coated, just underneath the turf. What has

broken them up but frost? Look again, as stronger proof, at the

talus of broken stones--screes, as they call them in Scotland;

rattles, as we call them in Devon--which lie along the base of many

mountain cliffs. What has brought them down but frost? If you ask

the country folk they will tell you whether I am right or not. If

you go thither, not in the summer, but just after the winter's frost,

you will see for yourselves, by the fresh frost-crop of newly-broken

bits, that I am right. Possibly you may find me to be even more

right than is desirable, by having a few angular stones, from the

size of your head to that of your body, hurled at you by the frost-

giants up above. If you go to the Alps at certain seasons, and hear

the thunder of the falling rocks, and see their long lines--moraines,

as they are called--sliding slowly down upon the surface of the

glacier, then you will be ready to believe the geologist who tells

you that frost, and probably frost alone, has hewn out such a peak as

the Matterhorn from some vast table-land; and is hewing it down

still, winter after winter, till some day, where the snow Alps now

stand, there shall be rolling uplands of rich cultivable soil.

So much for the mechanical action of rain, in the shape of ice. Now

a few words on its chemical action.

Rain water is seldom pure. It carries in it carbonic acid; and that

acid, beating in shower after shower against the face of a cliff--

especially if it be a limestone cliff--weathers the rock chemically;

changing (in case of limestone) the insoluble carbonate of lime into

a soluble bicarbonate, and carrying that away in water, which,

however clear, is still hard. Hard water is usually water which has

invisible lime in it; there are from ten to fifteen grains and more

of lime in every gallon of limestone water. I leave you to calculate

the enormous weight of lime which must be so carried down to the sea

every year by a single limestone or chalk brook. You can calculate

it, if you like, by ascertaining the weight of lime in each gallon,

and the average quantity of water which comes down the stream in a

day; and when your sum is done, you will be astonished to find it one

not of many pounds, but probably of many tons, of solid lime, which

you never suspected or missed from the hills around. Again, by the

time the rain has sunk through the soil, it is still less pure. It

carries with it not only carbonic acid, but acids produced by

decaying vegetables--by the roots of the grasses and trees which grow

above; and they dissolve the cement of the rock by chemical action,

especially if the cement be lime or iron. You may see this for

yourselves, again and again. You may see how the root of a tree,

penetrating the earth, discolours the soil with which it is in

contact. You may see how the whole rock, just below the soil, has

often changed in colour from the compact rock below, if the soil be

covered with a dense layer of peat or growing vegetables.

But there is another force at work, and quite as powerful as rain and

rivers, making the soil of alluvial flats. Perhaps it has helped,

likewise, to make the soil of all the lowlands in these isles--and

that is, the waves of the sea.

If you ever go to Parkgate, in Cheshire, try if you cannot learn

there a little geology.

Walk beyond the town. You find the shore protected for a long way by

a sea-wall, lest it should be eaten away by the waves. What the

force of those waves can be, even on that sheltered coast, you may

judge--at least you could have judged this time last year--by the

masses of masonry torn from their iron clampings during the gale of

three winters since. Look steadily at those rolled blocks, those

twisted stanchions, if they are there still; and then ask yourselves-

-it will be fair reasoning from the known to the unknown--What effect

must such wave-power as that have had beating and breaking for

thousands of years along the western coasts of England, Scotland,

Ireland? It must have eaten up thousands of acres--whole shires, may

be, ere now. Its teeth are strong enough, and it knows neither rest

nor pity, the cruel hungry sea. Give it but time enough, and what

would it not eat up? It would eat up, in the course of ages, all the

dry land of this planet, were it not baffled by another counteracting

force, of which I shall speak hereafter.

As you go on beyond the sea-wall, you find what it is eating up. The

whole low cliff is going visibly. But whither is it going? To form

new soil in the aestuary. Now you will not wonder how old harbours

so often become silted up. The sea has washed the land into them.

But more, the sea-currents do not allow the sands of the aestuary to

escape freely out to sea. They pile it up in shifting sand-banks

about the mouth of the aestuary. The prevailing sea-winds, from

whatever quarter, catch up the sand, and roll it up into sand-hills.

Those sand-hills are again eaten down by the sea, and mixed with the

mud of the tide-flats, and so is formed a mingled soil, partly of

clayey mud, partly of sand; such a soil as stretches over the greater

part of all our lowlands.

Now, why should not that soil, whether in England or in Scotland,

have been made by the same means as that of every aestuary.

You find over great tracts of East Scotland, Lancashire, Norfolk,

etc., pure loose sand just beneath the surface, which looks as if it

was blown sand from a beach. Is it not reasonable to suppose that it

is? You find rising out of many lowlands, crags which look exactly

like old sea-cliffs eaten by the waves, from the base of which the

waters have gone back. Why should not those crags be old sea-cliffs?

Why should we not, following our rule of explaining the unknown by

the known, assume that such they are till someone gives us a sound

proof that they are not; and say--These great plains of England and

Scotland were probably once covered by a shallow sea, and their soils

made as the soil of any tide-flat is being made now?

But you may say, and most reasonably "The tide-flats are just at the

sea-level. The whole of the lowland is many feet above the sea; it

must therefore have been raised out of the sea, according to your

theory: and what proofs have you of that?"

Well, that is a question both grand and deep, on which I shall not

enter yet; but meanwhile, to satisfy you that I wish to play fair

with you, I ask you to believe nothing but what you can prove for

yourselves. Let me ask you this: suppose that you had proof

positive that I had fallen into the river in the morning; would not

your meeting me in the evening be also proof positive that somehow or

other I had in the course of the day got out of the river? I think

you will accept that logic as sound.

Now if I can give you proof positive, proof which you can see with

your own eyes, and handle with your own hands, and alas! often feel

but too keenly with your own feet, that the whole of the lowlands

were once beneath the sea; then will it not be certain that, somehow

or other, they must have been raised out of the sea again?

And that I propose to do in my next paper, when I speak of the

pebbles in the street.

Meanwhile I wish you to face fairly the truly grand idea, which all I

have said tends to prove true--that all the soil we see is made by

the destruction of older soils, whether soft as clay, or hard as

rock; that rain, rivers, and seas are perpetually melting and

grinding up old land, to compose new land out of it; and that it must

have been doing so, as long as rain, rivers, and seas have existed.

"But how did the first land of all get made?" I can only reply: A

natural question: but we can only answer that, by working from the

known to the unknown. While we are finding out how these later lands

were made and unmade, we may stumble on some hints as to how the

first primeval continents rose out of the bosom of the sea.

And thus I end this paper. I trust it has not been intolerably dull.

But I wanted at starting to show my readers something of the right

way of finding out truth on this and perhaps on all subjects; to make

some simple appeals to your common sense; and to get you to accept

some plain rules founded on common sense, which will be of infinite

use to both you and me in my future papers.

I hope, meanwhile, that you will agree with me, that there is plenty

of geological matter to be seen and thought over in the neighbourhood

of any town.

Be sure, that wherever there is a river, even a drain; and a stone

quarry, or even a roadside bank; much more where there is a sea, or a

tidal aestuary, there is geology enough to be learnt, to explain the

greater part of the making of all the continents on the globe.

II. THE PEBBLES IN THE STREET

If you, dear reader, dwell in any northern town, you will almost

certainly see paving courts and alleys, and sometimes--to the

discomfort of your feet--whole streets, or set up as bournestones at

corners, or laid in heaps to be broken up for road-metal, certain

round pebbles, usually dark brown or speckled gray, and exceedingly

tough and hard. Some of them will be very large--boulders of several

feet in diameter. If you move from town to town, from the north of

Scotland as far down as Essex on the east, or as far down as

Shrewsbury and Wolverhampton (at least) on the west, you will still

find these pebbles, but fewer and smaller as you go south. It

matters not what the rocks and soils of the country round may be.

However much they may differ, these pebbles will be, on the whole,

the same everywhere.

But if your town be south of the valley of the Thames, you will find,

as far as I am aware, no such pebbles there. The gravels round you

will be made up entirely of rolled chalk flints, and bits of beds

immediately above or below the chalk. The blocks of "Sarsden"

sandstone--those of which Stonehenge is built--and the "plum-pudding

stones" which are sometimes found with them, have no kindred with the

northern pebbles. They belong to beds above the chalk.

Now if, seeing such pebbles about your town, you inquire, like a

sensible person who wishes to understand something of the spot on

which he lives, whence they come, you will be shown either a gravel-

pit or a clay-pit. In the gravel the pebbles and boulders lie mixed

with sand, as they do in the railway cutting just south of

Shrewsbury; or in huge mounds of fine sweet earth, as they do in the

gorge of the Tay about Dunkeld, and all the way up Strathmore, where

they form long grassy mounds--tomauns as they call them in some parts

of Scotland--askers as they call them in Ireland. These mounds, with

their sweet fresh turf rising out of heather and bog, were tenanted--

so Scottish children used to believe--by fairies. He that was lucky

might hear inside them fairy music, and, the jingling of the fairy

horses' trappings. But woe to him if he fell asleep upon the mound,

for he would be spirited away into fairyland for seven years, which

would seem to him but one day. A strange fancy; yet not so strange

as the actual truth as to what these mounds are, and how they came

into their places.

Or again, you might find that your town's pebbles and boulders came

out of a pit of clay, in which they were stuck, without any order or

bedding, like plums and raisins in a pudding. This clay goes usually

by the name of boulder-clay. You would see such near any town in

Cheshire and Lancashire; or along Leith shore, near Edinburgh; or, to

give one more instance out of hundreds, along the coast at

Scarborough. If you walk along the shore southward of that town, you

will see, in the gullies of the cliff, great beds of sticky clay,

stuffed full of bits of every rock between the Lake mountains and

Scarborough, from rounded pebbles of most ancient rock down to great

angular fragments of ironstone and coal. There, as elsewhere, the

great majority of the pebbles have nothing to do with the rock on

which the clay happens to lie, but have come, some of them, from

places many miles away.

Now if we find spread over a low land pebbles composed of rocks which

are only found in certain high lands, is it not an act of common

sense to say--These pebbles have come from the highlands? And if the

pebbles are rounded, while the rocks like them in the highlands

always break off in angular shapes, is it not, again, an act of mere

common sense to say--These pebbles were once angular, and have been

rubbed round, either in getting hither or before they started hither?

Does all this seem to you mere truism, my dear reader? If so, I am

sincerely glad to hear it. It was not so very long ago that such

arguments would have been considered not only no truisms, but not

even common sense.

But to return, let us take, as an example, a sample of these boulder

clay pebbles from the neighbourhood of Liverpool and Birkenhead, made

by Mr. De Rance, the government geological surveyor:

Granite, greenstone, felspar porphyry, felstone, quartz rock (all

igneous rocks, that is, either formed by, or altered by volcanic

heat, and almost all found in the Lake mountains), 37 per cent.

Silurian grits (the common stones of the Lake mountains deposited by

water), 43 per cent.

Ironstone, 1 per cent.

Carboniferous limestone, 5 per cent.

Permian or Triassic sandstones, i.e. rocks immediately round

Liverpool, 12 per cent.

Now, does not this sample show, as far as human common sense can be

depended on, that the great majority of these stones come from the

Lake mountains, sixty or seventy miles north of Liverpool? I think

your common sense will tell you that these pebbles are not mere

concretions; that is, formed out of the substance of the clay after

it was deposited. The least knowledge of mineralogy would prove

that. But, even if you are no mineralogist, common sense will tell

you, that if they were all concreted out of the same clay, it is most

likely that they would be all of the same kind, and not of a dozen or

more different kinds. Common sense will tell you, also, that if they

were all concreted out of the same clay, it is a most extraordinary

coincidence, indeed one too strange to be believed, if any less

strange explanation can be found--that they should have taken the

composition of different rocks which are found all together in one

group of mountains to the northward. You will surely say--If this be

granite, it has most probably come from a granite mountain; if this

be grit, from a grit-stone mountain, and so on with the whole list.

Why--are we to go out of our way to seek improbable explanations,

when there is a probable one staring us in the face?

Next--and this is well worth your notice--if you will examine the

pebbles carefully, especially the larger ones, you will find that

they are not only more or less rounded, but often scratched; and

often, too, in more than one direction, two or even three sets of

scratches crossing each other; marked, as a cat marks an elder stem

when she sharpens her claws upon it; and that these scratches have

not been made by the quarrymen's tools, but are old marks which

exist--as you may easily prove for yourself--while the stone is still

lying in its bed of clay. Would it not be an act of mere common

sense to say--These scratches have been made by the sharp points of

other stones which have rubbed against the pebbles somewhere, and

somewhen, with great force?

So far so good. The next question is--How did these stones get into

the clay? If we can discover that, we may also discover how they

wore rounded and scratched. We must find a theory which will answer

our question; and one which, as Professor Huxley would say, "will go

on all-fours," that is, will explain all the facts of the case, and

not only a few of them.

What, then, brought the stones?

We cannot, I think, answer that question, as some have tried to

answer it, by saying that they were brought by Noah's flood. For it

is clear, that very violent currents of water would be needed to

carry boulders, some of them weighing many tons, for many miles. Now

Scripture says nothing of any such violent currents; and we have no

right to put currents, or any other imagined facts, into Scripture

out of our own heads, and then argue from them as if not we, but the

text of Scripture had asserted their existence.

But still, they may have been rolled hither by water. That theory

certainly would explain their being rounded; though not their being

scratched. But it will not explain their being found in the clay.

Recollect what I said in my first paper: that water drops its

pebbles and coarser particles first, while it carries the fine clayey

mud onward in solution, and only drops it when the water becomes

still. Now currents of such tremendous violence as to carry these

boulder stones onward, would have carried the mud for many miles

farther still; and we should find the boulders, not in clay, but

lying loose together, probably on a hard rock bottom, scoured clean

by the current. That is what we find in the beds of streams; that is

just what we do not find in this case.

But the boulders may have been brought by a current, and then the

water may have become still, and the clay settled quietly round them.

What? Under them as well as over them? On that theory also we

should find them only at the bottom of the clay. As it is, we find

them scattered anywhere and everywhere through it, from top to

bottom. So that theory will not do. Indeed, no theory will do which

supposes them to have been brought by water alone.

Try yourself, dear reader, and make experiments, with running water,

pebbles, and mud. If you try for seven years, I believe, you will

never contrive to make your pebbles lie about in your mud, as they

lie about in every pit in the boulder clay.

Well then, there we are at fault, it seems. We have no explanation

drawn from known facts which will do--unless we are to suppose, which

I don't think you will do, that stones, clay, and all were blown

hither along the surface of the ground, by primeval hurricanes, ten

times worse than those of the West Indies, which certainly will roll

a cannon a few yards, but cannot, surely, roll a boulder stone a

hundred miles.

Now, suppose that there was a force, an agent, known--luckily for

you, not to you--but known too well to sailors and travellers; a

force which is at work over the vast sheets of land at both the north

and south poles; at work, too, on every high mountain range in the

world, and therefore a very common natural force; and suppose that

this force would explain all the facts, namely--

How the stones got here;

How they were scratched and rounded;

How they were imbedded in clay;

because it is notoriously, and before men's eyes now, carrying great

stones hundreds of miles, and scratching and rounding them also;

carrying vast deposits of mud, too, and mixing up mud and stones just

as we see them in the brick-pits,--Would not our common sense have a

right to try that explanation?--to suspect that this force, which we

do not see at work in Britain now, may have been at work here ages

since? That would at least be reasoning from the known to the

unknown. What state of things, then, do we find among the highest

mountains; and over whole countries which, though not lofty, lie far

enough north or south to be permanently covered with ice?

We find, first, an ice-cap or ice-sheet, fed by the winter's snows,

stretching over the higher land, and crawling downward and outward by

its own weight, along the valleys, as glaciers.

We find underneath the glaciers, first a moraine profonde, consisting

of the boulders and gravel, and earth, which the glacier has ground

off the hillsides, and is carrying down with it.

These stones, of course, grind, scratch, and polish each other; and

in like wise grind, scratch, and polish the rock over which they

pass, under the enormous weight of the superincumbent ice.

We find also, issuing from under each glacier a stream, carrying the

finest mud, the result of the grinding of the boulders against each

other and the glacier.

We find, moreover, on the surface of the glaciers, moraines

superieures--long lines of stones and dirt which had fallen from

neighbouring cliffs, and are now travelling downward with the

glaciers.

Their fate, if the glacier ends on land, is what was to be expected.

The stones from above the glacier fall over the ice-cliff at its end,

to mingle with those thrown out from underneath the glacier, and form

huge banks of boulders, called terminal moraines, while the mud runs

off, as all who have seen glaciers know, in a turbid torrent.

Their fate, again, is what was to be expected if the glacier ends, as

it commonly does in Arctic regions, in the sea. The ice grows out to

sea-ward for more than a mile sometimes, about one-eighth of it being

above water, and seven-eighths below, so that an ice-cliff one

hundred feet high may project into water eight hundred feet deep. At

last, when it gets out of its depth, the buoyancy of the water breaks

it off in icebergs, which float away, at the mercy of tides and

currents, often grounding again in shallower water, and ploughing the

sea-bottom as they drag along it. These bergs carry stones and dirt,

often in large quantities; so that, whenever a berg melts or

capsizes, it strews its burden confusedly about the sea-floor.

Meanwhile the fine mud which is flowing out from under the ice goes

out to sea likewise, colouring the water far out, and then subsiding

as a soft tenacious ooze, in which the stones brought out by the ice

are imbedded. And this ooze--so those who have examined it assert--

cannot be distinguished from the brick-clay, or fossiliferous

boulder-clay, so common in the North. A very illustrious

Scandinavian explorer, visiting Edinburgh, declared, as soon as he

saw the sections of boulder-clay exhibited near that city, that this

was the very substance which he saw forming in the Spitzbergen ice-

fiords. {3}

I have put these facts as simply and baldly as I can, in order that

the reader may look steadily at them, without having his attention

drawn off, or his fancy excited, by their real poetry and grandeur.

Indeed, it would have been an impertinence to have done otherwise;

for I have never seen a live glacier, by land or sea, though I have

seen many a dead one. And the public has had the opportunity,

lately, of reading so many delightful books about "peaks, passes, and

glaciers," that I am bound to suppose that many of my readers know as

much, or more, about them than I do.

But let us go a step farther; and, bearing in our minds what live

glaciers are like, let us imagine what a dead glacier would be like;

a glacier, that is, which had melted, and left nothing but its

skeleton of stones and dirt.

We should find the faces of the rock scored and polished, generally

in lines pointing down the valleys, or at least outward from the

centre of the highlands, and polished and scored most in their upland

or weather sides. We should find blocks of rock left behind, and

perched about on other rocks of a different kind. We should find in

the valleys the old moraines left as vast deposits of boulder and

shingle, which would be in time sawn through and sorted over by the

rivers. And if the sea-bottom outside were upheaved, and became dry

land, we should find on it the remains of the mud from under the

glacier, stuck full of stones and boulders iceberg-dropped. This mud

would be often very irregularly bedded; for it would have been

disturbed by the ploughing of the icebergs, and mixed here and there

with dirt which had fallen from them. Moreover, as the sea became

shallower and the mud-beds got awash one after the other, they would

be torn about, re-sifted, and re-shaped by currents and by tides, and

mixed with shore-sand ground out of shingle-beach, thus making

confusion worse confounded. A few shells, of an Arctic or northern

type, would be found in it here and there. Some would have lived

near those later beaches, some in deeper water in the ancient ooze,

wherever the iceberg had left it in peace long enough for sea-animals

to colonise and breed in it. But the general appearance of the dried

sea-bottom would be a dreary and lifeless waste of sands, gravels,

loose boulders, and boulder-bearing clays; and wherever a boss of

bare rock still stood up, it would be found ground down, and probably

polished and scored by the ponderous icebergs which had lumbered over

it in their passage out to sea.

In a word, it would look exactly as vast tracts of the English,

Scotch, and Irish lowlands must have looked before returning

vegetation coated their dreary sands and clays with a layer of brown

vegetable soil.

Thus, and I believe thus only, can we explain the facts connected

with these boulder pebbles. No agent known on earth can have stuck

them in the clay, save ice, which is known to do so still elsewhere.

No known agent can have scratched them as they are scratched, save

ice, which is known to do so still elsewhere.

No known agent--certainly not, in my opinion, the existing rivers--

can have accumulated the vast beds of boulders which lie along the

course of certain northern rivers; notably along the Dee about

Aboyne--save ice bearing them slowly down from the distant summits of

the Grampians.

No known agent, save ice, can have produced those rounded, and

polished, and scored, and fluted rochers moutonnes "sheep-backed

rocks"--so common in the Lake district; so common, too, in Snowdon,

especially between the two lakes of Llanberis; common in Kerry; to be

seen anywhere, as far as I have ascertained, around the Scotch

Highlands, where the turf is cleared away from an unweathered surface

of the rock, in the direction in which a glacier would have pressed

against it had one been there. Where these polishings and scorings

are found in narrow glens, it is, no doubt, an open question whether

some of them may not be the work of water. But nothing but the

action of ice can have produced what I have seen in land-locked and

quiet fords in Kerry--ice-flutings in polished rocks below high-water

mark, so large that I could lie down in one of them. Nothing but the

action of ice could produce what may be seen in any of our mountains-

-whole sheets of rock ground down into rounded flats, irrespective of

the lie of the beds, not in valleys, but on the brows and summits of

mountains, often ending abruptly at the edge of some sudden cliff,

where the true work of water, in the shape of rain and frost, is

actually destroying the previous work of ice, and fulfilling the rule

laid down (I think by Professor Geikie in his delightful book on

Scotch scenery as influenced by its geology), that ice planes down

into flats, while water saws out into crags and gullies; and that the

rain and frost are even now restoring Scotch scenery to something of

that ruggedness and picturesqueness which it must have lost when it

lay, like Greenland, under the indiscriminating grinding of a heavy

sheet of ice.

Lastly; no known agent, save ice, will explain those perched

boulders, composed of ancient hard rocks, which may be seen in so

many parts of these islands and of the Continent. No water power

could have lifted those stones, and tossed them up high and dry on

mountain ridges and promontories, upon rocks of a totally different

kind. Some of my readers surely recollect Wordsworth's noble lines

about these mysterious wanderers, of which he had seen many a one

about his native hills:

As a huge stone is sometimes seen to lie

Couched on the bald top of an eminence,

Wonder to all who do the same espy

By what means it could thither come, and whence;

So that it seems a thing endued with sense:

Like a sea-beast crawled forth, that on a shelf

Of rock or sand reposeth, there to sun itself.

Yes; but the next time you see such a stone, believe that the wonder

has been solved, and found to be, like most wonders in Nature, more

wonderful than we guessed it to be. It is not a sea-beast which has

crawled forth, but an ice-beast which has been left behind; lifted up

thither by the ice, as surely as the famous Pierre-a-bot, forty feet

in diameter, and hundreds of boulders more, almost as large as

cottages, have been carried by ice from the distant Alps right across

the lake of Neufchatel, and stranded on the slopes of the Jura, nine

hundred feet above the lake. {4}

Thus, I think, we have accounted for facts enough to make it probable

that Britain was once covered partly by an ice-sheet, as Greenland is

now, and partly, perhaps, by an icy sea. But, to make assurance more

sure, let us look for new facts, and try whether our ice-dream will

account for them also. Let us investigate our case as a good medical

man does, by "verifying his first induction."

He says: At the first glance, I can see symptoms a, b, c. It is

therefore probable that my patient has got complaint A. But if he

has he ought to have symptom d also. If I find that, my guess will

be yet more probable. He ought also to have symptom e, and so forth;

and as I find successively each of these symptoms which are proper to

A, my first guess will become more and more probable, till it reaches

practical certainty.

Now let us do the same, and say--If this strange dream be true, and

the lowlands of the North were once under an icy sea, ought we not to

find sea-shells in their sands and clays? Not abundantly, of course.

We can understand that the sea-animals would be too rapidly covered

up in mud, and too much disturbed by icebergs and boulders, to be

very abundant. But still, some should surely be found here and

there.

Doubtless; and if my northern-town readers will search the boulder-

clay pits near them, they will most probably find a few shells, if

not in the clay itself, yet in sand-beds mixed with them, and

probably underlying them. And this is a notable fact, that the more

species of shells they find, the more they will find--if they work

out their names from any good book of conchology--of a northern type;

of shells which notoriously, at this day, inhabit the colder seas.

It is impossible for me here to enter at length on a subject on which

a whole literature has been already written. Those who wish to study

it may find all that they need know, and more, in Lyell's "Student's

Elements of Geology," and in chapter xii. of his "Antiquity of Man."

They will find that if the evidence of scientific conchologists be

worth anything, the period can be pointed out in the strata, though

not of course in time, at which these seas began to grow colder, and

southern and Mediterranean shells to disappear, their places being

taken by shells of a temperate, and at last of an Arctic climate;

which last have since retreated either toward their native North, or

into cold water at great depths. From Essex across to Wales, from

Wales to the aestuary of the Clyde, this fact has been verified again

and again. And in the search for these shells, a fresh fact, and a

most startling one, was discovered. They are to be found not only in

the clay of the lowlands, but at considerable heights up the hills,

showing that, at some time or other, these hills have been submerged

beneath the sea.

Let me give one example, which any tourist into Wales may see for

himself. Moel Tryfaen is a mountain over Carnarvon. Now perched on

the side of that mountain, fourteen hundred feet above the present

sea-level, is an ancient sea-beach, five-and-thirty feet thick, lying

on great ice-scratched boulders, which again lie on the mountain

slates. It was discovered by the late Mr. Trimmer, now, alas! lost

to Geology. Out of that beach fifty-seven different species of

shells have been taken; eleven of them are now exclusively Arctic,

and not found in our seas; four of them are still common to the

Arctic seas and to our own; and almost all the rest are northern

shells.

Fourteen hundred feet above the present sea: and that, it must be

understood, is not the greatest height at which such shells may be

found hereafter. For, according to Professor Ramsay, drift of the

same kind as that on Moel Tryfaen is found at a height of two

thousand three hundred feet.

Now I ask my readers to use their common sense over this astounding

fact--which, after all, is only one among hundreds; to let (as Mr.

Matthew Arnold would well say) their "thought play freely" about it;

and consider for themselves what those shells must mean. I say not

may, but must, unless we are to believe in a "Deus quidam deceptor,"

in a God who puts shells upon mountain-sides only to befool honest

human beings, and gives men intellects which are worthless for even

the simplest work. Those shells must mean that that mountain, and

therefore the mountains round it, must have been once fourteen

hundred feet at least lower than they are now. That the sea in which

they were sunk was far colder than now. That icebergs brought and

dropped boulders round their flanks. That upon those boulders a sea-

beach formed, and that dead shells were beaten into it from a sea-

bottom close by. That, and no less, Moel Tryfaen must mean.

But it must mean, also, a length of time which has been well called

"appalling." A length of time sufficient to let the mountain sink

into the sea. Then length of time enough to enable those Arctic

shells to crawl down from the northward, settle, and propagate

themselves generation after generation; then length of time enough to

uplift their dead remains, and the beach, and the boulders, and all

Snowdonia, fourteen hundred feet into the air. And if anyone should

object that the last upheaval may have been effected suddenly by a

few tremendous earthquakes, we must answer--We have no proof of it.

Earthquakes upheave lands now only by slight and intermittent upward

pulses; nay, some lands we know to rise without any earthquake

pulses, but by simple, slow, upward swelling of a few feet in a

century; and we have no reason, and therefore no right, to suppose

that Snowdonia was upheaved by any means or at any rate which we do

not witness now; and therefore we are bound to allow, not only that

there was a past "age of ice," but that that age was one of

altogether enormous duration.

But meanwhile some of you, I presume, will be ready to cry--Stop! It

may be our own weakness; but you are really going on too fast and too

far for our small imaginations. Have you not played with us, as well

as argued with us, till you have inveigled us step by step into a

conclusion which we cannot and will not believe? That all this land

should have been sunk beneath an icy sea? That Britain should have

been as Greenland is now? We can't believe it, and we won't.

If you say so, like stout common-sense Britons, who have a wholesome

dread of being taken in with fine words and wild speculations, I

assure you I shall not laugh at you even in private. On the

contrary, I shall say--what I am sure every scientific man will say--

So much the better. That is the sort of audience which we want, if

we are teaching natural science. We do not want haste, enthusiasm,

gobe-moucherie, as the French call it, which is agape to snap up any

new and vast fancy, just because it is new and vast. We want our

readers to be slow, suspicious, conservative, ready to "gib," as we

say of a horse, and refuse the collar up a steep place, saying--I

must stop and think. I don't like the look of the path ahead of me.

It seems an ugly place to get up. I don't know this road, and I

shall not hurry over it. I must go back a few steps, and make sure.

I must see whether it is the right road; whether there are not other

roads, a dozen of them perhaps, which would do as well and better

than this.

This is the temper which finds out truth, slowly, but once and for

all; and I shall be glad, not sorry, to see it in my readers.

And I am bound to say that it has been by that temper that this

theory has been worked out, and the existence of this past age of

ice, or glacial epoch, has been discovered, through many mistakes,

many corrections, and many changes of opinion about details, for

nearly forty years of hard work, by many men, in many lands.

As a very humble student of this subject, I may say that I have been

looking these facts in the face earnestly enough for more than twenty

years, and that I am about as certain that they can only be explained

by ice, as I am that my having got home by rail can only be explained

by steam.

But I think I know what startles you. It is the being asked to

believe in such an enormous change in climate, and in the height of

the land above the sea. Well--it is very astonishing, appalling--all

but incredible, if we had not the facts to prove it. But of the

facts there can be no doubt. There can be no doubt that the climate

of this northern hemisphere has changed enormously more than once.

There can be no doubt that the distribution of land and water, the

shape and size of its continents and seas, have changed again and

again. There can be no doubt that, for instance, long before the age

of ice, the whole North of Europe was much warmer than it is now.

Take Greenland, for instance. Disco Island lies in Baffin's Bay, off

the west coast of Greenland, in latitude 70 degrees, far within the

Arctic circle. Now there certain strata of rock, older than the ice,

have not been destroyed by the grinding of the ice-cap; and they are

full of fossil plants. But of what kind of plants? Of the same

families as now grow in the warmer parts of the United States. Even

a tulip-tree has been found among them. Now how is this to be

explained?

Either we must say that the climate of Greenland was then so much

warmer than now, that it had summers probably as hot as those of New

York; or we must say that these leaves and stems were floated thither

from the United States. But if we say the latter, we must allow a

change in the shape of the land which is enormous. For nothing now

can float northward from the United States into Baffin's Bay. The

polar current sets OUT of Baffin's Bay southward, bringing icebergs

down, not leaves up, through Davis's Straits. And in any case we

must allow that the hills of Disco Island were then the bottom of a

sea: or how would the leaves have been deposited in them at all?

So much for the change of climate and land which can be proved to

have gone on in Greenland. It has become colder. Why should it not

some day become warmer again?

Now for England. It can be proved, as far as common sense can prove

anything, that England was, before the age of ice, much warmer than

it is now, and grew gradually cooler and cooler, just as, while the

age of ice was dying out, it grew warmer again.

Now what proof is there of that?

This. Underneath London--as, I dare say, many of you know--there

lies four or five hundred feet of clay. But not ice-clay. Anything

but that, as you will see. It belongs to a formation late

(geologically speaking), but somewhat older than those Disco Island

beds.

And what sort of fossils do we find in it?

In the first place, the shells, which are abundant, are tropical--

Nautili, Cones, and such like. And more, fruits and seeds are found

in it, especially at the Isle of Sheppey. And what are they? Fruits

of Nipa palms, a form only found now at river-mouths in Eastern India

and the Indian islands; Anona-seeds; gourd-seeds; Acacia fruits--all

tropical again; and Proteaceous plants too--of an Australian type.

Surely your common sense would hint to you, that this London clay

must be mud laid down off the mouth of a tropical river. But your

common sense would be all but certain of that, when you found, as you

would find, the teeth and bones of crocodiles and turtles, who come

to land, remember, to lay their eggs; the bones, too, of large

mammals, allied to the tapir of India and South America, and the

water-hog of the Cape. If all this does not mean that there was once

a tropic climate and a tropic river running into some sea or other

where London now stands, I must give up common sense and reason as

deceitful and useless faculties; and believe nothing, not even the

evidence of my own senses.

And now, have I, or have I not, fulfilled the promise which I made--

rashly, I dare say some of you thought--in my first paper? Have I,

or have I not, made you prove to yourself, by your own common sense,

that the lowlands of Britain were underneath the sea in the days in

which these pebbles and boulders were laid down over your plains?

Nay, have we not proved more? Have we not found that that old sea

was an icy sea? Have we not wandered on, step by step, into a whole

true fairyland of wonders? to a time when all England, Scotland, and

Ireland were as Greenland is now? when mud streams have rushed down

from under glaciers on to a cold sea-bottom, when "ice, mast high,

came floating by, as green as emerald?" when Snowdon was sunk for at

least fourteen hundred feet of its height? when (as I could prove to

you, had I time) the peaks of the highest Cumberland and Scotch

mountains alone stood out, as islets in a frozen sea?

We want to get an answer to one strange question, and we have found a

group of questions stranger still, and got them answered too. But so

it is always in science. We know not what we shall discover. But

this, at least, we know, that it will be far more wonderful than we

had dreamed. The scientific explorer is always like Saul of old, who

set out simply to find his father's asses, and found them--and a

kingdom besides.

I should have liked to have told you more about this bygone age of

ice. I should have liked to say something to you on the curious

question--which is still an open one--whether there were not two ages

of ice; whether the climate here did not, after perhaps thousands of

years of Arctic cold, soften somewhat for a while--a few thousand

years, perhaps--and then harden again into a second age of ice,

somewhat less severe, probably, than the first. I should have liked

to have hinted at the probable causes of this change--indeed, of the

age of ice altogether--whether it was caused by a change in the

distribution of land and water, or by change in the height and size

of these islands, which made them large enough, and high enough, to

carry a sheet of eternal snow inland; or whether, finally, the age of

ice was caused by an actual change in the position of the whole

planet with regard to its orbit round the sun--shifting at once the

poles and the tropics; a deep question that latter, on which

astronomers, whose business it is, are still at work, and on which,

ere young folk are old, they will have discovered, I expect, some

startling facts. On that last question, I, being no astronomer,

cannot speak. But I should have liked to have said somewhat on

matters on which I have knowledge enough, at least, to teach you how

much there is to be learnt. I should have liked to tell the student

of sea-animals--how the ice-age helps to explain, and is again

explained by, the remarkable discoveries which Dr. Carpenter and Mr.

Wyville Thompson have just made, in the deep-sea dredgings in the

North Atlantic. I should have liked to tell the botanist somewhat of

the pro-glacial flora--the plants which lived here before the ice,

and lasted, some of them at least, through all those ages of fearful

cold, and linger still on the summits of Snowdon, and the highest

peaks of Cumberland and Scotland. I should have liked to have told

the lovers of zoology about the animals which lived before the ice--

of the mammoth, or woolly elephant; the woolly rhinoceros, the cave

lion and bear, the reindeer, the musk oxen, the lemmings and the

marmots which inhabited Britain till the ice drove them out

southward, even into the South of France; and how as the ice

retreated, and the climate became tolerable once more, some of them--

the mammoth and rhinoceros, the bison, the lion, and many another

mighty beast reoccupied our lowlands, at a time when the

hippopotamus, at least in summer, ranged freely from Africa and Spain

across what was then dry land between France and England, and fed by

the side of animals which have long since retreated to Norway and to

Canada. I should have liked to tell the archaeologist of the human

beings--probably from their weapons and their habits--of the same

race as the present Laplanders, who passed northward as the ice went

back, following the wild reindeer herds from the South of France into

our islands, which were no islands then, to be in their turn driven

northward by stronger races from the east and south. But space

presses, and I fear that I have written too much already.

At least, I have turned over for you a few grand and strange pages in

the book of nature, and taught you, I hope, a key by which to

decipher their hieroglyphics. At least, I have, I trust, taught you

to look, as I do, with something of interest, even of awe, upon the

pebbles in the street.

III. THE STONES IN THE WALL

This is a large subject. For in the different towns of these

islands, the walls are built of stones of almost every age, from the

earliest to the latest; and the town-geologist may find a quite

different problem to solve in the nearest wall, on moving from one

town to another twenty miles off. All I can do, therefore, is to

take one set of towns, in the walls of which one sort of stones is

commonly found, and talk of them; taking care, of course, to choose a

stone which is widely distributed. And such, I think, we can find in

the so-called New Red sandstone, which, with its attendant marls,

covers a vast tract--and that a rich and busy one--of England. From

Hartlepool and the mouth of the Tees, down through Yorkshire and

Nottinghamshire; over the manufacturing districts of central England;

down the valley of the Severn; past Bristol and the Somersetshire

flats to Torquay in South Devon; up north-westward through Shropshire

and Cheshire; past Liverpool and northward through Lancashire;

reappearing again, north of the Lake mountains, about Carlisle and

the Scotch side of the Solway Frith, stretches the New Red sandstone

plain, from under which everywhere the coal-bearing rocks rise as

from a sea. It contains, in many places, excellent quarries of

building-stone; the most famous of which, perhaps, are the well-known

Runcorn quarries, near Liverpool, from which the old Romans brought

the material for the walls and temples of ancient Chester, and from

which the stone for the restoration of Chester Cathedral is being

taken at this day. In some quarters, especially in the north-west of

England, its soil is poor, because it is masked by that very boulder-

clay of which I spoke in my last paper. But its rich red marls,

wherever they come to the surface, are one of God's most precious

gifts to this favoured land. On them, one finds oneself at once in a

garden; amid the noblest of timber, wheat, roots, grass which is

green through the driest summers, and, in the western counties,

cider-orchards laden with red and golden fruit. I know, throughout

northern Europe, no such charming scenery, for quiet beauty and solid

wealth, as that of the New Red marls; and if I wished to show a

foreigner what England was, I should take him along them, from

Yorkshire to South Devon, and say--There. Is not that a country

worth living for,--and worth dying for if need be?

Another reason which I have for dealing with the New Red sandstone is

this--that (as I said just now) over great tracts of England,

especially about the manufacturing districts, the town-geologist will

find it covered immediately by the boulder clay.

The townsman, finding this, would have a fair right to suppose that

the clay was laid down immediately, or at least soon after, the

sandstones or marls on which it lies; that as soon as the one had

settled at the bottom of some old sea, the other settled on the top

of it, in the same sea.

A fair and reasonable guess, which would in many cases, indeed in

most, be quite true. But in this case it would be a mistake. The

sandstone and marls are immensely older than the boulder-clay. They

are, humanly speaking, some four or five worlds older.

What do I mean? This--that between the time when the one, and the

time when the other, was made, the British Islands, and probably the

whole continent of Europe, have changed four or five times; in shape;

in height above the sea, or depth below it; in climate; in the kinds

of plants and animals which have dwelt on them, or on their sea-

bottoms. And surely it is not too strong a metaphor, to call such

changes a change from an old world to a new one.

Mind. I do not say that these changes were sudden or violent. It is

far more probable that they are only part and parcel of that vast but

slow change which is going on everywhere over our whole globe. I

think that will appear probable in the course of this paper. But

that these changes have taken place, is my main thesis. The fact I

assert; and I am bound to try and prove it. And in trying to do so,

I shall no longer treat my readers, as I did in the first two papers,

like children. I shall take for granted that they now understand

something of the method by which geological problems are worked out;

and can trust it, and me; and shall state boldly the conclusions of

geologists, only giving proof where proof is specially needed.

Now you must understand that in England there are two great divisions

of these New Red sandstones, "Trias," as geologists call them. An

upper, called in Germany Keuper, which consists, atop, of the rich

red marl, below them, of sandstones, and of those vast deposits of

rock-salt, which have been long worked, and worked to such good

purpose, that a vast subsidence of land has just taken place near

Nantwich in Cheshire; and serious fears are entertained lest the town

itself may subside, to fill up the caverns below, from whence the

salt has been quarried. Underneath these beds again are those which

carry the building-stone of Runcorn. Now these beds altogether, in

Cheshire, at least, are about 3,400 feet thick; and were not laid

down in a year, or in a century either.

Below them lies a thousand feet of sandstones, known in Germany by

the name of "Bunter," from its mottled and spotted appearance. What

lies under them again, does not concern us just now.

I said that the geologists called these beds the Trias; that is, the

triple group. But as yet we have heard of only two parts of it.

Where is the third?

Not here, but in Germany. There, between the Keuper above and the

Bunter below, lies a great series of limestone beds, which, from the

abundance of fossils which they contain, go by the name of

Muschelkalk. A long epoch must therefore have intervened between the

laying down of the Bunter and of the Keuper. And we have a trace of

that long epoch, even in England. The Keuper lies, certainly,

immediately on the Bunter; but not always "conformably" on it. That

is, the beds are not exactly parallel. The Bunter had been slightly

tilted, and slightly waterworn, before the Keuper was laid on it.

It is reasonable, therefore, to suppose, that the Bunter in England

was dry land, and therefore safe from fresh deposit, through ages

during which it was deep enough beneath the sea in Germany, to have

the Muschelkalk laid down on it. Here again, then, as everywhere, we

have evidence of time--time, not only beyond all counting, but beyond

all imagining.

And now, perhaps, the reader will ask--If I am to believe that all

new land is made out of old land, and that all rocks and soils are

derived from the wear and tear of still older rocks, off what land

came this enormous heap of sands more than 5,000 feet thick in

places, stretching across England and into Germany?

It is difficult to answer. The shape and distribution of land in

those days were so different from what they are now, that the rocks

which furnished a great deal of our sandstone may be now, for aught I

know, a mile beneath the sea.

But over the land which still stands out of the sea near us there has

been wear and tear enough to account for any quantity of sand

deposit. As a single instance--It is a provable and proven fact--as

you may see from Mr. Ramsay's survey of North Wales--that over a

large tract to the south of Snowdon, between Port Madoc and Barmouth,

there has been ground off and carried away a mass of solid rock

20,000 feet thick; thick enough, in fact, if it were there still, to

make a range of mountains as high as the Andes. It is a provable and

proven fact that vast tracts of the centre of poor old Ireland were

once covered with coal-measures, which have been scraped off in

likewise, deprived of inestimable mineral wealth. The destruction of

rocks--"denudation" as it is called--in the district round Malvern,

is, I am told, provably enormous. Indeed, it is so over all Wales,

North England, and West and North Scotland. So there is enough of

rubbish to be accounted for to make our New Red sands. The round

pebbles in it being, I believe, pieces of Old Red sandstone, may have

come from the great Old Red sandstone region of South East Wales and

Herefordshire. Some of the rubbish, too, may have come from what is

now the Isle of Anglesey.

For you find in the beds, from the top to the bottom (at least in

Cheshire), particles of mica. Now this mica could not have been

formed in the sand. It is a definite crystalline mineral, whose

composition is well known. It is only found in rocks which have been

subjected to immense pressure, and probably to heat. The granites

and mica-slates of Anglesey are full of it; and from Anglesey--as

likely as from anywhere else--these thin scales of mica came. And

that is about all that I can say on the matter. But it is certain

that most of these sands were deposited in a very shallow water, and

very near to land. Sand and pebbles, as I said in my first paper,

could not be carried far out to sea; and some of the beds of the

Bunter are full of rounded pebbles. Nay, it is certain that their

surface was often out of water. Of that you may see very pretty

proofs. You find these sands ripple-marked, as you do shore-sands

now. You find cracks where the marl mud has dried in the sun: and,

more, you find the little pits made by rain. Of that I have no

doubt. I have seen specimens, in which you could not only see at a

glance that the marks had been made by the large drops of a shower,

but see also from what direction the shower had come. These delicate

markings must have been covered up immediately with a fresh layer of

mud or sand. How long since? How long since that flag had seen the

light of the sun, when it saw it once again, restored to the upper

air by the pick of the quarryman? Who can answer that? Not I.

Fossils are very rare in these sands; it is not easy to say why. It

may be that the red oxide of iron in them has destroyed them. Few or

none are ever found in beds in which it abounds. It is curious, too,

that the Keuper, which is all but barren of fossils in England, is

full of them in Wurtemberg, reptiles, fish, and remains of plants

being common. But what will interest the reader are the footprints

of a strange beast, found alike in England and in Germany--the

Cheirotherium, as it was first named, from its hand-like feet; the

Labyrinthodon, as it is now named, from the extraordinary structure

of its teeth. There is little doubt now, among anatomists, that the

bones and teeth of the so-called Labyrinthodon belong to the animal

which made the footprints. If so, the creature must have been a

right loathly monster. Some think him to have been akin to lizards;

but the usual opinion is that he was a cousin of frogs and toads.

Looking at his hands and other remains, one pictures him to oneself

as a short, squat brute, as big as a fat hog, with a head very much

the shape of a baboon, very large hands behind and small ones in

front, waddling about on the tide flats of a sandy sea, and dragging

after him, seemingly, a short tail, which has left its mark on the

sand. What his odour was, whether he was smooth or warty, what he

ate, and in general how he got his living, we know not. But there

must have been something there for him to eat; and I dare say that he

was about as happy and about as intellectual as the toad is now.

Remember always that there is nothing alive now exactly like him, or,

indeed, like any animal found in these sandstones. The whole animal

world of this planet has changed entirely more than once since the

Labyrinthodon waddled over the Cheshire flats. A lizard, for

instance, which has been found in the Keuper, had a skull like a

bird's, and no teeth--a type which is now quite extinct. But there

is a more remarkable animal of which I must say a few words, and one

which to scientific men is most interesting and significant.

Both near Warwick, and near Elgin in Scotland, in Central India, and

in South Africa, fossil remains are found of a family of lizards

utterly unlike anything now living save one, and that one is crawling

about, plentifully I believe--of all places in the world--in New

Zealand. How it got there; how so strange a type of creature should

have died out over the rest of the world, and yet have lasted on in

that remote island for long ages, ever since the days of the New Red

sandstone, is one of those questions--quite awful questions I

consider them--with which I will not puzzle my readers. I only

mention it to show them what serious questions the scientific man has

to face, and to answer, if he can. Only the next time they go to the

Zoological Gardens in London, let them go to the reptile-house, and

ask the very clever and courteous attendant to show them the

Sphenodons, or Hatterias, as he will probably call them--and then

look, I hope with kindly interest, at the oldest Conservatives they

ever saw, or are like to see; gentlemen of most ancient pedigree, who

have remained all but unchanged, while the whole surface of the globe

has changed around them more than once or twice.

And now, of course, my readers will expect to hear something of the

deposits of rock-salt, for which Cheshire and its red rocks are

famous. I have never seen them, and can only say that the salt does

not, it is said by geologists, lie in the sandstone, but at the

bottom of the red marl which caps the sandstone. It was formed most

probably by the gradual drying up of lagoons, such as are depositing

salt, it is said now, both in the Gulf of Tadjara, on the Abyssinian

frontier opposite Aden, and in the Runn of Cutch, near the Delta of

the Indus. If this be so, then these New Red sandstones may be the

remains of a whole Sahara--a sheet of sandy and all but lifeless

deserts, reaching from the west of England into Germany, and rising

slowly out of the sea; to sink, as we shall find, beneath the sea

again.

And now, as to the vast period of time--the four or five worlds, as I

called it--which elapsed between the laying down of the New Red

sandstones and the laying down of the boulder-clays.

I think this fact--for fact it is--may be better proved by taking

readers an imaginary railway journey to London from any spot in the

manufacturing districts of central England--begging them, meanwhile,

to keep their eyes open on the way.

And here I must say that I wish folks in general would keep their

eyes a little more open when they travel by rail. When I see young

people rolling along in a luxurious carriage, their eyes and their

brains absorbed probably in a trashy shilling novel, and never lifted

up to look out of the window, unconscious of all that they are

passing--of the reverend antiquities, the admirable agriculture, the

rich and peaceful scenery, the like of which no country upon earth

can show; unconscious, too, of how much they might learn of botany

and zoology, by simply watching the flowers along the railway banks

and the sections in the cuttings: then it grieves me to see what

little use people make of the eyes and of the understanding which God

has given them. They complain of a dull journey: but it is not the

journey which is dull; it is they who are dull. Eyes have they, and

see not; ears have they, and hear not; mere dolls in smart clothes,

too many of them, like the idols of the heathen.

But my readers, I trust, are of a better mind. So the next time they

find themselves running up southward to London--or the reverse way--

let them keep their eyes open, and verify, with the help of a

geological map, the sketch which is given in the following pages.

Of the "Black Countries"--the actual coal districts I shall speak

hereafter. They are in England either shores or islands yet

undestroyed, which stand out of the great sea of New Red sandstone,

and often carry along their edges layers of far younger rocks, called

now Permian, from the ancient kingdom of Permia, in Russia, where

they cover a vast area. With them I will not confuse the reader just

now, but will only ask him to keep his eye on the rolling plain of

New Red sands and marls past, say, Birmingham and Warwick. After

those places, these sands and marls dip to the south-east, and other

rocks and soils appear above them, one after another, dipping

likewise towards the south-east--that is, toward London.

First appear thin layers of a very hard blue limestone, full of

shells, and parted by layers of blue mud. That rock runs in a broad

belt across England, from Whitby in Yorkshire, to Lyme in

Dorsetshire, and is known as Lias. Famous it is, as some readers may

know, for holding the bones of extinct monsters--Ichthyosaurs and

Plesiosaurs, such as the unlearned may behold in the lake at the

Crystal Palace. On this rock lie the rich cheese pastures, and the

best tracts of the famous "hunting shires" of England.

Lying on it, as we go south-eastward, appear alternate beds of sandy

limestone, with vast depths of clay between them. These "oolites,"

or freestones, furnish the famous Bath stone, the Oxford stone, and

the Barnack stone of Northamptonshire, of which some of the finest

cathedrals are built--a stone only surpassed, I believe, by the Caen

stone, which comes from beds of the same age in Normandy. These

freestones and clays abound in fossils, but of kinds, be it

remembered, which differ more and more from those of the lias

beneath, as the beds are higher in the series, and therefore nearer.

There, too, are found principally the bones of that extraordinary

flying lizard, the Pterodactyle, which had wings formed out of its

fore-legs, on somewhat the same plan as those of a bat, but with one

exception. In the bat, as any one may see, four fingers of the hand

are lengthened to carry the wing, while the first alone is left free,

as a thumb: but in the Pterodactyle, the outer or "little" finger

alone is lengthened, and the other four fingers left free--one of

those strange instances in nature of the same effect being produced

in widely different plants and animals, and yet by slightly different

means, on which a whole chapter of natural philosophy--say, rather,

natural theology--will have to be written some day.

But now consider what this Lias, and the Oolites and clays upon it

mean. They mean that the New Red sandstone, after it had been dry

land, or all but dry land (as is proved by the footprints of animals

and the deposits of salt), was sunk again beneath the sea. Each

deposit of limestone signifies a long period of time, during which

that sea was pure enough to allow reefs of coral to grow, and shells

to propagate, at the bottom. Each great band of clay signifies a

long period, during which fine mud was brought down from some wasting

land in the neighbourhood. And that land was not far distant is

proved by the bones of the Pterodactyle, of Crocodiles, and of

Marsupials; by the fact that the shells are of shallow-water or shore

species; by the presence, mixed with them, of fragments of wood,

impressions of plants, and even wing-shells of beetles; and lastly,

if further proof was needed, by the fact that in the "dirt-bed" of

the Isle of Portland and the neighbouring shores, stumps of trees

allied to the modern sago-palms are found as they grew in the soil,

which, with them, has been covered up in layers of freshwater shale

and limestone. A tropic forest has plainly sunk beneath a lagoon;

and that lagoon, again, beneath the sea.

And how long did this period of slow sinking go on? Who can tell?

The thickness of the Lias and Oolites together cannot be less than a

thousand feet. Considering, then, the length of time required to lay

down a thousand feet of strata, and considering the vast difference

between the animals found in them, and the few found in the New Red

sandstone, we have a right to call them another world, and that one

which must have lasted for ages.

After we pass Oxford, or the Vale of Aylesbury, we enter yet another

world. We come to a bed of sand, under which the freestones and

their adjoining clays dip to the south-east. This is called commonly

the lower Greensand, though it is not green, but rich iron-red. Then

succeeds a band of stiff blue clay, called the Gault, and then

another bed of sand, the upper Greensand, which is more worthy of the

name, for it does carry, in most places, a band of green or

"glauconite" sand. But it and the upper layers of the lower

Greensand also, are worth our attention; for we are all probably

eating them from time to time in the form of bran.

It had been long remarked that certain parts of these beds carried

admirable wheatland; it had been remarked, too, that the finest hop-

lands--those of Farnham, for instance, and Tunbridge--lay upon them:

but that the fertile band was very narrow; that, as in the Surrey

Moors, vast sheets of the lower Greensand were not worth cultivation.

What caused the striking difference?

My beloved friend and teacher, the late Dr. Henslow, when Professor

of Botany at Cambridge, had brought to him by a farmer (so the story

ran) a few fossils. He saw, being somewhat of a geologist and

chemist, that they were not, as fossils usually are, carbonate of

lime, but phosphate of lime--bone-earth. He said at once, as by an

inspiration, "You have found a treasure--not a gold-mine, indeed, but

a food-mine. This is bone-earth, which we are at our wits' end to

get for our grain and pulse; which we are importing, as expensive

bones, all the way from Buenos Ayres. Only find enough of them, and

you will increase immensely the food supply of England, and perhaps

make her independent of foreign phosphates in case of war."

His advice was acted on; for the British farmer is by no means the

stupid personage which townsfolk are too apt to fancy him. This bed

of phosphates was found everywhere in the Greensand, underlying the

Chalk. It may be traced from Dorsetshire through England to

Cambridge, and thence, I believe, into Yorkshire. It may be traced

again, I believe, all round the Weald of Kent and Sussex, from Hythe

to Farnham--where it is peculiarly rich--and so to Eastbourne and

Beachey Head; and it furnishes, in Cambridgeshire, the greater part

of those so-called "coprolites," which are used perpetually now for

manure, being ground up, and then treated with sulphuric acid, till

they become a "soluble super-phosphate of lime."

So much for the useless "hobby," as some fancy it, of poking over old

bones and stones, and learning a little of the composition of this

earth on which God has placed us.

How to explain the presence of this vast mass of animal matter, in

one or two thin bands right across England, I know not. That the

fossils have been rolled on a sea-beach is plain to those who look at

them. But what caused so vast a destruction of animal life along

that beach, must remain one of the buried secrets of the past.

And now we are fast nearing another world, which is far younger than

that coprolite bed, and has been formed under circumstances the most

opposite to it. We are nearing, by whatever rail we approach London,

the escarpment of the chalk downs.

All readers, surely, know the white chalk, the special feature and

the special pride of the south of England. All know its softly-

rounded downs, its vast beech woods, its short and sweet turf, its

snowy cliffs, which have given--so some say--to the whole island the

name of Albion--the white land. But all do not, perhaps, know that

till we get to the chalk no single plant or animal has been found

which is exactly like any plant or animal now known to be living.

The plants and animals grow, on the whole, more and more like our

living forms as we rise in the series of beds. But only above the

chalk (as far as we yet know) do we begin to find species identical

with those living now.

This in itself would prove a vast lapse of time. We shall have a

further proof of that vast lapse when we examine the chalk itself.

It is composed--of this there is now no doubt--almost entirely of the

shells of minute animalcules; and animalcules (I use an unscientific

word for the sake of unscientific readers) like these, and in some

cases identical with them, are now forming a similar deposit of mud,

at vast depths, over the greater part of the Atlantic sea-floor.

This fact has been put out of doubt by recent deep-sea dredgings. A

whole literature has been written on it of late. Any reader who

wishes to know it, need only ask the first geologist he meets; and if

he has the wholesome instinct of wonder in him, fill his imagination

with true wonders, more grand and strange than he is like to find in

any fairy tale. All I have to do with the matter here is, to say

that, arguing from the known to the unknown, from the Atlantic deep-

sea ooze which we do know about, to the chalk which we do not know

about, the whole of the chalk must have been laid down at the bottom

of a deep and still ocean, far out of the reach of winds, tides, and

even currents, as a great part of the Atlantic sea-floor is at this

day.

Prodigious! says the reader. And so it is. Prodigious to think that

that shallow Greensand shore, strewed with dead animals, should sink

to the bottom of an ocean, perhaps a mile, perhaps some four miles

deep. Prodigious the time during which it must have lain as a still

ocean-floor. For so minute are the living atomies which form the

ooze, that an inch, I should say, is as much as we can allow for

their yearly deposit; and the chalk is at least a thousand feet

thick. It may have taken, therefore, twelve thousand years to form

the chalk alone. A rough guess, of course, but one as likely to be

two or three times too little as two or three times too big. Such,

or somewhat such, is the fact. It had long been suspected, and more

than suspected; and the late discoveries of Dr. Carpenter and Mr.

Wyville Thompson have surely placed it beyond doubt.

Thus, surely, if we call the Oolitic beds one new world above the New

Red sandstone, we must call the chalk a second new world in like

wise.

I will not trouble the reader here with the reasons why geologists

connect the chalk with the greensands below it, by regular

gradations, in spite of the enormous downward leap, from sea-shore to

deep ocean, which the beds seem (but only seem) to have taken. The

change--like all changes in geology--was probably gradual. Not by

spasmodic leaps and starts, but slowly and stately, as befits a God

of order, of patience, and of strength, have these great deeds been

done.

But we have not yet done with new worlds or new prodigies on our way

to London, as any Londoner may ascertain for himself, if he will run

out a few miles by rail, and look in any cutting or pit, where the

surface of the chalk, and the beds which lie on it, are exposed.

On the chalk lie--especially in the Blackheath and Woolwich district-

-sands and clays. And what do they tell us?

Of another new world, in which the chalk has been lifted up again, to

form gradually, doubtless, and at different points in succession, the

shore of a sea.

But what proof is there of this?

The surface of the chalk is not flat and smooth, as it must have been

when at the bottom of the sea. It is eaten out into holes and

furrows, plainly by the gnawing of the waves; and on it lie, in many

places, large rolled flints out of chalk which has been destroyed,

beds of shore-shingle, beds of oysters lying as they grew, fresh or

brackish water-shells standing as they lived, bits of lignite (fossil

wood half turned to coal), and (as in Katesgrove pits at Reading)

leaves of trees. Proof enough, one would say, that the chalk had

been raised till part of it at least became dry land, and carried

vegetation.

And yet we have not done. There is another world to tell of yet.

For these beds (known as the Woolwich and Reading beds) dip under

that vast bed of London clay, four hundred and more feet thick, which

(as I said in my last chapter) was certainly laid down by the estuary

of some great tropic river, among palm-trees and Anonas, crocodiles

and turtles.

Is the reader's power of belief exhausted?

If not: there are to be seen, capping almost every high land round

London, the remains of a fifth world. Some of my readers may have

been to Ascot races, or to Aldershot camp, and may recollect the

table-land of the sandy moors, perfectly flat atop, dreary enough to

those to whom they are not (as they have long been to me) a home and

a work-field. Those sands are several hundred feet thick. They lie

on the London clay. And they represent--the reader must take

geologists' word for it--a series of beds in some places thousands of

feet thick, in the Isle of Wight, in the Paris basin, in the volcanic

country of the Auvergne, in Switzerland, in Italy; a period during

which the land must at first have swarmed with forms of tropic life,

and then grown--but very gradually--more temperate, and then colder

and colder still; till at last set in that age of ice, which spread

the boulder pebbles over all rocks and soils indiscriminately, from

the Lake mountains to within a few miles of London.

For everywhere about those Ascot moors, the top of the sands has been

ploughed by shore-ice in winter, as they lay a-wash in the shallow

sea; and over them, in many places, is spread a thin sheet of ice

gravel, more ancient, the best geologists think, than the boulder and

the boulder-clay.

If any of my readers ask how long the period was during which those

sands of Ascot Heath and Aldershot have been laid down, I cannot

tell. But this we can tell. It was long enough to see such changes

in land and sea, that maps representing Europe during the greater

part of that period (as far as we can guess at it) look no more like

Europe than like America or the South Sea Islands. And this we can

tell besides: that that period was long enough for the Swiss Alps to

be lifted up at least 10,000 feet of their present height. And that

was a work which--though God could, if He willed it, have done it in

a single day--we have proof positive was not done in less than ages,

beside which the mortal life of man is as the life of the gnat which

dances in the sun.

And all this, and more--as may be proved from the geology of foreign

countries--happened between the date of the boulder-clay, and that of

the New Red sandstone on which it rests.

IV. THE COAL IN THE FIRE

My dear town-dwelling readers, let me tell you now something of a

geological product well known, happily, to all dwellers in towns, and

of late years, thanks to railroad extension, to most dwellers in

country districts: I mean coal.

Coal, as of course you know, is commonly said to be composed of

vegetable matter, of the leaves and stems of ancient plants and

trees--a startling statement, and one which I do not wish you to take

entirely on trust. I shall therefore spend a few pages in showing

you how this fact--for fact it is--was discovered. It is a very good

example of reasoning from the known to the unknown. You will have a

right to say at first starting, "Coal is utterly different in look

from leaves and stems. The only property which they seem to have in

common is that they can both burn." True. But difference of mere

look may be only owing to a transformation, or series of

transformations. There are plenty in nature quite as great, and

greater. What can be more different in look, for instance, than a

green field of wheat and a basket of loaves at the baker's? And yet

there is, I trust, no doubt whatsoever that the bread has been once

green wheat, and that the green wheat has been transformed into

bread--making due allowance, of course, for the bone-dust, or gypsum,

or alum with which the worthy baker may have found it profitable to

adulterate his bread, in order to improve the digestion of Her

Majesty's subjects.

But you may say, "Yes, but we can see the wheat growing, flowering,

ripening, reaped, ground, kneaded, baked. We see, in the case of

bread, the processes of the transformation going on: but in the case

of coal we do not see the wood and leaves being actually transformed

into coal, or anything like it."

Now suppose we laid out the wheat on a table in a regular series,

such as you may see in many exhibitions of manufactures; beginning

with the wheat plant at one end, and ending with the loaf at the

other; and called in to look at them a savage who knew nothing of

agriculture and nothing of cookery--called in, as an extreme case,

the man in the moon, who certainly can know nothing of either; for as

there is neither air nor water round the moon, there can be nothing

to grow there, and therefore nothing to cook--and suppose we asked

him to study the series from end to end. Do you not think that the

man in the moon, if he were half as shrewd as Crofton Croker makes

him in his conversation with Daniel O'Rourke, would answer after due

meditation, "How the wheat plant got changed into the loaf I cannot

see from my experience in the moon: but that it has been changed,

and that the two are the same thing I do see, for I see all the

different stages of the change." And so I think you may say of the

wood and the coal.

The man in the moon would be quite reasonable in his conclusion; for

it is a law, a rule, and one which you will have to apply again and

again in the study of natural objects, that however different two

objects may look in some respects, yet if you can find a regular

series of gradations between them, with all shades of likeness, first

to one of them and then to the other, then you have a fair right to

suppose them to be only varieties of the same species, the same kind

of thing, and that, therefore, they have a common origin.

That sounds rather magniloquent. Let me give you a simple example.

Suppose you had come into Britain with Brute, the grandson of AEneas,

at that remote epoch when (as all archaeologists know who have duly

read Geoffrey of Monmouth and the Arthuric legends) Britain was

inhabited only by a few giants. Now if you had met giants with one

head, and also giants with seven heads, and no others, you would have

had a right to say, "There are two breeds of giants here, one-headed

and seven-headed." But if you had found, as Jack the Giant-Killer

(who belongs to the same old cycle of myths) appears to have found,

two-headed giants also, and three-headed, and giants, indeed, with

any reasonable number of heads, would you not have been justified in

saying, "They are all of the same breed, after all; only some are

more capitate, or heady, than others!"

I hope that you agree to that reasoning; for by it I think we arrive

most surely at a belief in the unity of the human race, and that the

Negro is actually a man and a brother.

If the only two types of men in the world were an extreme white type,

like the Norwegians, and an extreme black type, like the Negros, then

there would be fair ground for saying, "These two types have been

always distinct; they are different races, who have no common

origin." But if you found, as you will find, many types of man

showing endless gradations between the white man and the Negro, and

not only that, but endless gradations between them both and a third

type, whose extreme perhaps is the Chinese--endless gradations, I

say, showing every conceivable shade of resemblance or difference,

till you often cannot say to what type a given individual belongs;

and all of them, however different from each other, more like each

other than they are like any other creature upon earth; then you are

justified in saying, "All these are mere varieties of one kind.

However distinct they are now, they were probably like each other at

first, and therefore all probably had a common origin." That seems

to me sound reasoning, and advanced natural science is corroborating

it more and more daily.

Now apply the same reasoning to coal. You may find about the world--

you may see even in England alone--every gradation between coal and

growing forest. You may see the forest growing in its bed of

vegetable mould; you may see the forest dead and converted into peat,

with stems and roots in it; that, again, into sunken forests, like

those to be seen below high-water mark on many coasts of this island.

You find gradations between them and beds of lignite, or wood coal;

then gradations between lignite and common or bituminous coal; and

then gradations between common coal and culm, or anthracite, such as

is found in South Wales. Have you not a right to say, "These are all

but varieties of the same kind of thing--namely, vegetable matter?

They have a common origin--namely, woody fibre. And coal, or rather

culm, is the last link in a series of transformations from growing

vegetation?"

This is our first theory. Let us try to verify it, as scientific men

are in the habit of doing, by saying, If that be true, then something

else is likely to be true too.

If coal has all been vegetable soil, then it is likely that some of

it has not been quite converted into shapeless coal. It is likely

that there will be vegetable fibre still to be seen here and there;

perhaps leaves, perhaps even stems of trees, as in a peat bog. Let

us look for them.

You will not need to look far. The coal, and the sands and shales

which accompany the coal, are so full of plant-remains, that three

hundred species were known to Adolphe Brongniart as early as 1849,

and that number has largely increased since.

Now one point is specially noticeable about these plants of the coal;

namely, that they may at least have grown in swamps.

First, you will be interested if you study the coal flora, with the

abundance, beauty, and variety of the ferns. Now ferns in these

islands grow principally in rocky woods, because there, beside the

moisture, they get from decaying vegetable or decaying rock,

especially limestone, the carbonic acid which is their special food,

and which they do not get on our dry pastures, and still less in our

cultivated fields. But in these islands there are two noble species,

at least, which are true swamp-ferns; the Lastraea Thelypteris, which

of old filled the fens, but is now all but extinct; and the Osmunda,

or King-fern, which, as all know, will grow wherever it is damp

enough about the roots. In Hampshire, in Devon, and Cornwall, and in

the southwest of Ireland, the King-fern too is a true swamp fern.

But in the Tropics I have seen more than once noble tree-ferns

growing in wet savannahs at the sea-level, as freely as in the

mountain-woods; ferns with such a stem as some of the coal ferns had,

some fifteen feet in height, under which, as one rode on horseback,

one saw the blazing blue sky, as through a parasol of delicate lace,

as men might have long ages since have seen it, through the plumed

fronds of the ferns now buried in the coal, had there only been a man

then created to enjoy its beauty.

Next we find plants called by geologists Calamites. There is no

doubt now that they are of the same family as our Equiseta, or horse-

tails, a race which has, over most parts of the globe, dwindled down

now from twenty or thirty feet in height, as they were in the old

coal measures, to paltry little weeds. The tallest Equisetum in

England--the beautiful E. Telmateia--is seldom five feet high. But

they, too, are mostly mud and swamp plants; and so may the Calamites

have been.

The Lepidodendrons, again, are without doubt the splendid old

representatives of a family now dwindled down to such creeping things

as our club-mosses, or Lycopodiums. Now it is a certain fact, which

can be proved by the microscope, that a very great part of the best

coal is actually made up of millions of the minute seeds of club-

mosses, such as grow--a few of them, and those very small--on our

moors; a proof, surely, not only of the vast amount of the vegetation

in the coal-making age, but also of the vast time during which it

lasted. The Lepidodendra may have been fifty or sixty feet high.

There is not a Lycopodium in the world now, I believe, five feet

high. But the club-mosses are now, in these islands and elsewhere,

lovers of wet and peaty soils, and so may their huger prototypes have

been, in the old forests of the coal.

Of the Sigillariae we cannot say as much with certainty, for

botanists are not agreed as to what low order of flowerless plants

they belong. But that they rooted in clay beds there is proof, as

you will hear presently.

And as to the Conifers, or pine-like trees--the Dadoxylon, of which

the pith goes by the name of Sternbergia, and the uncertain tree

which furnishes in some coal-measures bushels of a seed connected

with that of the yew--we may suppose that they would find no more

difficulty in growing in swamps than the cypress, which forms so

large a portion of the vegetation in the swamps of the Southern

United States.

I have given you these hints, because you will naturally wish to know

what sort of a world it was in which all these strange plants grew

and turned into coal.

My answer is, that it was most probably just like the world in which

we are living now, with the one exception that the plants and animals

are different.

It was the fashion a few years since to explain the coal--like other

phenomena of geology--by some mere hypothesis of a state of things

quite unlike what we see now. We were brought up to believe that in

the Carboniferous, or coal-bearing era, the atmosphere was intensely

moist and hot, and overcharged with carbonic acid, which had been

poured out from the interior of the planet by volcanic eruptions, or

by some other convulsion. I forget most of it now: and really there

is no need to remember; for it is all, I verily believe, a dream--an

attempt to explain the unknown not by the known, but by the still

more unknown. You may find such theories lingering still in

sensational school-books, if you like to be unscientific. If you

like, on the other hand, to be scientific you will listen to those

who tell you that instead of there having been one unique

carboniferous epoch, with a peculiar coal-making climate, all epochs

are carboniferous if they get the chance; that coal is of every age,

from that of the Scotch and English beds, up to the present day. The

great coal-beds along the Rocky Mountains, for instance, are

tertiary--that is, later than the chalk. Coal is forming now, I

doubt not, in many places on the earth, and would form in many more,

if man did not interfere with the processes of wild nature, by

draining the fens, and embanking the rivers.

Let me by a few words prove this statement. They will give you,

beside, a fresh proof of Sir Charles Lyell's great geological rule--

that the best way to explain what we see in ancient rocks is to take

for granted, as long as we can do so fairly, that things were going

on then very much as they are going on now.

When it was first seen that coal had been once vegetable, the

question arose--How did all these huge masses of vegetable matter get

there? The Yorkshire and Derbyshire coal-fields, I hear, cover 700

or 800 square miles; the Lancashire about 200. How large the North

Wales and the Scotch fields are I cannot say. But doubtless a great

deal more coal than can be got at lies under the sea, especially in

the north of Wales. Coal probably exists over vast sheets of England

and France, buried so deeply under later rocks, that it cannot be

reached by mining. As an instance, a distinguished geologist has

long held that there are beds of coal under London itself, which

rise, owing to a peculiar disturbance of the strata, to within 1,000

or 1,200 feet of the surface, and that we or our children may yet see

coal-mines in the marshes of the Thames. And more, it is a provable

fact that only a portion of the coal measures is left. A great part

of Ireland must once have been covered with coal, which is now

destroyed. Indeed, it is likely that the coal now known of in Europe

and America is but a remnant of what has existed there in former

ages, and has been eaten away by the inroads of the sea.

Now whence did all that enormous mass of vegetable soil come? Off

some neighbouring land, was the first and most natural answer. It

was a rational one. It proceeded from the known to the unknown. It

was clear that these plants had grown on land; for they were land-

plants. It was clear that there must have been land close by, for

between the beds of coal, as you all know, the rock is principally

coarse sandstone, which could only have been laid down (as I have

explained to you already) in very shallow water.

It was natural, then, to suppose that these plants and trees had been

swept down by rivers into the sea, as the sands and muds which buried

them had been. And it was known that at the mouths of certain

rivers--the Mississippi, for instance--vast rafts of dead floating

trees accumulated; and that the bottoms of the rivers were often full

of snags, etc.; trees which had grounded, and stuck in the mud; and

why should not the coal have been formed in the same way?

Because--and this was a serious objection--then surely the coal would

be impure--mixed up with mud and sand, till it was not worth burning.

Instead of which, the coal is usually pure vegetable, parted sharply

from the sandstone which lies on it. The only other explanation was,

that the coal vegetation had grown in the very places where it was

found. But that seemed too strange to be true, till that great

geologist, Sir W. Logan--who has since done such good work in Canada-

-showed that every bed of coal had a bed of clay under it, and that

that clay always contained fossils called Stigmaria. Then it came

out that the Stigmaria in the under clay had long filaments attached

to them, while when found in the sandstones or shales, they had lost

their filaments, and seemed more or less rolled--in fact, that the

natural place of the Stigmaria was in the under clay. Then Mr.

Binney discovered a tree--a Sigillaria, standing upright in the coal-

measures with its roots attached. Those roots penetrated into the

under clay of the coal; and those roots were Stigmarias. That seems

to have settled the question. The Sigillarias, at least, had grown

where they were found, and the clay beneath the coal-beds was the

original soil on which they had grown. Just so, if you will look at

any peat bog you will find it bottomed by clay, which clay is pierced

everywhere by the roots of the moss forming the peat, or of the

trees, birches, alders, poplars, and willows, which grow in the bog.

So the proof seemed complete, that the coal had been formed out of

vegetation growing where it was buried. If any further proof for

that theory was needed, it would be found in this fact, most

ingeniously suggested by Mr. Boyd Dawkins. The resinous spores, or

seeds of the Lepidodendra make up--as said above--a great part of the

bituminous coal. Now those spores are so light, that if the coal had

been laid down by water, they would have floated on it, and have been

carried away; and therefore the bituminous coal must have been

formed, not under water, but on dry land.

I have dwelt at length on these further arguments, because they seem

to me as pretty a specimen as I can give my readers of that regular

and gradual induction, that common-sense regulated, by which

geological theories are worked out.

But how does this theory explain the perfect purity of the coal? I

think Sir C. Lyell answers that question fully in p. 383 of his

"Student's Elements of Geology." He tells us that the dense growths

of reeds and herbage which encompass the margins of forest-covered

swamps in the valley and delta of the Mississippi, in passing through

them, are filtered and made to clear themselves entirely before they

reach the areas in which vegetable matter may accumulate for

centuries, forming coal if the climate be favourable; and that in the

cypress-swamps of that region no sediment mingles with the vegetable

matter accumulated from the decay of trees and semi-aquatic plants;

so that when, in a very dry season, the swamp is set on fire, pits

are burnt into the ground many feet deep, or as far as the fire can

go down without reaching water, and scarcely any earthy residuum is

left; just as when the soil of the English fens catches fire, red-hot

holes are eaten down through pure peat till the water-bearing clay

below is reached. But the purity of the water in peaty lagoons is

observable elsewhere than in the delta of the Mississippi. What can

be more transparent than many a pool surrounded by quaking bogs,

fringed, as they are in Ireland, with a ring of white water-lilies,

which you dare not stoop to pick, lest the peat, bending inward,

slide you down into that clear dark gulf some twenty feet in depth,

bottomed and walled with yielding ooze, from which there is no

escape? Most transparent, likewise, is the water of the West Indian

swamps. Though it is of the colour of coffee, or rather of dark

beer, and so impregnated with gases that it produces fever or cholera

when drunk, yet it is--at least when it does not mingle with the salt

water--so clear, that one might see every marking on a boa-

constrictor or alligator, if he glided along the bottom under the

canoe.

But now comes the question--Even if all this be true, how were the

forests covered up in shale and sandstone, one after another?

By gradual sinking of the land, one would suppose.

If we find, as we may find in a hundred coal-pits, trees rooted as

they grew, with their trunks either standing up through the coal, and

through the sandstone above the coal; their bark often remaining as

coal while their inside is filled up with sandstone, has not our

common-sense a right to say--The land on which they grew sank below

the water-line; the trees were killed; and the mud and sand which

were brought down the streams enveloped their trunks? As for the

inside being full of sandstone, have we not all seen hollow trees?

Do we not all know that when a tree dies its wood decays first, its

bark last? It is so, especially in the Tropics. There one may see

huge dead trees with their bark seemingly sound, and their inside a

mere cavern with touchwood at the bottom; into which caverns one used

to peep with some caution. For though one might have found inside

only a pair of toucans, or parrots, or a whole party of jolly little

monkeys, one was quite as likely to find a poisonous snake four or

five feet long, whose bite would have very certainly prevented me

having the pleasure of writing this book.

Now is it not plain that if such trees as that sunk, their bark would

be turned into lignite, and at last into coal, while their insides

would be silted up with mud and sand? Thus a core or pillar of hard

sandstone would be formed, which might do to the collier of the

future what they are too apt to do now in the Newcastle and Bristol

collieries. For there, when the coal is worked out below, the

sandstone stems--"coal-pipes" as the colliers call them--in the roof

of the seam, having no branches, and nothing to hold them up but

their friable bark of coal, are but too apt to drop out suddenly,

killing or wounding the hapless men below.

Or again, if we find--as we very often find--as was found at

Parkfield Colliery, near Wolverhampton, in the year 1814--a quarter

of an acre of coal-seam filled. with stumps of trees as they grew,

their trunks broken off and lying in every direction, turned into

coal, and flattened, as coal-fossils so often are, by the weight of

the rock above--should we not have a right to say--These trees were

snapped off where they grew by some violent convulsion; by a storm,

or by a sudden inrush of water owing to a sudden sinking of the land,

or by the very earthquake shock itself which sank the land?

But what evidence have we of such sinkings? The plain fact that you

have coal-seam above coal-seam, each with its bed of under-clay; and

that therefore the land MUST have sunk ere the next bed of soil could

have been deposited, and the next forest have grown on it.

In one of the Rocky Mountain coal-fields there are more than thirty

seams of coal, each with its under-clay below it. What can that mean

but thirty or more subsidences of the land, and the peat of thirty or

more forests or peat-mosses, one above the other? And now if any

reader shall say, Subsidence? What is this quite new element which

you have brought into your argument? You told us that you would

reason from the known to the unknown. What do we know of subsidence?

You offered to explain the thing which had gone on once by that which

is going on now. Where is subsidence going on now upon the surface

of our planet? And where, too, upheaval, such as would bring us

these buried forests up again from under the sea-level, and make

them, like our British coal-field, dry land once more?

The answer is--Subsidence and elevation of the land are common now,

probably just as common as they were in any age of this planet's

history.

To give two instances, made now notorious by the writings of

geologists. As lately as 1819 a single earthquake shock in Cutch, at

the mouth of the Indus, sunk a tract of land larger than the Lake of

Geneva in some places to a depth of eighteen feet, and converted it

into an inland sea. The same shock raised, a few miles off, a

corresponding sheet of land some fifty miles in length, and in some

parts sixteen miles broad, ten feet above the level of the alluvial

plain, and left it to be named by the country-people the "Ullah

Bund," or bank of God, to distinguish it from the artificial banks in

the neighbourhood.

Again: in the valley of the Mississippi--a tract which is now, it

would seem, in much the same state as central England was while our

coal-fields were being laid down--the earthquakes of 1811-12 caused

large lakes to appear suddenly in many parts of the district, amid

the dense forests of cypress. One of these, the "Sunk Country," near

New Madrid, is between seventy and eighty miles in length, and thirty

miles in breadth, and throughout it, as late as 1846, "dead trees

were conspicuous, some erect in the water, others fallen, and strewed

in dense masses over the bottom, in the shallows, and near the

shore." I quote these words from Sir Charles Lyell's "Principles of

Geology" (11th edit.), vol. i. p. 453. And I cannot do better than

advise my readers, if they wish to know more of the way in which coal

was formed, to read what is said in that book concerning the Delta of

the Mississippi, and its strata of forests sunk where they grew, and

in some places upraised again, alternating with beds of clay and

sand, vegetable soil, recent sea-shells, and what not, forming, to a

depth of several hundred feet, just such a mass of beds as exists in

our own coal-fields at this day.

If, therefore, the reader wishes to picture to himself the scenery of

what is now central England, during the period when our coal was

being laid down, he has only, I believe, to transport himself in

fancy to any great alluvial delta, in a moist and warm climate,

favourable to the growth of vegetation. He has only to conceive

wooded marshes, at the mouth of great rivers, slowly sinking beneath

the sea; the forests in them killed by the water, and then covered up

by layers of sand, brought down from inland, till that new layer

became dry land, to carry a fresh crop of vegetation. He has thus

all that he needs to explain how coal-measures were formed. I myself

saw once a scene of that kind, which I should be sorry to forget; for

there was, as I conceived, coal, making, or getting ready to be made,

before my eyes: a sheet of swamp, sinking slowly into the sea; for

there stood trees, still rooted below high-water mark, and killed by

the waves; while inland huge trees stood dying, or dead, from the

water at their roots. But what a scene--a labyrinth of narrow

creeks, so narrow that a canoe could not pass up, haunted with

alligators and boa-constrictors, parrots and white herons, amid an

inextricable confusion of vegetable mud, roots of the alder-like

mangroves, and tangled creepers hanging from tree to tree; and

overhead huge fan-palms, delighting in the moisture, mingled with

still huger broad-leaved trees in every stage of decay. The drowned

vegetable soil of ages beneath me; above my head, for a hundred feet,

a mass of stems and boughs, and leaves and flowers, compared with

which the richest hothouse in England was poor and small. But if the

sinking process which was going on continued a few hundred years, all

that huge mass of wood and leaf would be sunk beneath the swamp, and

covered up in mud washed down from the mountains, and sand driven in

from the sea; to form a bed many feet thick, of what would be first

peat, then lignite, and last, it may be, coal, with the stems of

killed trees standing up out of it into the new mud and sand-beds

above it, just as the Sigillariae and other stems stand up in the

coal-beds both of Britain and of Nova Scotia; while over it a fresh

forest would grow up, to suffer the same fate--if the sinking process

went on--as that which had preceded it.

That was a sight not easily to be forgotten. But we need not have

gone so far from home, at least, a few hundred years ago, to see an

exactly similar one. The fens of Norfolk and Cambridgeshire, before

the rivers were embanked, the water pumped off, the forests felled,

and the reed-beds ploughed up, were exactly in the same state. The

vast deposits of peat between Cambridge and the sea, often filled

with timber-trees, either fallen or upright as they grew, and often

mixed with beds of sand or mud, brought down in floods, were formed

in exactly the same way; and if they had remained undrained, then

that slow sinking, which geologists say is going on over the whole

area of the Fens, would have brought them gradually, but surely,

below the sea-level, to be covered up by new forests, and converted

in due time into coal. And future geologists would have found--they

may find yet, if, which God forbid, England should become barbarous

and the trees be thrown out of cultivation--instead of fossil

Lepidodendra and Sigillariae, Calamites and ferns, fossil ashes and

oaks, alders and poplars, bulrushes and reeds. Almost the only

fossil fern would have been that tall and beautiful Lastraea

Thelypteris, once so abundant, now all but destroyed by drainage and

the plough.

We need not, therefore, fancy any extraordinary state of things on

this planet while our English coal was being formed. The climate of

the northern hemisphere--Britain, at least, and Nova Scotia--was

warmer than now, to judge from the abundance of ferns; and especially

of tree-ferns; but not so warm, to judge from the presence of

conifers (trees of the pine tribe), as the Tropics. Moreover, there

must have been, it seems to me, a great scarcity of animal-life.

Insects are found, beautifully preserved; a few reptiles, too, and

land-shells; but very few. And where are the traces of such a

swarming life as would be entombed were a tropic forest now sunk;

which is found entombed in many parts of our English fens? The only

explanation which I can offer is this--that the club-mosses, tree-

ferns, pines, and other low-ranked vegetation of the coal afforded

little or no food for animals, as the same families of plants do to

this day; and if creatures can get nothing to eat, they certainly

cannot multiply and replenish the earth. But, be that as it may, the

fact that coal is buried forest is not affected.

Meanwhile, the shape and arrangements of sea and land must have been

utterly different from what they are now. Where was that great land,

off which great rivers ran to deposit our coal-measures in their

deltas? It has been supposed, for good reasons, that north-western

France, Belgium, Holland, and Germany were then under the sea; that

Denmark and Norway were joined to Scotland by a continent, a tongue

of which ran across the centre of England, and into Ireland, dividing

the northern and southern coal-fields. But how far to the west and

north did that old continent stretch? Did it, as it almost certainly

did long ages afterwards, join Greenland and North America with

Scotland and Norway? Were the northern fields of Nova Scotia, which

are of the same geological age as our own, and contain the same

plants, laid down by rivers which ran off the same continent as ours?

Who can tell now? That old land, and all record of it, save what

these fragmentary coal-measures can give, are buried in the dark

abyss of countless ages; and we can only look back with awe, and

comfort ourselves with the thought--Let Time be ever so vast, yet

Time is not Eternity.

One word more. If my readers have granted that all for which I have

argued is probable, they will still have a right to ask for further

proof.

They will be justified in saying: "You say that coal is transformed

vegetable matter; but can you show us how the transformation takes

place? Is it possible according to known natural laws?"

The chemist must answer that. And he tells us that wood can become

lignite, or wood-coal, by parting with its oxygen, in the shape of

carbonic acid gas, or choke-damp; and then common or bituminous coal,

by parting with its hydrogen, chiefly in the form of carburetted

hydrogen--the gas with which we light our streets. That is about as

much as the unscientific reader need know. But it is a fresh

corroboration of the theory that coal has been once vegetable fibre,

for it shows how vegetable fibre can, by the laws of nature, become

coal. And it certainly helps us to believe that a thing has been

done, if we are shown that it can be done.

This fact explains, also, why in mines of wood-coal carbonic acid,

i.e. choke-damp, alone is given off. For in the wood-coal a great

deal of the hydrogen still remains. In mines of true coal, not only

is choke-damp given off, but that more terrible pest of the miners,

fire-damp, or explosive carburetted hydrogen and olefiant gases. Now

the occurrence of that fire-damp in mines proves that changes are

still going on in the coal: that it is getting rid of its hydrogen,

and so progressing toward the state of anthracite or culm--stone-coal

as it is sometimes called. In the Pennsylvanian coal-fields some of

the coal has actually done this, under the disturbing force of

earthquakes; for the coal, which is bituminous, like our common coal,

to the westward where the strata are horizontal, becomes gradually

anthracite as it is tossed and torn by the earthquake faults of the

Alleghany and Appalachian mountains.

And is a further transformation possible? Yes; and more than one.

If we conceive the anthracite cleared of all but its last atoms of

oxygen, hydrogen, and nitrogen, till it has become all but pure

carbon, it would become--as it has become in certain rocks of immense

antiquity, graphite--what we miscall black-lead. And, after that, it

might go through one transformation more, and that the most startling

of all. It would need only perfect purification and crystallisation

to become--a diamond; nothing less. We may consider the coal upon

the fire as the middle term of a series, of which the first is live

wood, and the last diamond; and indulge safely in the fancy that

every diamond in the world has probably, at some remote epoch, formed

part of a growing plant.

A strange transformation; which will look to us more strange, more

truly poetical, the more steadily we consider it.

The coal on the fire; the table at which I write--what are they made

of? Gas and sunbeams; with a small percentage of ash, or earthy

salts, which need hardly be taken into account.

Gas and sunbeams. Strange, but true.

The life of the growing plant--and what that life is who can tell?--

laid hold of the gases in the air and in the soil; of the carbonic

acid, the atmospheric air, the water--for that too is gas. It drank

them in through its rootlets: it breathed them in through its leaf-

pores, that it might distil them into sap, and bud, and leaf, and

wood. But it has to take in another element, without which the

distillation and the shaping could never have taken place. It had to

drink in the sunbeams--that mysterious and complex force which is for

ever pouring from the sun, and making itself partly palpable to our

senses as heat and light. So the life of the plant seized the

sunbeams, and absorbed them, buried them in itself--no longer as

light and heat, but as invisible chemical force, locked up for ages

in that woody fibre.

So it is. Lord Lytton told us long ago, in a beautiful song, how

The Wind and the Beam loved the Rose.

But Nature's poetry was more beautiful than man's. The wind and the

beam loved the rose so well that they made the rose--or rather, the

rose took the wind and the beam, and built up out of them, by her own

inner life, her exquisite texture, hue, and fragrance.

What next? The rose dies; the timber tree dies; decays down into

vegetable fibre, is buried, and turned to coal: but the plant cannot

altogether undo its own work. Even in death and decay it cannot set

free the sunbeams imprisoned in its tissue. The sun-force must stay,

shut up age after age, invisible, but strong; working at its own

prison-cells; transmuting them, or making them capable of being

transmuted by man, into the manifold products of coal--coke,

petroleum, mineral pitch, gases, coal-tar, benzole, delicate aniline

dyes, and what not, till its day of deliverance comes.

Man digs it, throws it on the fire, a black, dead-seeming lump. A

corner, an atom of it, warms till it reaches the igniting point; the

temperature at which it is able to combine with oxygen.

And then, like a dormant live thing, awaking after ages to the sense

of its own powers, its own needs, the whole lump is seized, atom

after atom, with an infectious hunger for that oxygen which it lost

centuries since in the bottom of the earth. It drinks the oxygen in

at every pore; and burns.

And so the spell of ages is broken. The sun-force bursts its prison-

cells, and blazes into the free atmosphere, as light and heat once

more; returning in a moment into the same forms in which it entered

the growing leaf a thousand centuries since.

Strange it all is, yet true. But of nature, as of the heart of man,

the old saying stands--that truth is stranger than fiction.

V. THE LIME IN THE MORTAR

I shall presume in all my readers some slight knowledge about lime.

I shall take for granted, for instance, that all are better informed

than a certain party of Australian black fellows were a few years

since.

In prowling on the track of a party of English settlers, to see what

they could pick up, they came--oh joy!--on a sack of flour, dropped

and left behind in the bush at a certain creek. The poor savages had

not had such a prospect of a good meal for many a day. With endless

jabbering and dancing, the whole tribe gathered round the precious

flour-bag with all the pannikins, gourds, and other hollow articles

it could muster, each of course with a due quantity of water from the

creek therein, and the chief began dealing out the flour by handfuls,

beginning of course with the boldest warriors. But, horror of

horrors, each man's porridge swelled before his eyes, grew hot,

smoked, boiled over. They turned and fled, man, woman, and child,

from before that supernatural prodigy; and the settlers coming back

to look for the dropped sack, saw a sight which told the whole tale.

For the poor creatures, in their terror, had thrown away their pans

and calabashes, each filled with that which it was likely to contain,

seeing that the sack itself had contained, not flour, but quick-lime.

In memory of which comi-tragedy, that creek is called to this day,

"Flour-bag Creek."

Now I take for granted that you are all more learned than these black

fellows, and know quick-lime from flour. But still you are not bound

to know what quick-lime is. Let me explain it to you.

Lime, properly speaking, is a metal, which goes among chemists by the

name of calcium. But it is formed, as you all know, in the earth,

not as a metal, but as a stone, as chalk or limestone, which is a

carbonate of lime; that is, calcium combined with oxygen and

carbonic-acid gases.

In that state it will make, if it is crystalline and hard, excellent

building stone. The finest white marble, like that of Carrara in

Italy, of which the most delicate statues are carved, is carbonate of

lime altered and hardened by volcanic heat. But to make mortar of

it, it must be softened and then brought into a state in which it can

be hardened again; and ages since, some man or other, who deserves to

rank as one of the great inventors, one of the great benefactors of

his race, discovered the art of making lime soft and hard again; in

fact of making mortar. The discovery was probably very ancient; and

made, probably like most of the old discoveries, in the East,

spreading Westward gradually. The earlier Greek buildings are

cyclopean, that is, of stone fitted together without mortar. The

earlier Egyptian buildings, though the stones are exquisitely squared

and polished, are put together likewise without mortar. So, long

ages after, were the earlier Roman buildings, and even some of the

later. The famous aqueduct of the Pont du Gard, near Nismes, in the

south of France, has, if I recollect right, no mortar whatever in it.

The stones of its noble double tier of circular arches have been

dropped into their places upon the wooden centres, and stand unmoved

to this day, simply by the jamming of their own weight; a miracle of

art. But the fact is puzzling; for these Romans were the best mortar

makers of the world. We cannot, I believe, surpass them in the art

even now; and in some of their old castles, the mortar is actually to

this day harder and tougher than the stones which it holds together.

And they had plenty of lime at hand if they had chosen to make

mortar. The Pont du Gard crosses a limestone ravine, and is itself

built of limestone. But I presume the cunning Romans would not trust

mortar made from that coarse Nummulite limestone, filled with gritty

sand, and preferred, with their usual carefulness, no mortar at all

to bad.

But I must return, and tell my readers, in a few words, the chemical

history of mortar. If limestone be burnt, or rather roasted, in a

kiln, the carbonic acid is given off--as you may discover by your own

nose; as many a poor tramp has discovered too late, when, on a cold

winter night, he has lain down by the side of the burning kiln to

keep himself warm, and woke in the other world, stifled to death by

the poisonous fumes.

The lime then gives off its carbonic acid, and also its water of

crystallisation, that is, water which it holds (as do many rocks)

locked up in it unseen, and only to be discovered by chemical

analysis. It is then anhydrous--that is, waterless--oxide of lime,

what we call quick-lime; that which figured in the comi-tragedy of

"Flour-bag Creek;" and then, as you may find if you get it under your

nails or into your eyes, will burn and blister like an acid.

This has to be turned again into a hard and tough artificial

limestone, in plain words, into mortar; and the first step is to

slack it--that is, to give it back the water which it has lost, and

for which it is as it were thirsting. So it is slacked with water,

which it drinks in, heating itself and the water till it steams and

swells in bulk, because it takes the substance of the water into its

own substance. Slacked lime, as we all know, is not visibly wetter

than quick-lime; it crumbles to a dry white powder in spite of all

the water which it contains.

Then it must be made to set, that is, to return to limestone, to

carbonate of lime, by drinking in the carbonic acid from water and

air, which some sorts of lime will do instantly, setting at once, and

being therefore used as cements. But the lime usually employed must

be mixed with more or less sand to make it set hard: a mysterious

process, of which it will be enough to tell the reader that the sand

and lime are said to unite gradually, not only mechanically, that is,

by sticking together; but also in part chemically--that is, by

forming out of themselves a new substance, which is called silicate

of lime.

Be that as it may, the mortar paste has now to do two things; first

to dry, and next to take up carbonic acid from the air and water,

enough to harden it again into limestone: and that it will take some

time in doing. A thick wall, I am informed, requires several years

before it is set throughout, and has acquired its full hardness, or

rather toughness; and good mortar, as is well known, will acquire

extreme hardness with age, probably from the very same cause that it

did when it was limestone in the earth. For, as a general rule, the

more ancient the strata is in which the limestone is found, the

harder the limestone is; except in cases where volcanic action and

earthquake pressure have hardened limestone in more recent strata, as

in the case of the white marbles of Carrara in Italy, which are of

the age of our Oolites, that is, of the freestone of Bath, etc.,

hardened by the heat of intruded volcanic rocks.

But now: what is the limestone? and how did it get where it is--not

into the mortar, I mean, but into the limestone quarry? Let me tell

you, or rather, help you to tell yourselves, by leading you, as

before, from the known to the unknown. Let me lead you to places

unknown indeed to most; but there may be sailors or soldiers among my

readers who know them far better than I do. Let me lead you, in

fancy, to some island in the Tropic seas. After all, I am not

leading you as far away as you fancy by several thousand miles, as

you will see, I trust, ere I have done.

Let me take you to some island: what shall it be like? Shall it be

a high island, with cliff piled on cliff, and peak on peak, all rich

with mighty forests, like a furred mantle of green velvet, mounting

up and up till it is lost among white clouds above? Or shall it be a

mere low reef, which you do not see till you are close upon it; on

which nothing rises above the water, but here and there a knot of

cocoa-nut palms or a block of stone, or a few bushes, swarming with

innumerable sea-fowl and their eggs? Let it be which you will: both

are strange enough; both beautiful; both will tell us a story.

The ship will have to lie-to, and anchor if she can; it may be a

mile, it may be only a few yards, from the land. For between it and

the land will be a line of breakers, raging in before the warm trade-

wind. And this, you will be told, marks the edge of the coral reef.

You will have to go ashore in a boat, over a sea which looks

unfathomable, and which may be a mile or more in depth, and search

for an opening in the reef, through which the boat can pass without

being knocked to pieces.

You find one: and in a moment, what a change! The deep has suddenly

become shallow; the blue white, from the gleam of the white coral at

the bottom. But the coral is not all white, only indeed a little of

it; for as you look down through the clear water, you find that the

coral is starred with innumerable live flowers, blue, crimson, grey,

every conceivable hue; and that these are the coral polypes, each

with its ring of arms thrust out of its cell, who are building up

their common habitations of lime. If you want to understand, by a

rough but correct description, what a coral polype is: all who have

been to the sea-side know, or at least have heard of, sea-anemones.

Now coral polypes are sea-anemones, which make each a shell of lime,

growing with its growth. As for their shapes, the variety of them,

the beauty of them, no tongue can describe them. If you want to see

them, go to the Coral Rooms of the British or Liverpool Museums, and

judge for yourselves. Only remember that you must re-clothe each of

those exquisite forms with a coating of live jelly of some delicate

hue, and put back into every one of the thousand cells its living

flower; and into the beds, or rather banks, of the salt-water flower

garden, the gaudiest of shell-less sea-anemones, such as we have on

our coasts, rooted in the cracks, and live shells and sea-slugs, as

gaudy as they, crawling about, with fifty other forms of fantastic

and exuberant life. You must not overlook, too, the fish, especially

the parrot-fish, some of them of the gaudiest colours, who spend

their lives in browsing on the live coral, with strong clipping and

grinding teeth, just as a cow browses the grass, keeping the animal

matter, and throwing away the lime in the form of an impalpable white

mud, which fills up the interstices in the coral beds.

The bottom, just outside the reef, is covered with that mud, mixed

with more lime-mud, which the surge wears off the reef; and if you

have, as you should have, a dredge on board, and try a haul of that

mud as you row home, you may find, but not always, animal forms

rooted in it, which will delight the soul of a scientific man. One,

I hope, would be some sort of Terebratula, or shell akin to it. You

would probably think it a cockle: but you would be wrong. The

animal which dwells in it has about the same relationship to a cockle

as a dog has to a bird. It is a Brachiopod; a family with which the

ancient seas once swarmed, but which is rare now, all over the world,

having been supplanted and driven out of the seas by newer and

stronger forms of shelled animals. The nearest spot at which you are

likely to dredge a live Brachiopod will be in the deep water of Loch

Fyne, in Argyleshire, where two species still linger, fastened,

strangely enough, to the smooth pebbles of a submerged glacier,

formed in the open air during the age of ice, but sunk now to a depth

of eighty fathoms. The first time I saw those shells come up in the

dredge out of the dark and motionless abyss, I could sympathise with

the feelings of mingled delight and awe which, so my companion told

me, the great Professor Owen had in the same spot first beheld the

same lingering remnants of a primaeval world.

The other might be (but I cannot promise you even a chance of

dredging that, unless you were off the coast of Portugal, or the

windward side of some of the West India Islands) a live Crinoid; an

exquisite starfish, with long and branching arms, but rooted in the

mud by a long stalk, and that stalk throwing out barren side

branches; the whole a living plant of stone. You may see in museums

specimens of this family, now so rare, all but extinct. And yet

fifty or a hundred different forms of the same type swarmed in the

ancient seas: whole masses of limestone are made up of little else

but the fragments of such animals.

But we have not landed yet on the dry part of the reef. Let us make

for it, taking care meanwhile that we do not get our feet cut by the

coral, or stung as by nettles by the coral insects. We shall see

that the dry land is made up entirely of coral, ground and broken by

the waves, and hurled inland by the storm, sometimes in huge

boulders, mostly as fine mud; and that, under the influence of the

sun and of the rain, which filters through it, charged with lime from

the rotting coral, the whole is setting, as cement sets, into rock.

And what is this? A long bank of stone standing up as a low cliff,

ten or twelve feet above high-water mark. It is full of fragments of

shell, of fragments of coral, of all sorts of animal remains; and the

lower part of it is quite hard rock. Moreover, it is bedded in

regular layers, just such as you see in a quarry. But how did it get

there? It must have been formed at the sea-level, some of it,

indeed, under the sea; for here are great masses of madrepore and

limestone corals imbedded just as they grew. What lifted it up?

Your companions, if you have any who know the island, have no

difficulty in telling you. It was hove up, they say, in the

earthquake in such and such a year; and they will tell you, perhaps,

that if you will go on shore to the main island which rises inside

the reef, you may see dead coral beds just like these lying on the

old rocks, and sloping up along the flanks of the mountains to

several hundred feet above the sea. I have seen such many a time.

Thus you find the coral being converted gradually into a limestone

rock, either fine and homogeneous, composed of coral grown into pulp,

or filled with corals and shells, or with angular fragments of older

coral rock. Did you never see that last? No? Yes, you have a

hundred times. You have but to look at the marbles commonly used

about these islands, with angular fragments imbedded in the mass, and

here and there a shell, the whole cemented together by water holding

in solution carbonate of lime, and there see the very same phenomenon

perpetuated to this day.

Thus, I think, we have got first from the known to the unknown; from

a tropic coral island back here to the limestone hills of Great

Britain; and I did not speak at random when I said that I was not

leading you away as far as you fancied by several thousand miles.

Examine any average limestone quarry from Bristol to Berwick, and you

will see there all that I have been describing; that is, all of it

which is not soft animal matter, certain to decay. You will see the

lime-mud hardened into rock beds; you will see the shells embedded in

it; you will see the corals in every stage of destruction; you will

see whole layers made up of innumerable fragments of Crinoids--no

wonder they are innumerable, for, it has been calculated, there are

in a single animal of some of the species 140,000 joints--140,000

bits of lime to fall apart when its soft parts decay. But is it not

all there? And why should it not have got there by the same process

by which similar old coral beds get up the mountain sides in the West

Indies and elsewhere; namely, by the upheaving force of earthquakes?

When you see similar effects, you have a right to presume similar

causes. If you see a man fall off a house here, and break his neck;

and some years after, in London or New York, or anywhere else, find

another man lying at the foot of another house, with his neck broken

in the same way, is it not a very fair presumption that he has fallen

off a house likewise?

You may be wrong. He may have come to his end by a dozen other

means: but you must have proof of that. You will have a full right,

in science and in common sense, to say--That man fell off the house,

till some one proves to you that he did not.

In fact, there is nothing which you see in the limestones of these

isles--save and except the difference in every shell and coral--which

you would not see in the coral-beds of the West Indies, if such

earthquakes as that famous one at St. Thomas's, in 1866, became

common and periodic, upheaving the land (they needs upheave it a very

little, only two hundred and fifty feet), till St. Thomas's, and all

the Virgin Isles, and the mighty mountain of Porto Rico, which looms

up dim and purple to the west, were all joined into dry land once

more, and the lonely coral-shoal of Anegada were raised, as it would

be raised then, into a limestone table-land, like that of Central

Ireland, of Galway, or of County Clare.

But you must clearly understand, that however much these coralline

limestones have been upheaved since they were formed, yet the sea-

bottom, while they were being formed, was sinking and not rising.

This is a fact which was first pointed out by Mr. Darwin, from the

observations which he made in the world-famous Voyage of the Beagle;

and the observations of subsequent great naturalists have all gone to

corroborate his theory.

It was supposed at first, you must understand, that when a coral

island rose steeply to the surface of the sea out of blue water,

perhaps a thousand fathoms or more, that fact was plain proof that

the little coral polypes had begun at the bottom of the sea, and, in

the course of ages, built up the whole island an enormous depth.

But it soon came out that that theory was not correct; for the coral

polypes cannot live and build save in shallow water--say in thirty to

forty fathoms. Indeed, some of the strongest and largest species

work best at the very surface, and in the cut of the fiercest surf.

And so arose a puzzle as to how coral rock is often found of vast

thickness, which Mr. Darwin explained. His theory was, and there is

no doubt now that it is correct, that in these cases the sea-bottom

is sinking; that as it sinks, carrying the coral beds down with it,

the coral dies, and a fresh live crop of polypes builds on the top of

the houses of their dead ancestors: so that, as the depression goes

on, generation after generation builds upwards, the living on the

dead, keeping the upper surface of the reef at the same level, while

its base is sinking downward into the abyss.

Applying this theory to the coral reef of the Pacific Ocean, the

following interesting facts were made out:

That where you find an Island rising out of deep water, with a ring

of coral round it, a little way from the shore--or, as in Eastern

Australia, a coast with a fringing reef (the Flinders reef of

Australia is eleven thousand miles long)--that is a pretty sure sign

that that shore, or mountain, is sinking slowly beneath the sea.

That where you find, as you often do in the Pacific, a mere atoll, or

circular reef of coral, with a shallow pond of smooth water in the

centre, and deep sea round, that is a pretty sure sign that the

mountain-top has sunk completely into the sea, and that the corals

are going on building where its peak once was.

And more. On working out the geography of the South Sea Islands by

the light of this theory of Mr. Darwin's, the following extraordinary

fact has been discovered:

That over a great part of the Pacific Ocean sinking is going on, and

has been going on for ages; and that the greater number of the

beautiful and precious South Sea Islands are only the remnants of a

vast continent or archipelago, which once stretched for thousands of

miles between Australia and South America.

Now, applying the same theory to limestone beds, which are, as you

know, only fossil coral reefs, we have a right to say, when we see in

England, Scotland, Ireland, limestones several thousand feet thick,

that while they were being laid down as coral reef, the sea-bottom,

and probably the neighbouring land, must have been sinking to the

amount of their thickness--to several thousand feet--before that

later sinking which enabled several hundred feet of millstone grit to

be laid down on the top of the limestone.

This millstone grit is a new and a very remarkable element in our

strange story. From Derby to Northumberland it forms vast and lofty

moors, capping, as at Whernside and Penygent, the highest limestone

hills with its hard, rough, barren, and unfossiliferous strata.

Wherever it is found, it lies on the top of the "mountain," or

carboniferous limestone. Almost everywhere, where coal is found in

England, it lies on the millstone grit. I speak roughly, for fear of

confusing my readers with details. The three deposits pass more or

less, in many places, into each other: but always in the order of

mountain limestone below, millstone grit on it, and coal on that

again.

Now what does its presence prove? What but this? That after the

great coral reefs which spread over Somersetshire and South Wales,

around the present estuary of the Severn,--and those, once perhaps

joined to them, which spread from Derby to Berwick, with a western

branch through North-east Wales,--were laid down--after all this, I

say, some change took place in the sea-bottom, and brought down on

the reefs of coral sheets of sand, which killed the corals and buried

them in grit. Does any reader wish for proof of this? Let him

examine the "cherty," or flinty, beds which so often appear where the

bottom of the millstone grit is passing into the top of the mountain

limestone--the beds, to give an instance, which are now quarried on

the top of the Halkin Mountain in Flintshire, for chert, which is

sent to Staffordshire to be ground down for the manufacture of china.

He will find layers in those beds, of several feet in thickness, as

hard as flint, but as porous as sponge. On examining their cavities

he will find them to be simply hollow casts of innumerable joints of

Crinoids, so exquisitely preserved, even to their most delicate

markings, that it is plain they were never washed about upon a beach,

but have grown where, or nearly where, they lie. What then, has

happened to them? They have been killed by the sand. The soft parts

of the animals have decayed, letting the 140,000 joints (more or

less) belonging to each animal fall into a heap, and be imbedded in

the growing sand-rock; and then, it may be long years after, water

filtering through the porous sand has removed the lime of which the

joints were made, and left their perfect casts behind.

So much for the millstone grits. How long the deposition of sand

went on, how long after it that second deposition of sands took

place, which goes by the name of the "gannister," or lower coal-

measures, we cannot tell. But it is clear, at least, that parts of

that ancient sea were filling up and becoming dry land. For coal, or

fossilised vegetable matter, becomes more and more common as we

ascend in the series of beds; till at last, in the upper coal-

measures, the enormous wealth of vegetation which grew, much of it,

where it is now found, prove the existence of some such sheets of

fertile and forest-clad lowland as I described in my last paper.

Thousands of feet of rich coral reef; thousands of feet of barren

sands; then thousands of feet of rich alluvial forest--and all these

sliding into each other, if not in one place, then in another,

without violent break or change; this is the story which the lime in

the mortar and the coal on the fire, between the two, reveal.

VI. THE SLATES ON THE ROOF

The slates on the roof should be, when rightly understood, a pleasant

subject for contemplation to the dweller in a town. I do not ask him

to imitate the boy who, cliff-bred from his youth, used to spend

stolen hours on the house-top, with his back against a chimney-stalk,

transfiguring in his imagination the roof-slopes into mountain-sides,

the slates into sheets of rock, the cats into lions, and the sparrows

into eagles. I only wish that he should--at least after reading this

paper--let the slates on the roof carry him back in fancy to the

mountains whence they came; perhaps to pleasant trips to the lakes

and hills of Cumberland, Westmoreland, and North Wales; and to

recognise--as he will do if he have intellect as well as fancy--how

beautiful and how curious an object is a common slate.

Beautiful, not only for the compactness and delicacy of its texture,

and for the regularity and smoothness of its surface, but still more

for its colour. Whether merely warm grey, as when dry, or bright

purple, as when wet, the colour of the English slate well justifies

Mr. Ruskin's saying, that wherever there is a brick wall and a slate

roof there need be no want of rich colour in an English landscape.

But most beautiful is the hue of slate, when, shining wet in the

sunshine after a summer shower, its blue is brought out in rich

contrast by golden spots of circular lichen, whose spores, I presume,

have travelled with it off its native mountains. Then, indeed, it

reminds the voyager of a sight which it almost rivals in brilliancy--

of the sapphire of the deep ocean, brought out into blazing intensity

by the contrast of the golden patches of floating gulf-weed beneath

the tropic sun.

Beautiful, I say, is the slate; and curious likewise, nay, venerable;

a most ancient and elaborate work of God, which has lasted long

enough, and endured enough likewise, to bring out in it whatsoever

latent capabilities of strength and usefulness might lie hid in it;

which has literally been--as far as such words can apply to a thing

inanimate--

Heated hot with burning fears,

And bathed in baths of hissing tears,

And battered by the strokes of doom

To shape and use.

And yet it was at first naught but an ugly lump of soft and shapeless

ooze.

Therefore, the slates to me are as a parable, on which I will not

enlarge, but will leave each reader to interpret it for himself. I

shall confine myself now to proofs that slate is hardened mud, and to

hints as to how it assumed its present form.

That slate may have been once mud, is made probable by the simple

fact that it can be turned into mud again. If you grind tip slate,

and then analyse it, you will find its mineral constituents to be

exactly those of a fine, rich, and tenacious clay. The slate

districts (at least in Snowdon) carry such a rich clay on them,

wherever it is not masked by the ruins of other rocks. At

Ilfracombe, in North Devon, the passage from slate below to clay

above, may be clearly seen. Wherever the top of the slate beds, and

the soil upon it, is laid bare, the black layers of slate may be seen

gradually melting--if I may use the word--under the influence of rain

and frost, into a rich tenacious clay, which is now not black, like

its parent slate, but red, from the oxidation of the iron which it

contains.

But, granting this, how did the first change take place?

It must be allowed, at starting, that time enough has elapsed, and

events enough have happened, since our supposed mud began first to

become slate, to allow of many and strange transformations. For

these slates are found in the oldest beds of rocks, save one series,

in the known world; and it is notorious that the older and lower the

beds in which the slates are found, the better, that is, the more

perfectly elaborate, is the slate. The best slates of Snowdon--I

must confine myself to the district which I know personally--are

found in the so-called "Cambrian" beds. Below these beds but one

series of beds is as yet known in the world, called the "Laurentian."

They occur, to a thickness of some eighty thousand feet, in Labrador,

Canada, and the Adirondack mountains of New York: but their

representatives in Europe are, as far as is known only to be found in

the north-west highlands of Scotland, and in the island of Lewis,

which consists entirely of them. And it is to be remembered, as a

proof of their inconceivable antiquity, that they have been upheaved

and shifted long before the Cambrian rocks were laid down

"unconformably" on their worn and broken edges.

Above the "Cambrian" slates--whether the lower and older ones of

Penrhyn and Llanberris, which are the same--one slate mountain being

worked at both sides in two opposite valleys--or the upper and newer

slates of Tremadoc, lie other and newer slate-bearing beds of

inferior quality, and belonging to a yet newer world, the "Silurian."

To them belong the Llandeilo flags and slates of Wales, and the

Skiddaw slates of Cumberland, amid beds abounding in extinct fossil

forms. Fossil shells are found, it is true, in the upper Cambrian

beds. In the lower they have all but disappeared. Whether their

traces have been obliterated by heat and pressure, and chemical

action, during long ages; or whether, in these lower beds, we are

actually reaching that "Primordial Zone" conceived of by M. Barrande,

namely, rocks which existed before living things had begun to people

this planet, is a question not yet answered. I believe the former

theory to be the true one. That there was life, in the sea at least,

even before the oldest Cambrian rocks were laid down, is proved by

the discovery of the now famous fossil, the Eozoon, in the Laurentian

limestones, which seems to have grown layer after layer, and to have

formed reefs of limestone as do the living coral-building polypes.

We know no more as yet. But all that we do know points downwards,

downwards still, warning us that we must dig deeper than we have dug

as yet, before we reach the graves of the first living things.

Let this suffice at present for the Cambrian and Laurentian rocks.

The Silurian rocks, lower and upper, which in these islands have

their chief development in Wales, and which are nearly thirty-eight

thousand feet thick; and the Devonian or Old Red sandstone beds,

which in the Fans of Brecon and Carmarthenshire attain a thickness of

ten thousand feet, must be passed through in an upward direction

before we reach the bottom of that Carboniferous Limestone of which I

spoke in my last paper. We thus find on the Cambrian rocks forty-

five thousand feet at least of newer rocks, in several cases lying

unconformably on each other, showing thereby that the lower beds had

been upheaved, and their edges worn off on a sea-shore, ere the upper

were laid down on them; and throughout this vast thickness of rocks,

the remains of hundreds of forms of animals, corals, shells, fish,

older forms dying out in the newer rocks, and new ones taking their

places in a steady succession of ever-varying forms, till those in

the upper beds have become unlike those in the lower, and all are

from the beginning more or less unlike any existing now on earth.

Whole families, indeed, disappear entirely, like the Trilobites,

which seem to have swarmed in the Silurian seas, holding the same

place there as crabs and shrimps do in our modern seas. They vanish

after the period of the coal, and their place is taken by an allied

family of Crustaceans, of which only one form (as far as I am aware)

lingers now on earth, namely, the "King Crab," or Limulus, of the

Indian Seas, a well-known animal, of which specimens may sometimes be

seen alive in English aquaria. So perished in the lapse of those

same ages, the armour-plated or "Ganoid" fish which Hugh Miller made

so justly famous--and which made him so justly famous in return--

appearing first in the upper Silurian beds, and abounding in vast

variety of strange forms in the old Red Sandstone, but gradually

disappearing from the waters of the world, till their only

representatives, as far as known, are the Lepidostei, or "Bony

Pikes," of North America; the Polypteri of the Nile and Senegal; the

Lepidosirens of the African lakes and Western rivers; the Ceratodus

or Barramundi of Queensland (the two latter of which approach

Amphibians), and one or two more fantastic forms, either rudimentary

or degraded, which have lasted on here and there in isolated stations

through long ages, comparatively unchanged while all the world is

changed around them, and their own kindred, buried like the fossil

Ceratodus of the Trias beneath thousands of feet of ancient rock,

among creatures the likes whereof are not to be found now on earth.

And these are but two examples out of hundreds of the vast changes

which have taken place in the animal life of the globe, between the

laying down of the Cambrian slates and the present time.

Surely--and it is to this conclusion I have been tending throughout a

seemingly wandering paragraph--surely there has been time enough

during all those ages for clay to change into slate.

And how were they changed?

I think I cannot teach my readers this more simply than by asking

them first to buy Sheet No. LXXVIII. S.E. (Bangor) of the Snowdon

district of the Government Geological Survey, which may be ordered at

any good stationer's, price 3s.; and study it with me. He will see

down the right-hand margin interpretations of the different colours

which mark the different beds, beginning with the youngest (alluvium)

atop, and going down through Carboniferous Limestone and Sandstone,

Upper Silurian, Lower Silurian, Cambrian, and below them certain

rocks marked of different shades of red, which signify rocks either

altered by heat, or poured out of old volcanic vents. He will next

see that the map is covered with a labyrinth of red patches and

curved lines, signifying the outcrop or appearance at the surface of

these volcanic beds. They lie at every conceivable slope; and the

hills and valleys have been scooped out by rain and ice into every

conceivable slope likewise. Wherefore we see, here a broad patch of

red, where the back of a sheet of Lava, Porphyry, Greenstone, or what

not is exposed; there a narrow line curving often with the curve of

the hill-side, where only the edge of a similar sheet is exposed; and

every possible variety of shape and attitude between these two. He

will see also large spaces covered with little coloured dots, which

signify (as he will find at the margin) beds of volcanic ash. If he

look below the little coloured squares on the margin, he will see

figures marking the strike, or direction of the inclination of the

beds--inclined, vertical, horizontal, contorted; that the white lines

in the map signify faults, i.e. shifts in the strata; the gold lines,

lodes of metal--the latter of which I should advise him strongly, in

this district at least, not to meddle with: but to button up his

pockets, and to put into the fire, in wholesome fear of his own

weakness and ignorance, any puffs of mining companies which may be

sent him--as one or two have probably been sent him already.

Furnished with which keys to the map, let him begin to con it over,

sure that there is if not an order, still a grand meaning in all its

seeming confusion; and let him, if he be a courteous and grateful

person, return due thanks to Professor Ramsay for having found it all

out; not without wondering, as I have often wondered, how even

Professor Ramsay's acuteness and industry could find it all out.

When my reader has studied awhile the confusion--for it is a true

confusion--of the different beds, he will ask, or at least have a

right to ask, what known process of nature can have produced it? How

have these various volcanic rocks, which he sees marked as Felspathic

Traps, Quartz Porphyries, Greenstones, and so forth, got intermingled

with beds which he is told to believe are volcanic ashes, and those

again with fossil-bearing Silurian beds and Cambrian slates, which he

is told to believe were deposited under water? And his puzzle will

not be lessened when he is told that, in some cases, as in that of

the summit of Snowdon, these very volcanic ashes contain fossil

shells.

The best answer I can give is to ask him to use his imagination, or

his common sense; and to picture to himself what must go on in the

case of a submarine eruption, such as broke out off the coast of

Iceland in 1783 and 1830, off the Azores in 1811, and in our day in

more than one spot in the Pacific Ocean.

A main bore or vent--or more than one--opens itself between the

bottom of the sea and the nether fires. From each rushes an enormous

jet of high-pressure steam and other gases, which boils up through

the sea, and forms a cloud above; that cloud descends again in heavy

rain, and gives out often true lightning from its under side.

But it does more. It acts as a true steam-gun, hurling into the air

fragments of cold rock rasped off from the sides of the bore, and

fragments also of melted lava, and clouds of dust, which fall again

into the sea, and form there beds either of fine mud or of breccia--

that is, fragments of stone embedded in paste. This, the reader will

understand, is no fancy sketch, as far as I am concerned. I have

steamed into craters sawn through by the sea, and showing sections of

beds of ash dipping outwards and under the sea, and in them boulders

and pebbles of every size, which had been hurled out of the crater;

and in them also veins of hardened lava, which had burrowed out

through the soft ashes of the cone. Of those lava veins I will speak

presently. What I want the reader to think of now is the immense

quantity of ash which the steam-mitrailleuse hurls to so vast a

height into the air, that it is often drifted many miles down to

leeward. To give two instances: The jet of steam from Vesuvius, in

the eruption of 1822, rose more than four miles into the air; the jet

from the Souffriere of St. Vincent in the West Indies, in 1812,

probably rose higher; certainly it met the N.E. trade-wind, for it

poured down a layer of ashes, several inches thick, not only on St.

Vincent itself, but on Barbadoes, eighty miles to windward, and

therefore on all the sea between. Now let us consider what that

represents--a layer of fine mud, laid down at the bottom of the

ocean, several inches thick, eighty miles at least long, and twenty

miles perhaps broad, by a single eruption. Suppose that hardened in

long ages (as it would be under pressure) into a bed of fine grained

Felstone, or volcanic ash; and we can understand how the ash-beds of

Snowdonia--which may be traced some of them for many square miles--

were laid down at the bottom of an ancient sea.

But now about the lavas or true volcanic rocks, which are painted (as

is usual in geological maps) red. Let us go down to the bottom of

the sea, and build up our volcano towards the surface.

First, as I said, the subterranean steam would blast a bore. The

dust and stones, rasped and blasted out of that hole would be spread

about the sea-bottom as an ash-bed sloping away round the hole; then

the molten lava would rise in the bore, and flow out over the ashes

and the sea-bottom--perhaps in one direction, perhaps all round.

Then, usually, the volcano, having vented itself, would be quieter

for a time, till the heat accumulated below, and more ash was blasted

out, making a second ash-bed; and then would follow a second lava

flow. Thus are produced the alternate beds of lava and ash which are

so common.

Now suppose that at this point the volcano was exhausted, and lay

quiet for a few hundred years, or more. If there was any land near,

from which mud and sand were washed down, we might have layers on

layers of sediment deposited, with live shells, etc., living in them,

which would be converted into fossils when they died; and so we

should have fossiliferous beds over the ashes and lavas. Indeed,

shells might live and thrive in the ash-mud itself, when it cooled,

and the sea grew quiet, as they have lived and thriven in Snowdonia.

Now suppose that after these sedimentary beds are laid down by water,

the volcano breaks out again--what would happen?

Many things: specially this, which has often happened already.

The lava, kept down by the weight of these new rocks, searches for

the point of least resistance, and finds it in a more horizontal

direction. It burrows out through the softer ash-beds, and between

the sedimentary beds, spreading itself along horizontally. This

process accounts for the very puzzling, though very common case in

Snowdon and elsewhere, in which we find lavas interstratified with

rocks which are plainly older than those lavas. Perhaps when that is

done the volcano has got rid of all its lava, and is quiet. But if

not, sooner or later, it bores up through the new sedimentary rocks,

faulting them by earthquake shocks till it gets free vent, and begins

its layers of alternate ash and lava once more.

And consider this fact also: If near the first (as often happens)

there is another volcano, the lava from one may run over the lava

from the other, and we may have two lavas of different materials

overlying each other, which have come from different directions. The

ashes blown out of the two craters may mingle also, and so, in the

course of ages, the result may be such a confusion of ashes, lavas,

and sedimentary rocks as we find throughout most mountain ranges in

Snowdon, in the Lake mountains, in the Auvergne in France, in Sicily

round Etna, in Italy round Vesuvius, and in so many West Indian

Islands; the last confusion of which is very likely to be this:

That when the volcano has succeeded--as it did in the case of Sabrina

Island off the Azores in 1811, and as it did, perhaps often, in

Snowdonia--in piling up an ash cone some hundred feet out of the sea;

that--as has happened to Sabrina Island--the cone is sunk again by

earthquakes, and gnawn down at the same time by the sea-waves, till

nothing is left but a shoal under water. But where have all its vast

heaps of ashes gone? To be spread about over the bottom of the sea,

to mingle with the mud already there, and so make beds of which, like

many in Snowdon, we cannot say whether they are of volcanic or of

marine origin, because they are of both.

But what has all this to do with the slates?

I shall not be surprised if my readers ask that question two or three

times during this paper. But they must be kind enough to let me tell

my story my own way. The slates were not made in a day, and I fear

they cannot be explained in an hour: unless we begin carefully at

the beginning in order to end at the end. Let me first make my

readers clearly understand that all our slate-bearing mountains, and

most also of the non-slate-bearing ones likewise, are formed after

the fashion which I have described, namely, beneath the sea. I do

not say that there may not have been, again, and again, ash-cones

rising above the surface of the waves. But if so, they were washed

away, again and again, ages before the land assumed anything of its

present shape; ages before the beds were twisted and upheaved as they

are now.

And therefore I beg my readers to put out of their minds once and for

all the fancy that in any known part of these islands craters are to

be still seen, such as exist in Etna, or Vesuvius, or other volcanoes

now at work in the open air.

It is necessary to insist on this, because many people hearing that

certain mountains are volcanic, conclude--and very naturally and

harmlessly--that the circular lakes about their tops are true

craters. I have been told, for instance, that that wonderful little

blue Glas Llyn, under the highest cliff of Snowdon, is the old crater

of the mountain; and I have heard people insist that a similar lake,

of almost equal grandeur, in the south side of Cader Idris, is a

crater likewise.

But the fact is not so. Any one acquainted with recent craters would

see at once that Glas Llyn is not an ancient one; and I am not

surprised to find the Government geologists declaring that the Llyn

on Cader Idris is not one either. The fact is, that the crater, or

rather the place where the crater has been, in ancient volcanoes of

this kind, is probably now covered by one of the innumerable bosses

of lava.

For, as an eruption ceases, the melted lava cools in the vents, and

hardens; usually into lava infinitely harder than the ash-cone round

it; and this, when the ash-cone is washed off, remains as the highest

part of the hill, as in the Mont Dore and the Cantal in France, and

in several extinct volcanoes in the Antilles. Of course the lava

must have been poured out, and the ashes blown out from some vents or

other, connected with the nether world of fire; probably from many

successive vents. For in volcanoes, when one vent is choked, another

is wont to open at some fresh point of least resistance among the

overlying rocks. But where are these vents? Buried deep under

successive eruptions, shifted probably from their places by

successive upheavings and dislocations; and if we wanted to find them

we should have to quarry the mountain range all over, a mile deep,

before we hit upon here and there a tap-root of ancient lava,

connecting the upper and the nether worlds. There are such tap-

roots, probably, under each of our British mountain ranges. But

Snowdon, certainly, does not owe its shape to the fact of one of

these old fire vents being under it. It owes its shape simply to the

accident of some of the beds toward the summit being especially hard,

and thus able to stand the wear and tear of sea-wave, ice, and rain.

Its lakes have been formed quite regardless of the lie of the rocks,

though not regardless of their relative hardness. But what forces

scooped them out--whether they were originally holes left in the

ground by earthquakes, and deepened since by rain and rivers, or

whether they were scooped out by ice, or by any other means, is a

question on which the best geologists are yet undecided--decided only

on this--that craters they are not.

As for the enormous changes which have taken place in the outline of

the whole of the mountains, since first their strata were laid down

at the bottom of the sea: I shall give facts enough, before this

paper is done, to enable readers to judge of them for themselves.

The reader will now ask, naturally enough, how such a heap of beds as

I have described can take the shape of mountains like Snowdon.

Look at any sea cliff in which the strata are twisted and set on

slope. There are hundreds of such in these isles. The beds must

have been at one time straight and horizontal. But it is equally

clear that they have been folded by being squeezed laterally. At

least, that is the simplest explanation, as may be proved by

experiment. Take a number of pieces of cloth, or any such stuff; lay

them on each other and then squeeze them together at each end. They

will arrange themselves in folds, just as the beds of the cliff have

done. And if, instead of cloth, you take some more brittle matter,

you will find that, as you squeeze on, these folds will tend to snap

at the points of greatest tension or stretching, which will be of

course at the anticlinal and synclinal lines--in plain English, the

tops and bottoms of the folds. Thus cracks will be formed; and if

the pressure goes on, the ends of the layers will shift against each

other in the line of those cracks, forming faults like those so

common in rocks.

But again, suppose that instead of squeezing these broken and folded

lines together any more, you took off the pressure right and left,

and pressed them upwards from below, by a mimic earthquake. They

would rise; and as they rose leave open space between them. Now if

you could contrive to squeeze into them from below a paste, which

would harden in the cracks and between the layers, and so keep them

permanently apart, you would make them into a fair likeness of an

average mountain range--a mess--if I may make use of a plain old

word--of rocks which have, by alternate contraction and expansion,

helped in the latter case by the injection of molten lava, been

thrust about as they are in most mountain ranges.

That such a contraction and expansion goes on in the crust of the

earth is evident; for here are the palpable effects of it. And the

simplest general cause which I can give for it is this: That things

expand as they are heated, and contract as they are cooled.

Now I am not learned enough--and were I, I have not time--to enter

into the various theories which philosophers have put forward, to

account for these grand phenomena.

The most remarkable, perhaps, and the most probable, is the theory of

M. Elie de Beaumont, which is, in a few words, this:

That this earth, like all the planets, must have been once in a state

of intense heat throughout, as its mass inside is probably now.

That it must be cooling, and giving off its heat into space.

That, therefore, as it cools, its crust must contract.

That, therefore, in contracting, wrinkles (for the loftiest mountain

chains are nothing but tiny wrinkles, compared with the whole mass of

the earth), wrinkles, I say, must form on its surface from time to

time. And that the mountain chains are these wrinkles.

Be that as it may, we may safely say this. That wherever the

internal heat of the earth tends (as in the case of volcanoes)

towards a particular spot, that spot must expand, and swell up,

bulging the rocks out, and probably cracking them, and inserting

melting lava into those cracks from below. On the other hand, if the

internal heat leaves that spot again, and it cools, then it must

contract more or less, in falling inward toward the centre of the

earth; and so the beds must be crumpled, and crushed, and shifted

against each other still more, as those of our mountains have been.

But here may arise, in some of my readers' minds, a reasonable

question--If these upheaved beds were once horizontal, should we not

be likely to find them, in some places, horizontal still?

A reasonable question, and one which admits of a full answer.

They know, of course, that there has been a gradual, but steady,

change in the animals of this planet; and that the relative age of

beds can, on the strength of that known change, be determined

generally by the fossils, usually shells, peculiar to them: so that

if we find the same fashion of shells, and still more the same

species of shells, in two beds in different quarters of the world,

then we have a right to say--These beds were laid down at least about

the same time. That is a general rule among all geologists, and not

to be gainsaid.

Now I think I may say, that, granting that we can recognise a bed by

its fossils, there are few or no beds which are found in one place

upheaved, broken, and altered by heat, which are not found in some

other place still horizontal, unbroken, unaltered, and more or less

as they were at first.

From the most recent beds; from the upheaved coral-rocks of the West

Indies, and the upheaved and faulted boulder clay and chalk of the

Isle of Moen in Denmark--downwards through all the strata, down to

that very ancient one in which the best slates are found, this rule,

I believe, stands true.

It stands true, certainly, of the ancient Silurian rocks of Wales,

Cumberland, Ireland, and Scotland.

For, throughout great tracts of Russia, and in parts of Norway and

Sweden, Sir Roderick Murchison discovered our own Silurian beds,

recognisable from their peculiar fossils. But in what state? Not

contracted, upheaved, and hardened to slates and grits, as they are

in Wales and elsewhere: but horizontal, unbroken, and still soft,

because undisturbed by volcanic rooks and earthquakes. At the bottom

of them all, near Petersburg, Sir Roderick found a shale of dried mud

(to quote his own words), "so soft and incoherent that it is even

used by sculptors for modelling, although it underlies the great mass

of fossil-bearing Silurian rocks, and is, therefore, of the same age

as the lower crystalline hard slates of North Wales. So entirely

have most of these eldest rocks in Russia been exempted from the

influence of change, throughout those enormous periods which have

passed away since their accumulation."

Among the many discoveries which science owes to that illustrious

veteran, I know none more valuable for its bearing on the whole

question of the making of the earth-crust, than this one magnificent

fact.

But what a contrast between these Scandinavian and Russian rocks and

those of Britain! Never exceeding, in Scandinavia, a thousand feet

in thickness, and lying usually horizontal, as they were first laid

down, they are swelled in Britain to a thickness of thirty thousand

feet, by intruded lavas and ashes; snapt, turned, set on end at every

conceivable angle; shifted against each other to such an extent,

that, to give a single instance, in the Vale of Gwynnant, under

Snowdon, an immense wedge of porphyry has been thrust up, in what is

now the bottom of the valley, between rocks far newer than it, on one

side to a height of eight hundred, on the other to a height of

eighteen hundred feet--half the present height of Snowdon. Nay, the

very slate beds of Snowdonia have not forced their way up from under

the mountain--without long and fearful struggles. They are set in

places upright on end, then horizontal again, then sunk in an

opposite direction, then curled like sea-waves, then set nearly

upright once more, and faulted through and through, six times, I

believe, in the distance of a mile or two; they carry here and there

on their backs patches of newer beds, the rest of which has long

vanished; and in their rise they have hurled back to the eastward,

and set upright, what is now the whole western flank of Snowdon, a

mass of rock which was then several times as thick as it is now.

The force which thus tortured them was probably exerted by the great

mass of volcanic Quartz-porphyry, which rises from under them to the

north-west, crossing the end of the lower lake of the Llanberris; and

indeed the shifts and convulsions which have taken place between them

and the Menai Straits are so vast that they can only be estimated by

looking at them on the section which may be found at the end of

Professor Ramsay's "Geological Survey of North Wales." But anyone

who will study that section, and use (as with the map) a little

imagination and common sense, will see that between the heat of that

Porphyry, which must have been poured out as a fluid mass as hot,

probably, as melted iron, and the pressure of it below, and of the

Silurian beds above, the Cambrian mud-strata of Llanberris and

Penrhyn quarries must have suffered enough to change them into

something very different from mud, and, therefore, probably, into

what they are now--namely, slate.

And now, at last, we have got to the slates on the roof, and may

disport ourselves over them--like the cats.

Look at any piece of slate. All know that slate splits or cleaves

freely, in one direction only, into flat layers. Now any one would

suppose at first sight, and fairly enough, that the flat surface--the

"plane of cleavage"--was also the plane of bedding. In simpler

English we should say--The mud which has hardened into the slate was

laid down horizontally; and therefore each slate is one of the little

horizontal beds of it, perhaps just what was laid down in a single

tide. We should have a right to do so, because that would be true of

most sedimentary rocks. But it would not be true of slate. The

plane of bedding in slate has nothing to do with the plane of

cleavage. Or, more plainly, the mud of which the slate is made may

have been deposited at the sea-bottom at any angle to the plane of

cleavage. We may sometimes see the lines of the true bedding--the

lines which were actually horizontal when the mud was laid down--in

bits of slate, and find them sometimes perpendicular to, sometimes

inclined to, and sometimes again coinciding with the plane of

cleavage, which they have evidently acquired long after.

Nay, more. These parallel planes of cleavage, at each of which the

slate splits freely, will run through a whole mountain at the same

angle, though the beds through which they run may be tilted at

different angles, and twisted into curves.

Now what has made this change in the rook? We do not exactly know.

One thing is clear, that the particles of the now solid rock have

actually moved on themselves. And this is proved by a very curious

fact--which the reader, if he geologises about slate quarries much,

may see with his own eyes. The fossils in the slate are often

distorted into quaint shapes, pulled out long if they lie along the

plane of cleavage, or squeezed together, or doubled down on both

sides, if they lie across the plane. So that some force has been at

work which could actually change the shape of hard shells, very

slowly, no doubt, else it would have snapped and crumbled them.

If I am asked what that force was, I do not know. I should advise

young geologists to read what Sir Henry de la Beche has said on it in

his admirable "Geological Observer," pp. 706-725. He will find

there, too, some remarks on that equally mysterious phenomena of

jointing, which you may see in almost all the older rocks; it is

common in limestones. All we can say is, that some force has gone

on, or may be even now going on, in the more ancient rocks, which is

similar to that which produces single crystals; and similar, too, to

that which produced the jointed crystals of basalt, i.e. lava, at the

Giant's Causeway, in Ireland, and Staffa, in the Hebrides. Two

philosophers--Mr. Robert Were Fox and Mr. Robert Hunt--are of opinion

that the force which has determined the cleavage of slates may be

that of the electric currents, which (as is well known) run through

the crust of the earth. Mr. Sharpe, I believe, attributes the

cleavage to the mere mechanical pressure of enormous weights of rock,

especially where crushed by earthquakes. Professor Rogers, again,

points out that as these slates may have been highly heated, thermal

electricity (i.e. electricity brought out by heat) may have acted on

them.

One thing at least is clear. That the best slates are found among

ancient lavas, and also in rocks which are faulted and tilted

enormously, all which could not have happened without a

proportionately enormous pressure, and therefore heat; and next, that

the best slates are invariably found in the oldest beds--that is, in

the beds which have had most time to endure the changes, whether

mechanical or chemical, which have made the earth's surface what we

see it now.

Another startling fact the section of Snowdonia, and I believe of

most mountain chains in these islands, would prove--namely, that the

contour of the earth's surface, as we see it now, depends very

little, certainly in mountains composed of these elder rocks upon the

lie of the strata, or beds, but has been carved out by great forces,

long after those beds were not only laid down and hardened, but

faulted and tilted on end. Snowdon itself is so remarkable an

instance of this fact that, as it is a mountain which every one in

these happy days of excursion-trains and steamers either has seen or

can see, I must say a few more words about it.

Any one who saw that noble peak leaping high into the air, dominating

all the country round, at least upon three sides, and was told that

its summit consisted of beds much newer, not much older, than the

slate-beds fifteen hundred feet down on its north-western flank--any

one, I say, would have the right at first sight, on hearing of

earthquake faults and upheavals, to say--The peak of Snowdon has been

upheaved to its present height above and out of the lower lands

around. But when he came to examine sections, he would find his

reasonable guess utterly wrong. Snowdon is no swelling up of the

earth's crust. The beds do not, as they would in that case, slope up

to it. They slope up from it, to the north-west in one direction,

and the south-south-west in the other; and Snowdon is a mere

insignificant boss, left hanging on one slope of what was once an

enormous trough, or valley, of strata far older than itself. By

restoring these strata, in the direction of the angles, in which they

crop out, and vanish at the surface, it is found that to the north-

west--the direction of the Menai Straits--they must once have risen

to a height of at least six or seven thousand feet; and more, by

restoring them, specially the ash-bed of Snowdon, towards the south-

east--which can be done by the guidance of certain patches of it left

on other hills--it is found that south of Ffestiniog, where the

Cambrian rocks rise again to the surface, the south side of the

trough must have sloped upwards to a height of from fifteen to twenty

thousand feet, whether at the bottom of the sea, or in the upper air,

we cannot tell. But the fact is certain, that off the surface of

Wales, south of Ffestiniog a mass of solid rock as high as the Andes

has been worn down and carried bodily away; and that a few miles

south again, the peak of Arran Mowddy, which is now not two thousand

feet high, was once--either under the sea or above it--nearer ten

thousand feet.

If I am asked whither is all that enormous mass of rock--millions of

tons--gone? Where is it now? I know not. But if I dared to hazard

a guess, I should say it went to make the New Red sandstones of

England.

The New Red sandstones must have come from somewhere. The most

likely region for them to have come from is from North Wales, where,

as we know, vast masses of gritty rock have been ground off, such as

would make fine sandstones if they had the chance. So that many a

grain of sand in Chester walls was probably once blasted out of the

bowels of the earth into the old Silurian sea, and after a few

hundreds of thousands of years' repose in a Snowdonian ash-bed, was

sent eastward to build the good old city and many a good town more.

And the red marl--the great deposit of red marl which covers a wide

region of England--why should not it have come from the same quarter?

Why should it not be simply the remains of the Snowdon Slate? Mud

the slate was, and into mud it has returned. Why not? Some of the

richest red marl land I know, is, as I have said, actually being made

now, out of the black slates of Ilfracombe, wherever they are

weathered by rain and air. The chemical composition is the same.

The difference in colour between black slate and red marl is caused

simply by the oxidation of the iron in the slate.

And if my readers want a probable cause why the sandstones lie

undermost, and the red marl uppermost--can they not find one for

themselves? I do not say that it is the cause, but it is at least a

causa vera, one which would fully explain the fact, though it may be

explicable in other ways. Think, then, or shall I think for my

readers?

Then do they not see that when the Welsh mountains were ground down,

the Silurian strata, being uppermost, would be ground down first, and

would go to make the lower strata of the great New Red Sandstone

Lowland; and that being sandy, they would make the sandstones? But

wherever they were ground through, the Lower Cambrian slates would be

laid bare; and their remains, being washed away by the sea the last,

would be washed on to the top of the remains of the Silurians; and so

(as in most cases) the remains of the older rock, when redeposited by

water, would lie on the remains of the younger rock. And do they not

see that (if what I just said is true) these slates would grind up

into red marl, such as is seen over the west and south of Cheshire

and Staffordshire and far away into Nottinghamshire? The red marl

must almost certainly have been black slate somewhere, somewhen. Why

should it not have been such in Snowdon? And why should not the

slates in the roof be the remnants of the very beds which are now the

marl in the fields?

And thus I end my story of the slates in the roof, and these papers

on Town Geology. I do so, well knowing how imperfect they are:

though not, I believe, inaccurate. They are, after all, merely

suggestive of the great amount that there is to be learnt about the

face of the earth and how it got made, even by the townsman, who can

escape into the country and exchange the world of man for the world

of God, only, perhaps, on Sundays--if, alas! even then--or only once

a year by a trip in a steamer or an excursion train. Little, indeed,

can he learn of the planet on which he lives. Little in that

direction is given to him, and of him little shall be required. But

to him, for that very reason, all that can be given should be given;

he should have every facility for learning what he can about this

earth, its composition, its capabilities; lest his intellect, crushed

and fettered by that artificial drudgery which we for a time miscall

civilisation, should begin to fancy, as too many do already, that the

world is composed mainly of bricks and deal, and governed by acts of

parliament. If I shall have awakened any townsmen here and there to

think seriously of the complexity, the antiquity, the grandeur, the

true poetry, of the commonest objects around them, even the stones

beneath their feet; if I shall have suggested to them the solemn

thought that all these things, and they themselves still more, are

ordered by laws, utterly independent of man's will about them, man's

belief in them; if I shall at all have helped to open their eyes that

they may see, and their ears that they may hear, the great book which

is free to all alike, to peasant as to peer, to men of business as to

men of science, even that great book of nature, which is, as Lord

Bacon said of old, the Word of God revealed in facts--then I shall

have a fresh reason for loving that science of geology, which has

been my favourite study since I was a boy.

Footnotes:

{1} See "Nature," No. XXV. (Macmillan & Co.)

{2} These Lectures were delivered to the members of the Natural

Science Class at Chester in 1871.

{3} See a most charming paper on "The Physics of Arctic Ice," by Dr.

Robert Brown of Campster, published in the Quarterly Journal of the

Geological Society, June, 1870. This article is so remarkable, not

only for its sound scientific matter, but for the vividness and

poetic beauty of its descriptions, that I must express a hope that

the learned author will some day enlarge it, and publish it in a

separate form.

{4} See Lyell, "Antiquity of Man," p. 294 et seq.

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