EDINBURGH PAPERS

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ICE AND WATER:

A

REVIEW OF THE SUPERFICIAL FORMATION

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LONDON AND EDINBURGH.

1861.

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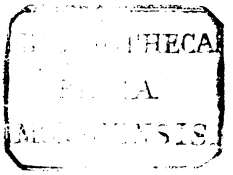


ICE AND WATER:

A REVIEW OF THE SUPERFICIAL FORMATION.*

THE Sedimentary Rocks—composed partly of inorganic matters, as sandstones and slates, partly of matters of organic origin, as limestones, coal, &c.—which form so large a part of the exterior of our Globe, and afford an imperfect, but interesting record of the progress of Life upon its surface—are all, as is well known, to be traced to one simple and intelligible mode of formation, as sediments in the bottoms of ancient seas.

First and deepest, comes a series of beds, styled *Azoic*, forming in the whole a mass of great thickness, and deriving this general name from the fact that hitherto no fossils have been found in them, to betray that, at the time of their deposition, either plants or animals existed on the earth. Next in order, we have another long series—*Cambrian* or *Lower Silurian*—indicating the lapse of a long space of time, and presenting remains of sea-weeds and various humble classes of marine animals, but no land-plants, and no creatures so high in grade as fishes. Next, *Upper Silurian* and *Devonian* Rocks add Cartilaginous Fishes to the stock of marine life, yet still leaving us without any decided traces of terrestrial plants and animals. Then comes the *Carboniferous Formation*, indicating an abundant land vegetation, air-pervading insects, and a commencement of reptilian life. In the subsequent *Trias*, *Lias*, *Oolite*, *Wealden*, and *Chalk* strata, relics of reptiles are abundant, traces of birds appear, and we begin to have remains of mammalia, though only of the lower grades—*marsupialia* and *insectivora*. Lastly comes the *Tertiary Formation*, exhibiting an abundance of mammalia of higher types, though of genera not now inhabiting the earth. Animals so high as the monkey tribes then existed; but there has never yet been found

* Some expressions in this Paper are to be explained by the fact, that it was first read to an Edinburgh audience.

any trace of Man; and, as far as negative evidence entitles us to speak, we may say that the introduction of that highest of all living creatures was left to an age subsequent to the deposition of all the indurated sediments now enumerated.

These rocks had been formed—subjected at intervals throughout to disturbing agencies which had thrown them in many places out of their natal seas, and mixed them confusedly with volcanic products, but still left them on the whole a tolerably clear, though fragmentary record of that Progressive March of Life upon earth, which may well be styled the most remarkable addition made to human knowledge in our age—a surface was left of such inequality as we may suppose to have resulted from so many tiltings of strata here, and depressions and compressions of strata there—here a mass of the very latest sediments (the Tertiary Rocks) raised into Alps several thousands of feet above the sea—there an extensive continent lowered till it became the bed of a wide ocean: such was the history of the crust of the globe up to this point, when, without any cessation of the main operations, wearing down and deposition of materials, and mobility of the surface in vertical directions, but rather for certain with a continuance of these, there came in what the main appearances lead us to call new agencies, which, with the old, resulted in producing that *Covering* of comparatively loose and unindurated matters most commonly called the Superficial Formation—alternatively the *Pleistocene*, as implying that it is a series of beds containing the greatest number of shells of recent species, as compared with certain beds preceding it. In speaking here of new agencies, I must be understood as not meaning to exclude the possible discovery of traces of their working in earlier ages. On the contrary, it is very likely that they have acted in earlier times, and my great sense of the value of a thorough knowledge of the Superficial Formation rests mainly in this—that I regard it as the best access we can have to a perfect knowledge of the physical phenomena connected with the ancient rocks. It will not, therefore, surprise me to find geologists ultimately accepting the alleged proofs of glacial action adduced by Professor Ramsay from the Permian formation. I must also be understood as implying that some of the more important phenomena of the Superficial Formation have only been traced in parts of the earth extending from the polar into the temperate regions, and chiefly in the northern hemisphere.

Regarding what I have now to state, let it be premised that ancient operations on the surface of the earth are assumed by the geologist as having taken place, when he finds effects similar to

those which the same causes now produce. He proceeds upon an assumption—the guide and pole-star of all science—that the laws of nature are immutable—immutable as their Divine Author himself. If he can be proved to be wrong in making this assumption, then his inferences are wrong also, and all his speculations fall to the ground. In describing the successive beds of the Superficial Formation, I shall endeavour in each case to awaken attention by picturing the state of things under which they were produced; after which I will proceed to shew, in the surviving appearances, in each case, the grounds for believing that the former state of things was as described. It will be understood that this is not presented as a philosophical mode of proceeding, but simply as the one best adapted for a popular exposition of the subject.

First let me set up a table of the Superficial Formation, as a sort of text to preach from. Here is one which I have framed from my own observations in Scotland, with the assistance of my late friend, Professor Fleming. In other countries, the system is more or less developed than in Scotland; but generally, even in America, with great appearances of conformity in point of order, and character of materials.

TABLE OF THE SUPERFICIAL FORMATION IN SCOTLAND.

7.	Vegetable Soil—Mosses.
6.	Ancient Sea-margins—Erratic Blocks.
5.	Ancient Valley Glaciers and Moraines.
4.	Beds of Sand and Gravel.
3.	Upper Boulder Clay or Coarse Gravel, implying Glacial Conditions.
2.	Silt forming Brick Clay, alternated with Beds of Sand and Gravel.
1.	Boulder Clay, implying Glacial Conditions.

Here, it will be observed, we have seven different kinds of deposit, each arguing a peculiar condition of the surface, during the course of the Pleistocene Era. Let it be understood, however, that, as in the ancient formations, the whole of the deposits are never present in any one place, and each is liable to great local

variations. Most generally, there are not above three or four to be found in any single section, either in this country or any other. As in the ancient rocks, so in the superficial formation, a bed of one kind of material in one place is represented by one of a considerably different material, or appearance, in another. So also have the superficial beds sustained their denudations—that is, been partially removed—as in many places the ancient rocks have been.

The first and earliest of these epochs exhibits to us, at its commencement, a rough condition of the surface; that is to say, it did not present the flowing outlines and undulations which we now see. Sea and land were at first upon nearly the same relative level as at present—here I speak of our island especially—but their meeting-point seems slowly and gradually to have risen: in other words, such as most geologists would use, the land was gradually sinking into the sea, and did sink to the extent of many hundred feet. And the sea, as far south as Austria in one continent, and Pennsylvania in another, appears to have been an ice-bearing one, but exhibiting the ice in a volume beyond all example in the Arctic Ocean of our epoch. It probably moved in *packs* and *floes*—to use the technical terms of the arctic voyagers—but of what would now be held as abnormal extent and depth, impelled by forces greater than the winds and currents of our day, but on the character of which we can now only indulge in conjecture, and moving in directions to some extent determined by the inequalities of the bed of the ocean in which it moved. We shall presently see the reasons for picturing this state of things. It may meanwhile be remarked, that geologists in general only speak of a sea containing such masses of ice as now float along the Arctic Ocean, conceiving that such masses, occasionally grounding on, and grating along, the bottom of the sea, were sufficient to produce all the phenomena which are to be accounted for. But, in reality, these phenomena have not been much studied by geologists; and when we look into Dr Scoresby's work on the Arctic Ocean, which is the best account of it we have, we find, in his descriptions of icebergs, ice-floes, and packs of ice, nothing to lead us to suppose that the gelid masses which occasionally ground there, affect the bottom to anything like the extent required. I therefore venture to affirm that, if a Glacial Sea was the main condition of the surface of the present northern continents during this first Pleistocene epoch, the ice was exhibited in a volume prodigiously beyond all present examples, and must have moved under impulses of a much more powerful character than either winds or currents.

The ice of this epoch was in masses of sufficient extent and depth to embrace, hold fast, and work upon large irregular surfaces—whole provinces of the present world—which it moulded down into certain outlines, partly determined by the character of the subjacent rocks. In what is now Scotland, mountains up to at least three thousand feet, and connected valleys of many miles in width, were undoubtedly swept, worn, and moulded by *one connected movement* of this mighty agent. While this state of things lasted, there could be no animal or vegetable life where it prevailed. The shells of sea-mollusks became part of the detritus swept along, and the large quadrupeds could only preserve their lives if they were fortunate enough to gain footing on mountain-tops above the ice-flood, or to escape to southern climes to which it did not extend.

The basis of all that is certain in this description, is the observation we make of the operations of moving ice in such regions as the Alps. The valleys are there filled with ice in the condition of an imperfect fluid—Glaciers—which, moving slowly downward to levels of mild temperature, carry fragments and particles of rock, and partly by these mixed up with their mass, wear smooth their beds, leaving the subjacent rocks reduced to a flowing outline and glassy exterior, entirely different from any surface on which water has operated. The blocks carried along by ice are found, moreover, to make long incisions—*striæ* or scratches—on the smoothed surface, in the direction of the glacier's movement—the blocks, again, being worn round and flat, and also scratched, by passing gratingly over the bed of the glacier. This peculiar ice-work or glacier-work, or whatever it may be called, being traced over surfaces where glaciers do not now exist, we infer that the same agent was formerly at work in those places, although perhaps applied in somewhat different circumstances, and to somewhat different results. Such an inference, it will be observed, is in strict accordance with the rule of geological investigation already adverted to; indeed cannot, if we admit that rule, be resisted or avoided.

Now the fact is, that surfaces with the peculiar rounding, glassy smoothing, and determinate striation, of the present glacier-beds of the Alps, are found in various situations where ice is not now seen working. These characteristic effects are seen extensively diffused over the British Islands, the north of Europe, and the north of America, wherever there exist rocks of a suitable character for taking on, and suitably protected for preserving, the appearances. That is to say, when in these countries, a

properly hard sandstone, or limestone, or trap-rock, is laid bare by the removal of its ancient covering, we are tolerably sure to find it smoothed and scratched. Even surfaces which have for ages been exposed to the atmosphere and all its wearing agencies, preserve in many instances the same features with more or less clearness. But we are called upon not to limit our view to the bits of surface here and there found so marked. When we see certain rocks of a specially hard character generally so marked, and others of a brittle or soft kind near by unmarked; when we see a well-protected surface marked, and an exposed one near by unmarked; we may infer with tolerable safety that all would have equally borne the memorials of the agency, if all had been equally qualified and circumstanced for doing so; consequently that all may have been, and in all probability were, subjected to the same influence. More than this: In our own valley of the Forth, for example, we find every suitable piece of surface that is laid bare, smoothed, and marked with striæ directed to a point 15° north of east. We find the surface of the country variegated with hills, of a longitudinal form, and many of them with hollows or troughs between—such as the Dalmahoy Hill, the hill on which the Old Town of Edinburgh is built, and the Garleton Hills in East Lothian—and all of these hills and hollows lie precisely in the direction of the striæ or scratches on the subjacent surfaces; shewing that they got their mould and general form from the same agent which smoothed and scratched the surfaces. An examination of the lately published survey map of the neighbourhood of Edinburgh will readily shew that our district is wholly composed of ridges and troughs, all of them lying in the direction indicated; the very direction of the main streets of our city has been determined by this primeval fact, because a line of buildings like Princes Street is naturally laid down along the front of such a ridge, and in the same direction. If we cast our eyes, moreover, on a sunny afternoon, to the face of the Pentland Hills—rising as they do sixteen or seventeen hundred feet above the sea—we shall see certain great *flutings* or *mouldings*, forming nearly horizontal bars of alternate light and shade along the mountain-slopes; these, too (and they are repeated on almost all the Scottish hills), fall into a conformity with the lines of striation, and may consequently be set down as the work of the same agent. It is a startling deduction to come to—yet the steps are clear and irresistible—that the same Power which grazed, smoothed, and scratched the beach rocks at Granton and Joppa, and the hollow ways at Samson's Ribs and the Windygowl on Arthur's Seat,

moulded not merely the low hills of the district, but the Pentland and Fife hills, which form the sides of the Forth valley; consequently, can only be conceived of as a vast mass of ice—vast enough to envelop lofty hills and fill deep valleys, fluid enough to move over and along such a country, yet tenacious enough to hold firmly the grazing blocks and gravel by which it moulded, smoothed, and incised the surface. What we see in the valley of the Forth is but an example of what we may see in many parts of our own country, of Scandinavia, and of America. Professor H. D. Rogers tells us that the smoothed surfaces occur, in his country, at all altitudes from the sea-level up to eminences of 5000 feet, all the mountains of the valley of St Lawrence and the great lakes having their summits visibly worn, excepting only Mount Washington, which is 6228 feet in elevation. I have myself traced striated surfaces on cols or passes of the Dovrefield in Norway, 4000 feet above the sea; and it was after seeing the wonderful effects of ice in that country * in giving a palpable mould to large parts of its surface, that I was enabled to advance the proposition that the general configuration of our own country was due, in part, to the same cause. It indeed appears that one set of phenomena of this kind have prevailed over the whole of the northern continents, as far south as the fortieth parallel of latitude. It may be remarked that, in America, the general direction of the movement is to south-south-east; in Scotland, it is to the south-east, though in Lothian it has been turned slightly northward; in Norway, it is likewise south-east in the northern parts of the country, but about Christiania turns away to the south-west.

There is a harmony in the details of the Ancient Ice-work which gives it a surprising verity. The hills of our district have a peculiarity which arrested attention long before any surmise of the true cause had been formed; they are mostly bold and steep, sometimes precipitous, towards the west, while they slope away gently towards the eastward. This is manifestly the form which would result from a current moving from west to east. In Sweden and Norway, where the ice-work is much more conspicuous than with us, each little eminence has in like manner a smoothed extremity or side towards the north, and a rough extremity or side towards the south, the one having been exposed to, and the other protected from, this powerful agent. Then the *Detritus* of the ancient ice—let us view its character and

* During a tour performed in the summer of 1849.

dispositions. It is the *Boulder Clay* or *Drift* of the geologist. It may be described as a compact tenacious bed of clay, blue or ruddy, of all thicknesses up to sixty feet, resting in general on the smoothed surfaces, and including blocks of all sizes confusedly interspersed throughout its composition. The colour is that of the general rock surfaces over which it has moved, and out of which it has been composed. The blocks are the spoil of rocks lying in its past course, sometimes at the distance of fifty miles and upwards. The general composition is different from that of the detritus of subaërial glaciers, being much more compact and stiff, and betraying a much greater amount of trituration in water; hence it is, indeed, that we are compelled to suppose aqueous conditions for the application of the glacial agent of this period. Moreover, throughout its apparently unbedded mass, there are interspersed short, thin nests (as they may be called) of sand and gravel, arguing that in reality it was laid down in beds, and with local intermissions of tranquil and purely watery action. We even possess proofs on the shore of the Firth of Forth—first adduced by the late Hugh Miller—that beds, already deposited, had subsequently been subjected to the grinding, grazing operation of the moving ice; the agent in these cases moving in precisely the same direction, and producing on the subjacent boulders precisely the same abrasion, as it had done when gliding over the rock surfaces below.

The blocks, of whatever size, are usually partially rounded, but almost always with one or more flat and smoothed sides, whereon are inscribed striæ exactly like those impressed on the subjacent rocks; and nine-tenths of these striæ are in the line of the length of the stone. It is evident that these stones have been the graving tools—so to speak—used by the ice, giving and taking smoothness and striation as they were borne along from their original situations. Not less clearly is it shewn how and with what degree of force they were applied. It must have been by a firm substance that they were pressed on the surface, otherwise they would have rolled freely along, and been completely rounded. The striation being in the line of the major axis or length of the stone, also shews that the boulders were held by a firm substance; for, when so held on, a stone is forced to move in the direction in which it will meet least resistance—namely, in the line of its length—just as a skater on the ice finds himself scarcely able to move otherwise than in the line of the length of his skates. At the same time, the existence of a few scratches slightly oblique shews that the boulders were not held so firmly but that they could occasionally

shift a little sideways. A glacial boulder is thus a most interesting object. We can usually ascertain where it was brought from. We know that it was carried in a tenacious matrix, having weight and exercising pressure, for it has moved in the line of least resistance—a mechanical necessity resulting from such conditions. We know that it was the immediate instrument by which the subjacent surface of fast rock was polished and scored, for it still bears the marks of the work in which it was engaged. Entering a deserted joiner's yard, where we see the workmen's tools lying about, with some of the products of their handiwork, we are not led more naturally and certainly to infer that the tools were what cut, planed, and moulded the work, than we are led by the sight of a collection of boulders on a glacialised surface to believe that *they* were the tools which produced the marvellous smoothness and striation presented to our view.

It has been implied that the great Ice-flow above described had the effect of moulding the surface of the country over which it passed. By this is meant, that the uneven surface which existed at the commencement of the period, was worn down by this agent, in some proportion to the unevenness, the power of resistance of the various parts of the surface, and perhaps, also, the measure of force applied. There were hitches or dislocations of the strata, leaving one mass at an elevation of several hundred feet above that with which it had once tallied; for example, in the celebrated Ninety-fathom Hitch in the Durham coal-field, there must have been one part raised 540 feet above that adjacent to it. The glacial agent has made all such inequalities smack smooth. Yet this does not exhibit the utmost of its powers. For fifty miles along the west coast of Sutherland and Ross, there is a range of isolated mountains of horizontally disposed Cambrian rocks, seated on a platform of gneiss. They are from 3000 to 3500 feet in height, and stand widely apart from each other; yet it is evident that they have all been at one time parts of a continuous formation, large interspaces having been subsequently formed. What carried away the matter of the interspaces? We find along the mountain-sides and on the gneissic platform whereon the mountains rest, ample memorials of the work of ice, in longitudinal hollows containing lakes, all in the same direction as the major axes of the hills, in smoothings, scratchings, and transported boulders. A geologist acquainted with the glacial phenomena sees that ice has been the agent here. He is forced to own that what his science calls *denudation*, has here been wrought on a great scale, not by water, as heretofore

supposed, but by ice. It required water invested with the increased mechanical powers which it derives from congelation, to carve out those prodigious gaps, and sweep away so much of the disengaged matters. The mountains of Sutherland and Ross are but specimens of ancient rock districts on which such vast carvings have been executed. Professor Ramsay has shewn us how in some parts of Western England there are formations of Silurian, Old Red Sandstone, and Carboniferous rocks, which have been crumpled in vast foldings and bends; after which some powerful agent has passed over them, and worn down the upper part of the foldings, carrying away matter to the depth of fully three and even four thousand feet. I am unacquainted with the superficial features of the districts he alludes to; but I have examined the similar district of Silurian rocks in Peeblesshire and Selkirkshire, and, seeing the Boulder Clay on uplands 1350 feet above the sea-level, and considering how all the hills have the mammillated forms peculiar to glacial surfaces, I am left little room to doubt that the ice has given that country its mould and outline, sweeping away prominences of its original flexures to an extent fully as great as in the cases described by Professor Ramsay. This is not to be taken as an insinuation that water has done little in the way of denudation, or is able to do little, and that ice has done all work of that kind. Water has unquestionably great power when beating on cliffs opposed to it; it has also wonderful powers for the transportation of blocks. But there is a specific difference between the dilapidations produced by water, and those produced by ice. Water leaves all rough and shattered, strewing its ruins confusedly about on the scene of its devastations: ice cuts sharply through, and sweeps away its débris to a great distance. Ice, moreover, can carry blocks up hill, and leave them on higher levels than their original seat; which is the predicament of many huge masses, whereon mere water-currents would spend their utmost force without moving them an inch from the spot. It therefore seems a fair hypothesis, that the general mould of the country, in its heights and its hollows—scarcely excepting the highest or the deepest—in at least a large part of the northern hemisphere, has been imparted by Ice; a hill being simply a piece of the surface which, from comparative hardness of material, has been able to resist that degrading power, while a valley or low country is one which, being in the opposite predicament, has experienced the opposite fate. We can everywhere trace the principle here indicated, and consequently know what is hard and soft in any district by the

comparative prominence. Unless there had been a degrading agent at work on the surface, this could not have been the case, for the probability against it as a mere coincidence is overwhelming.

It will appear to most persons that these are very bold speculations, or rather deductions, and I readily own they are so. For their justification, I cannot do better than repeat the remark of Playfair, how often we are carried by reason where the imagination can scarce venture to follow. Yet I speculate in no dogmatic way, and confess myself prepared to find that my views, being formed on knowledge liable hereafter to become both larger and clearer, will yet have to submit to some modification. For one thing, I must even now regard it as possible that we shall have to admit that some of the denudations of the ancient rocks were effected at epochs long antecedent to that of the Boulder Clay. There are hitches in the Coal-measures of Somersetshire, which have been worn down to an equality, and then had the beds of the New Red Sandstone laid over them. It may yet appear that the great carvings in the ancient rocks of Sutherlandshire were executed before the age of the Old Red Sandstone, and that the resulting detritus has been a conglomerate rock for nearly as long a time. This, however, would lead us into speculations on early glacial epochs, for which we have as yet extremely little safe ground; so I gladly leave the matter to the inquirers of a future generation.

It seems as if we might best consider at this place a special set of physical features of the surface of Scotland, which are connected in a curious way with the era of the great Ice-flow.

Along our bolder coasts, particularly in the counties of Forfar and Caithness, there are numerous narrow inlets of from a hundred yards to a quarter of a mile, along which the sea rushes with terrific violence, and which have evidently been carved out by it, in consequence of local weaknesses in the rock, through what are termed *faults*. In the north, they are commonly called *geoes* or *goes*, and the syllable figures appropriately in names of places, such as Girnigo and Staxigo. Now, both in these counties and some others, there are what may be called *ancient goes*—that is, goes now removed above the reach of the sea. Of such a nature is the great ravine of the Peaths in Berwickshire, which proved of such peril to the army of Cromwell in the year 1650. There is a similar, but smaller one, at Duninnald, in Forfarshire. Now, these ancient goes are found partially occupied by the Boulder Clay, shewing that they are of earlier date. My first observation to this effect took

place when I was accompanying a party of pleasure to the celebrated Bullers of Buchan ; and when, in the midst of the gaiety of the hour, my eye accidentally and unexpectedly detected the Boulder Clay in the ancient geo near by, I could not but appreciate the power of even such a slight knowledge of science as has fallen to my share, to give a charm to situations where no such thing is looked for. In various districts of Scotland there are inland valleys of the like appearance cut through sandstones ; for example, that through which the Esk pours at Roslin, and those of the Allan below Dunblane, the Water of Leith at the Dean, and the Ericht at Craighall. We know that the present rivers did not carve out these sections, because they run in a shrunk course at the bottom—as it were in a small valley at the bottom of a larger (a case well illustrated by the Esk at Roslin)—and because we find the Boulder Clay along the cliffs on the sides of these valleys, shewing that the river never could have touched those cliffs—a case well illustrated by the great clay-bank overhanging the village of Water-of-Leith, and by the similar banks near the Bridge of Allan railway station. Most probably, these valleys of erosion, as they may be called, have been the work of the sea, in the same manner as the goes. It is a subject worthy of being followed out. Perhaps some light may yet be derived from it on a point in physical geography, as yet very obscure—namely, the passing of rivers in some places across mountain-chains.

In our country, the peculiar features of the ancient ice-work are much obliterated by weathering, in all places where they have been exposed to the open air. They have survived better in Scandinavia, and perhaps also in America, especially in the districts near the great lakes. In some parts of Sweden—I may instance, as having fallen under my own observation, the tract near Oregrund, on the Gulf of Bothnia—spaces of many acres are seen with scarcely any covering, and all smoothed and striated. Very often throughout Southern Sweden, a farmstead is placed on an exposed glacial surface, and the grooving and scoring continues traceable after ages of wearing from wagon-wheels and the feet of men and animals. On the shores of the Christiania fiord, the exposed rock surfaces appear finely polished, with curious channellings several inches deep, and sometimes narrower at the top than the bottom, all of which are not less finely smoothed than the open-surface work. There is also throughout Scandinavia a class of ice-works, of which I have seen no certain example in this country ; neither do I hear of any in America.

The Norwegians name them *Jette-gryder*, or Giants' Tubs. At Gottenburg, for instance, on the wide level plain of rock on the opposite side of the fiord, as you walk about among the scattered blocks and heaps of rubbish, you come to a round hole in the ground, a hole as large as a good-sized caldron or tub, chiselled out, evidently by some extraordinary natural force, and perhaps half full of rounded pebbles of the size of a man's head. Or you are taken to a hillside behind the town, and there find in the smooth rocky slope, a pit like a shallow well, about eight feet in diameter, and ten deep. You are told it was discovered a few years ago, full of rubbish; but it has now been cleared out, excepting only that a few large, round, and spheroidal pebbles are left in the bottom. Now, the strange thing is, that the smoothing and scoring of the adjacent surface passes down into these pits, with appearances of a spirality of movement, as if the wearing-agent had gone into them like a tongue, and licked and worked all round, and up and down, and then gone out again and passed on, leaving, however, the pebbles which it had used as an assistance in the performance of its work. It is hardly possible to form any perfectly acceptable conception of the mode of formation of these Jette-gryder; but it is perfectly clear that they are inseparable in history from the superficial ice-work. I have been informed by a Scotch gentleman residing a day's journey from Gottenburg, that there are scores of such pits, all within a small space, in his neighbourhood.

If we consider how unfavourable for animal life were the conditions of this epoch, we shall not be surprised to learn how barren the Boulder Clay is of fossils. Shells of marine mollusks, of species still inhabiting arctic seas, have been found in a few places, but usually so much worn as to shew that they were carried along in precisely the same way as boulders, and subjected to the same treatment. A few years ago, Mr Peach, of Wick, and Mr Dick, of Thurso, found each an example of a calcareous zoophyte in the Boulder Clay of Caithness. Such rare discoveries serve chiefly to shew the extreme poverty of the Fauna of this formation. It appears but fair to suppose that, during this period, any superior animals which formerly inhabited the surface were driven southward to grounds exempt from the ice-flood, and where a temperature compatible with life was still to be obtained. At one time, it was fancied that the Boulder Clay denoted a period of universal death; but the idea of any entire break in the chain of life during geological ages has long been generally abandoned.

The Boulder Clay was described as having the boulders diffusedly floating in it, with occasional beds or nests of sand interspersed. Such sand-beds sometimes lie on the subjacent rock; in Aberdeenshire, for example, a considerable district is found to have sand undermost. It shews that the block-charged clay must in some places have passed wholly over, and left an interval where watery action alone prevailed. It also shews that the Boulder Clay must afterwards have, in some places, been laid down from some medium in which it was partially sustained; for otherwise it would have swept away the subjacent sand. It may be remarked that these beds of sand in the Boulder Clay occasionally add to the difficulties of working it for engineering purposes. When the remarkable section of about seventy feet was made on Middleton Muir for the Hawick branch of the North British Railway, the workmen were very much troubled with water pouring in from the interjected sand-beds. We have all heard of submarine forests; that is, remnants of once sylvan ground, now covered by the sea at high-water, and presenting stumps of large trees mingled with moss, sand, and silt. It was at first generally concluded that these submerged forests were proofs of local subsidence of the land in recent times. But Mr John Cunningham, of Liverpool, investigating the subject a few years ago, by the examination of the well-known Leasowe submerged forest at the mouth of the Mersey, found, on boring through the Boulder Clay, a quicksand, and has very reasonably suggested that the subsidence in these cases is caused by the attack of the sea upon the sand-beds of the Boulder Clay, sweeping it out, and so causing the ground simply to collapse—a minor, yet still interesting phenomenon.

We now come to the Second Epoch—that of the Silt, or Brick Clay, alternating with beds of sand. This was a time of tranquillity and of moderate temperature in the northern parts of the earth. The Glacial Agent—in whatever form it came over the world—had passed away. The land lay several hundred feet deeper in the sea than at present. Its diminished spaces were occupied by the elephant, hippopotamus, and other large mammals; and the seas gave life and sustenance to the *Tellina*, *Littorina*, *Saxicava rugosa*, and other mollusks still largely found in sub-arctic regions. Seas and rivers, working upon the Boulder Clay, carried off and re-deposited in quiet nooks, estuaries, and river-mouths, the finer particles of that great formation, thus producing those beds of fine silt or clay which we now employ

in making bricks and pottery. In intermissions of this work, as currents and other local circumstances might determine, the sea alternated these fine clays with deposits of sand and gravel, brought in part from the great glacial formation. It is a group of conditions and occurrences, all to be clearly seen in the clays and sands themselves, as read off in the light of the workings of nature in our own day. And, as for the animals of the period, we as usual trace them in their fossil remains.

To this Second succeeded a Third Epoch, during which the land was still submerged to a considerably greater depth than at present, and which was characterised by a brief, but violent return of icy action. It appears as if subaërial glaciers prevailed to a great extent, producing the usual rough gravelly débris which we see created by them in Alpine regions, and that this débris was carried off by floating ice, and distributed partially over the submerged surface. The result was the formation of a second, but locally partial bed of glacial drift, composed of a coarse gravel containing abundance of large sub-angular blocks, generally not far travelled. It is sometimes called the *Upper Boulder Clay*, from the blocks which it contains; but its light colour, its looser consistence, the comparative angularity of the boulders, and their being generally from near situations, give it a highly distinctive character. Very often, it lies directly over the true Boulder Clay, forming with its huddlement of coarse stones a striking contrast to the fine compact blue or red argillaceous paste with the equably diffused and polished blocks which rests below.

The Fourth Epoch was one of tranquil conditions, during which alternating sands and clays were again laid down in many situations, taking their place, of course, over the Coarse Gravel of the preceding era, wherever it existed. The meeting-point of sea and land gradually sunk till it rested at a point near to that which has been maintained, with comparatively little change, throughout the Historical Era of the world. The recently laid-down clays and gravels then became dry land, forming no inconsiderable part of the surface; and there is tolerable—though I will not say conclusive evidence—that the state of things now arrived at lasted throughout a very long space of time.

This evidence partly lies in a *Terrace of Erosion*, which is to be traced all round the coasts of Argyleshire and the Western Islands, at the height of twenty-five feet above the present sea-level. It has evidently been at one time a sea-beach, exactly like the present one—the result, like it, of the long-continued

erosive action of the sea. Now the present beach has, there is good reason to believe, been the margin of the sea since at least the time of the Romans, sixteen hundred years ago. If it has taken this long time to be formed, the old beach must have taken a longer time—perhaps twice as long—for it is much more thoroughly cut. Now, there is reason to believe—as will presently be shewn—that this old terrace of erosion was cut before the present epoch, and most probably during the Fourth.

Another probable evidence for the long duration of the state of things described, is afforded by the existence of extensive caves in the limestone strata of various parts of the earth, that shew as if they had been used for a lengthened period during this epoch as haunts of carnivorous mammalia. One of the most remarkable limestone caves in England is that of Kirkdale, in the wolds of Yorkshire, which was carefully examined by Dr Buckland in 1821. It appeared that, after the floor of this cave had been coated with a thin bed of stalagmite from the calcareous droppings of the roof, it received a thick deposit of the bones of animals, generally in a fragmentary state, and in many instances bearing marks of the teeth by which they had been broken to pieces. Then a muddy sediment had been laid over the bones, enveloping all except a few long ones left prominent above the general mass; and finally over this a new bed of stalagmite had been laid down, forming a complete preservative for the animal remains below.

Here was an accidentally formed, yet for the geologist most serviceable museum of at least a certain number of the animals which existed at a certain period. There were remains of four pachydermata—the elephant, rhinoceros, hippopotamus, and horse; of four ruminants—an ox, and three species of deer; of four rodents—the hare, rabbit, water-rat, and mouse; of five birds—raven, pigeon, lark, snipe, and duck; and finally, of six carnivores—the hyæna, tiger, bear, wolf, fox, and weasel; but all bearing peculiarities which distinguish them from species now existing. As many of the large bones exhibited marks of the hyæna's teeth, it was plausibly inferred, with a regard to the known habits of the animal, that the cave had been a haunt of that genus: ancient hyænas had dragged into it the bodies and fragments of bodies of vegetable-feeding animals, to be there devoured at leisure. The smaller animals may be presumed to have been brought into the cave under other circumstances, or from other causes; and it is to be observed that the remains of some of the larger ones were not numerous. But Dr Buckland

calculated that parts, chiefly teeth, of fully three hundred individuals of the hyæna tribe were found in the cave; and it fully appeared that these animals had devoured their own species, as well as others, as the animal still does in a state of nature, when any one becomes helpless.

The discovery and description of this bone-cave formed one of the most notable events in the history of geology, and naturally led to a great amount of discussion. Attempts were made to invalidate the conclusions arrived at by Dr Buckland, and to establish that the remains of the animals had been floated into the cave by diluvial action. But Dr Buckland brought forward facts which served to refute every objection. Not only did he point to the generally crushed and fragmentary condition of the bones, and the marks of the teeth of the hyænas upon them, but he shewed the *ejecta* of the stomachs of those animals, which he had found strewed about the floor of the cave. He likewise adverted to the large proportion of teeth among the fragments of bone, as a fact strongly corroborative of his view of the history of the cave, seeing that, while the hyæna breaks down, masticates, and digests all ordinary bones, however large, it rejects teeth, both on account of their hardness, and by reason of their containing no nutriment. His reasonings have met a triumphant reception in the scientific world, and his work on the subject, entitled *Reliquiæ Diluvianæ*, must be admitted to present a most interesting section of a chapter of the early and unwritten history of the world.

We are now in possession of a great number of observations that have been made upon ossiferous caves, both in England and the continent, particularly those of Oreston near Plymouth, and Kent's Hole near Torquay, those of Gailenreuth, Glucksbrunn, and Kluterhole in Germany, and several of more recent discovery in France; and are in a position to form a tolerable idea of the broad features of the Fauna of Europe during this long era. The grandest animal of the period appears to have been the *Elephas Primigenius*, or Mammoth, which was of considerably greater bulk than the largest elephants now living in Ceylon and in Africa, and appears to have ranged to the north of the fortieth parallel of latitude, since its remains are alone common in that part of the earth. One is startled to find that a species now confined to tropical climes, and which requires the foliage of rich forests for its subsistence, formerly prospered as far north as the Arctic Circle and beyond it; but the fact that it did so is indubitable from the abundance of its remains in those regions. Bones and teeth of the elephant are not only furnished from the

caves of England and Germany, but they are frequently found in the gravels and clays of this epoch, and in Siberia the collection of their tusks is the subject of a special trade. The finding of an entire one in the frozen ground near the mouth of the Lena, in Siberia, has solved the difficulty as to the climate, for the animal was found covered with a fur of reddish wool, through which grew long hair, shewing that nature had furnished its kind with a protection against the cold. As to the remaining difficulty on the score of food, Professor Owen has given it as his opinion, founded on the structure of the teeth, that the *elephas primigenius* might obtain a sufficient subsistence from the ligneous structure of those hardy shrubs which still grow in the extreme north of Europe.*

The remainder of the picture which this learned physiologist gives of the animal tenantry of England in those days is very striking. He says: 'Two horned rhinoceroses, of at least two species, forced their way through the ancient forests, or wallowed in the swamps. The lakes and rivers were tenanted by hippopotamuses as bulky and with as formidable tusks as those of Africa. Three kinds of wild oxen, two of gigantic size and strength, and one of these maned and villous like the bonassus, found subsistence in the plains. Deer, as gigantic in proportion to existing species, were the contemporaries of the old uri and bisontes, and may have disputed with them the pasturage of that ancient land; one of these deer is well known under the name of "Irish Elk," by the enormous expanse of its broad-palmed antlers; another has horns more like those of the wapiti, but surpassed the great Canadian deer in bulk; a third extinct species more resembled the Indian hippelaphus, and with these were associated the red-deer, the rein-deer, and the roe. A wild horse, a wild ass or quagga, and the wild boar, complete the known series of British pliocene hoofed mammalia.† The carnivora, organised to enjoy a life of rapine at the expense of the vegetable-feeders, to restrain their undue increase, and abridge the pangs of the maimed and sickly, were duly adjusted in numbers, size, and ferocity to the fell task assigned them in the organic economy. Besides a British tiger, of larger size, and with proportionably larger paws than that of Bengal, there existed a stronger feline animal of equal size (*Machairodus*), which, from the great length and sharpness of its sabre-shaped canines, was probably the most ferocious and

* *British Fossil Mammals*, 1846, page 267.

† At the time when Professor Owen wrote, the phenomena here described were considered as belonging to the Pliocene, or last section of the Tertiary.

destructive of its peculiarly carnivorous family. Of the smaller felines, we recognise the remains of a leopard or large lynx, and of a wild cat.

'Troops of savage hyænas, larger than the fierce crocuta of South Africa, which they most resembled, devoured what the nobler beasts of prey had left. A species of bear, surpassing the Ursus Ferox of the Rocky Mountains, found its hiding-place in many of the existing limestone caves of England. With it was associated a somewhat smaller kind, more like the common European bear, but larger than the present individuals of the ursus ferox. Wolves and foxes, the badger, the otter, the foumart, and the stoat, complete the catalogue of the known pliocene carnivora of Britain. Bats, moles, and shrews were then, as now, the forms that preyed upon the insect world; good evidence of the hedgehog has not yet been got, but remains of an extinct insectivore of equal size, and with closer affinities to the mole tribe, have been discovered. Two kinds of beaver, hares and rabbits, water-moles and field-moles, rats and mice, richly represented the rodent order.' The *trogonthere*—an animal allied to the beaver—and the *lagomys*, or tailless hare, are also cited by Professor Owen as animals of this era, and to these must now be added the musk-ox and a species of monkey.

The existence of common forms at this era in England and the continent, has led to a very interesting deduction respecting the ancient geography of this part of the earth. It appears in a high degree unlikely, if not impossible, that so many bulky animals should have made their way to Britain, if it had always been divided from the rest of Europe, as it now is, by a wide sea-channel. It is therefore inferred, that when Britain first became a seat of these animals, it was not an island, but a portion of a continent.

On the whole, the abundance of large mammalia—ruminant, pachydermatous, and carnivorous—during this epoch in Europe, implies a country much like South Africa at the present moment.

Keeping in view those philosophical principles which have been laid down for our guidance in geological inference, we must now describe an Epoch, the Fifth of the entire series, during which all the mountain systems of this country were the seat of persistent snow, and consequently of glaciers which descended into the neighbouring plains. It was a third occurrence of a Cold Period, but for certain, as far as this island at least is concerned, under sub-aërial conditions.

The evidence of this remarkable fact is to be seen in every

British mountain system, in the grooving and striation of the rock surfaces of the valleys, along the line of their several directions—in the ancient moraines or banks and masses of detritus which are to be traced at certain places in the valleys—and in the perching of travelled blocks in elevated situations; these features being precisely those which we see produced by what may be called the living glaciers of the Alps—insomuch that, were that mountain system lowered so as to be below the influence of persistent snow, it would shew exactly the phenomena which we can now trace in Wales, in Cumberland, and in the Highlands of Scotland; allowing only for the absence of the subsequent effect of partially obliterating and metamorphosing causes.

This system of local glaciers has necessarily swept over, and in some measure obliterated the products of that general *glaciation* which is chronicled by the Boulder Clay. In the valleys in question, there is no striation to be seen but in the lines of the valleys, radiating of course from the centre of greatest elevation. The Boulder Clay, moreover, has been swept out from the valleys, and only left on the *cols* or elevated passes among the mountains, where the glaciers never reached. So Professor Ramsay has pointed out as the case in Wales; and I have repeated the observation in Cumberland and in Scotland. The posteriority of the local to the general glaciation is thus clearly proved. Another fact for the chronology of the local glaciation fell under my notice in 1854. In the island of Arran, where the rocky parts of the coast are strongly marked with the terrace of erosion twenty-five feet above the present sea-level, the terminal moraine of one of the valleys, called Glen Iorsa, is thrown over upon the terrace, so as to fill up its deep angle. It thus fully appears that the long epoch of that terrace, with all its attendant phenomena of a South African fauna in England, hyænas haunting bone-caves, &c., was antecedent to the time of the ancient British glaciers. We shall presently see that the Glen Iorsa moraine also presented proofs of a deep submersion of the land, and a slow re-emergence, having subsequently taken place.

It seems at present beyond our power to ascertain the causes of the repeated and so great changes of temperature upon the surface, which have here been referred to. Some geologists point to the fact that, by reason of the current of warmed water which is reflected upon our shores from the Gulf of Mexico, we enjoy a temperature considerably higher than is due to our situation in point of latitude, which is identical with that of the inhospitable Labrador. It seems to them that minor changes of the surface,

giving us alternately an insular and a continental climate, might be accepted as the causes why England was at one time under the influence of ice, and at another enjoying a genial, or perhaps a sub-tropical temperature. Most persons, however, will feel that, though a true cause of change of local temperature is here touched upon, it is one far from sufficient to account for changes so very violent, and which operated over so wide a portion of the surface of the earth. The idea of M. Poisson, that our solar system has gone through cold portions of space, and been thus temporarily reduced on various occasions to an arctic temperature, seems scarcely worthy of serious notice in application to this question, as it is now admitted that the general fauna of the world has never experienced any decided interruption—and such must inevitably have happened, if the whole globe were at any time reduced to the temperature which our ancient glacial phenomena would argue. This, like some other questions regarding ancient ice, must be left to be solved at some future time, if ever. Let us not, meanwhile, be discouraged by the mysteriousness of the subject. Suppose, for a moment, that our world were now at such a temperature as to afford us no example of snow or ice. How doubly mysterious, yea, inscrutable, in that case, would have been those roundings and smoothings, and groovings and scratches, of the surface, as well as those heaps and beds of partially polished and scored blocks, which we now securely speculate on, as indicative of the presence and working of ancient ice. Just as, in that case, we should not have known anything of ice at all, so it may be that there are points in regard to its ancient applications and conditions, on which we cannot now obtain a satisfactory, or anything more than a partial light, and which may never be fully clear to us.

The Epoch of Local Glaciers was followed by a great change in the relative level of sea and land, leaving their meeting-point at a position several hundred feet above the present. From this it fell by steps, making a pause at each, so as to produce a series of more or less well-marked terraces or ancient sea-margins, till it reached a point somewhat below the present shore; after which it appears to have reascended through a short space, finally resting where it now is. I regard this period, being the *seventh* of the entire series, as that during which the so-called *Parallel Roads of Glenroy* were formed, the sea first making an incision on the boulder-clay coverings of the hills in that district at 1139 feet above its present level; then another at 1059; and finally, a third at 847—for such are the ascertained elevations of those

remarkable objects. In this case, the frame of the land does not appear to have been disturbed since, because over a tract of twelve miles these terraces preserve the most perfect horizontality. Such is also the case of the numerous terrace-markings in Scotland at points below that elevation; of which the most remarkable are set down at 545, 280, 202, 165, 92, and 65 feet above the present high-water of spring-tides. And it is probably the general case. There is, however, in the district of Altenfiord, in Lapland, a very well-marked ancient beach, partly expressed in a sandy terrace, and partly in a terrace of erosion, which stoops equably from about 220 feet at the southern, to 85 feet at the northern extremity, the space between being about thirty miles. Here a movement of the land, and one which has been unequal, is clearly indicated, and we ought not to be too much surprised to find such a phenomenon in those ancient times, since we have certain proof that the land of the Scandinavian peninsula is moving slowly upwards at its northern, and downwards at its southern extremity, at the present day.

It will be remembered that we ascertained the great twenty-five feet terrace to be a work anterior to the period of local glaciers, by finding the moraine of one of these glaciers thrown over upon it and filling up its angle. We, in like manner, ascertain the period of local glaciers to be anterior to that of the other ancient sea-margins, by finding these marked upon the same moraine, up to at least 140 feet. This is but an isolated, though a very interesting indication of the comparative chronology of these events. Everywhere throughout this island, we find that the spoils of the local glaciers have been greatly modified by the subsequent action of the sea. What was laid down originally as a coarse gravel, composed of angular or sub-angular blocks, mixed with smaller detritus and clay, has been laid hold of by the sea, washed and jumbled about, strewn and laid out in terraces, fashioned into spits and sand-banks, or carried into lakes and river-courses, where it now appears chiefly as a water-worn gravel, alternating with beds of silt and sand. At the openings of all the Highland valleys into the low country—in the case of the Forth at Stirling, of the Tay between Dunkeld and Perth, of the Dee at Aboyne, of the Spey at Fochabers and Elgin, and of the Conan at Contin—we find prodigious formations of gravel, suggesting strongly some peculiar cause. I regard these as all of them modified moraines; that is to say, the spoils laid down by the glaciers of those valleys at their several outlets, have been seized and worked upon by the sea, so as to result in characteristic gravel-beds.

Let me here interrupt my general sketch of this interesting subject, by recalling to my hearers certain examples of the objects in question with which they must be familiar; thus impressing the reality of the general results more firmly upon their minds. The people of Edinburgh are, for instance, well acquainted with the twenty-five feet ancient beach, as that sloping platform of sand on which the town of Portobello is built; and they can readily trace it, as a sort of bench or terrace westward along the shores of the Firth of Forth to Borrowstounness, where a bed of shells fully confirms this view of its ancient history. The people of Glasgow must recognise the same beach as that on which the lower and principal part of their city is built; and a day's sail along the Firth of Clyde will shew them its continuation as a terrace of erosion along the shores of Cowal and Arran. We may see the long slope of the ninety-two feet ancient beach extending for miles west of Trinity and Granton; at St Andrews, on one side of the opening of the Tay estuary, and at Carnoustie on the other; at Inverness; and in many other parts of Scotland. The terrace at 165 feet above the present sea-level is conspicuous all round the eastern part of Fife—equally behind Anstruther and behind St Andrews. It presents itself in Moray, Inverness-shire, and other districts. On the sloping ridge on which the Old Town of Edinburgh is built, there are indentations or level spaces at 165, 202, and 280 feet above the sea, being the places where Moray House, the Netherbow Port, and the High Church are or have been seated; and it seems far from unlikely that these indentations have been produced by the sea when its restless lip worked at those elevations upon the land, as evinced more clearly by terraces at identical levels in the neighbourhood and at a distance. Generally, these mementoes of the ancient ebb and flow of tides on what are now inland situations are marked by waterlaid gravel and sand; seldom in our northern land by shells, to the duration of which the humidity of our climate is obviously an enemy. To account for the markings being local, not universal, it is only necessary to point to the accidental character of the conditions necessary for our having any such markings; the chief of which is the presence of gravelly detritus. Mr Hugh Miller, in friendly conversation with me, used to start what appeared to him a difficulty regarding the ancient beaches. He remarked that the undoubted one at twenty-five feet was marked by a deep erosion in the rocky frame of the land, with a line of caves in the overhanging sea-cliff, all testifying strongly to the long continuing action of the sea at that level,

while there was no such memorial of its working at any higher level. That there really is no such memorial at higher levels, I believe not to be strictly the case; for in Caithness, in Dumbartonshire, and in Mid-Lothian, I have seen what I could not regard as other than ancient sea-cliffs at levels above twenty-five feet. But even though this were not the case, I may point to the fact now ascertained, that the twenty-five feet terrace of erosion belonged to a prior order of events, as helping us well to a solution of the difficulty. The rest of the terraces, being the memorials of one movement of the relative sea-level subsequent to the last glacial period, were probably beaches for a much less space of time than was the great terrace of erosion. The case seems to be of value as a caution against our laying too great stress on apparent difficulties, where a phenomenon of broad and generally intelligible characters is concerned.

Along the sides of all the mountain-valleys of our island, and equally along the mountain-valleys of Switzerland, of America, and, I suppose, all mountain-valleys whatsoever, there exist here and there, or rather with little intermission, gravel-terraces somewhat different in character from those already described, in as far as they usually slope downwards along their respective valleys, yet equally memorials of the former presence of the sea in inland situations. You see such terraces well marked in the upper part of the valley of the Tweed, at Tweedsmuir—along Tayside between Dunkeld and Blair—on the Spey at Rothes, and even above Kingussie, at 900 feet above the sea: not less in the valleys of the Jura on the French side—in the upper parts of the valleys of the Rhine and Rhone—in the valleys of Connecticut, well described by Professor Hitchcock. The gravel of which they are composed is simply, for the most part, the spoil of the mountains in the upper part of the valleys; chiefly, as I believe, the detritus of the ancient glaciers.

What is very significant, the pebbles always decrease in size as you descend the valley. Thus, in Glenlyon, an elevated branch valley of the Tay, you find the gravel composing the terraces to contain many stones of the size of cocoa-nuts; but in one which sweeps in a marked manner along the wider main valley at Perth, the gravel is comparatively small. Finally, in the Carse of Gowrie, you find only a fine clay; that is to say, in the low flats of the Carse, for the eminences called the *Inches* are masses of the Boulder Clay starting up through this fine and comparatively modern clay. There are many curious observations to be made regarding the laying down of these gravels; some of which have

been explained in a most ingenious manner by Mr Sorby of Sheffield. But I must confine myself to a few of the broader features of the theoretical history of these valley gravels.

One primary fact, of the highest importance in the case, is that, wherever a river meets the extremity of an estuary in a valley, it delivers and lays down in the sea, gravel, sand, and silt, which it has brought from places on its course, the gravel passing least way into the sea, the sand going further, and the silt or mud being carried furthest. The received matters are spread out in a slope under the waters, part going to form a margin or beach, which will observe a level. Let the relative level of sea and land sink forty feet—or, as some would say, let the sea be withdrawn, so as to sink through that vertical space—then we have the sloping detritus left in a subaërial state. The river, passing over this, cuts it down, carrying forward the separated matter into the sea, to form a new subaqueous slope; of course bearing the lightest particles the longest way, as before; leaving, at the same time, relics of the old alluvium as terraces high and dry on the sides of the valley. Let this process be repeated a sufficient number of times, and the result is a series of generally sloping terraces along the valley, from its higher reaches even down to the open country, where they will connect themselves with the ancient sea-margins. Now this is no ideal case. The operation was shewn to the present generation, when, a few years ago, the Lake of Lungern, in the Bernese Alps, was drained off for economic purposes. In that case, the incoming waters at the head of the lake and all round made each its valley and its terraces out of the old lake-bed, clearly exhibiting the process by which terraces on higher parts of their courses had been formed during the last great change of relative level between sea and land.

Connected with this subject is the formation of *Deltas*, out-spreading sheets of detritus usually seen at the mouths of great rivers. These alluvial formations alone—the most superficial of the superficial, the latest of the latest—speak of large spaces of time—spaces compared with which all historical periods become utterly insignificant. We must look to distant regions for the most august examples of alluvia; to the Delta of the Nile and the great plain which borders the mouth of the Mississippi. The former is a level tract with a hundred and twenty miles of sea-board, and a still longer, though tapering stretch inland. It is to be regarded as the remains of the bed formed by the matters poured in by the Nile immediately before the last shift of relative level of sea and land, by which it was thrown up a few feet above

the sea; after which the river, in several branches, poured over it and cut out the present channels. Even since this event, an immensely long space of time has elapsed, for not only is the Delta the site of ancient and long ruined cities, but works of human art are found at such depths in the present flood-course of the river, as shew the present state of things to have lasted since a period certainly on the lowest computation antecedent to the remotest of even the hypothetical dates of Egyptian history. We have then, first, a long period for the present alluvial formations of the Nile, and then another long period for the formation of the older ground now called the Delta. If there be terraces along the borders of the Nile valley, they will argue, of course, a third and remoter, but probably not less extensive period, and yet all of them are but the last hour of a round of the clock of Time, marking the entire Era of the Superficial Formations. So, also, is the Delta of the Mississippi an extensive plain—the extent is said to be not less than 30,000 square miles. At New Orleans, it is 600 feet deep at least, for borings to that depth do not reach the bottom. Here, also, we have the long period of the present arrangements; behind that, the long period during which the present plain was in the course of being formed as a sea bottom; finally, we have bluffs rising to the height of 250 feet above the river, the remains of an earlier and similar plain, and the record of an earlier and similarly immense stretch of time. If we consider that, of calculations based on the present rate of deposit of the mud brought down by the river, the lowest assigns a hundred thousand years for the forming of the present plain at New Orleans; and if we further reflect that the alluvium of the bluffs speaks of a long stretch of time altogether antecedent to this, we shall be somewhat prepared for a consideration of the entire Era of the last Alluvial Formation. It is important to observe that the loam of the bluffs contains shells, many of which exist in the neighbouring seas unchanged, mingled with remains of the mastodon, elephant, and tapir, the megalonyx, and other megatheroid animals, together with the horse, ox, and other mammalia, mostly of extinct species. It appears that the higher animals of the era of the bluffs have all been changed in more recent times, but that many of the marine mollusks, probably from living in more equable and lasting conditions, have survived.

These observations in some degree prepare us for a question essentially connected with this subject, to which a good deal of attention has of late been directed—namely, whether our species existed before any of the latest geological changes. Up to a very

recent period, the tendency of belief amongst English geologists was certainly to the effect that no true grounds existed for answering this question in the affirmative. The late Dr Mantell, a most ingenious and diligent geologist, wrote a paper so lately as 1850, to shew that all reports as to the finding of human remains and human works in any but the last-formed surface of the earth were fallacious; consequently, that Man was a very recently planted colonist of the globe. I must candidly admit that many of the reasons adduced by Dr Mantell and others against the acceptance of the aforesaid reports, were merely those easy assumptions of fallacy by which we so often see important truths opposed by men of science, under a laudable, though often overstrained wish to keep down the wonderful. Yet, such as they were, these reasons availed with British geologists, during a considerable number of years, to exclude many facts which, it now appears, rested on very fair and sound observations, and are beginning to be generally accepted.

A generation has passed away since public attention in Scotland was called to the discovery of the skeletons of two large whales in the loam of the Carse of Stirling, a plain twenty-five feet above the level of the tidal river Forth, which flows through it, to join the sea several miles onward. One of these skeletons was found at Airthrey, a mile from the river, and seven miles from the sea; the other was found at a place several miles more inland. The most obvious inference in the case was, that these whales had been stranded in their final situation at a time when the Carse was the bottom of an estuary, being the time antecedent to the last change of the relative level of sea and land. In both cases, however, it was reported that a knife of deer's horn—manifestly a piece of human workmanship—was found amidst the remains, as if it had been employed by some one of a rude people in flensing the animal. It was therefore held as most likely, that the whales had been thrown ashore by some extraordinary tide or inundation, during the historical epoch—a supposition certainly of a very violent character, yet which appeared preferable to the belief that man and his works preceded the last change of sea-level.

During several years following upon 1847, the workmen employed in making excavations for a new harbour along the south bank of the Clyde at Glasgow, discovered several rude canoes imbedded at the depth of ten, fourteen, and even seventeen feet in the ancient silt there abounding. They were formed each of a single oak log, hollowed out, with certain grooves and

apertures, implying a kind of joinery not of the most primitive description. Considerations as to their workmanship, and the bed in which they lay, led the local geologists to the conclusion that these canoes were only archæological curiosities; and, as far as the canoes in question were concerned, this deduction was justifiable. It was recollected, however, that similar canoes had been found long before, deeply imbedded in water-laid matters under the site of St Enoch's Church, and at the Cross, places where the surface of the ground was twenty-five feet above the present sea-level, and eight above that of the highest recorded inundations. Within the canoe, moreover, which underlay St Enoch's Church, there had been found a *celt* or stone-axe, beautifully fashioned. In preparing a work in which these objects and their situations were described, and which was published in 1848,* I ventured to say that they implied the occupation of the valley of the Clyde by a rude people, at a time when the estuary covered the plain which now forms the site of the principal part of Glasgow—an epoch necessarily remote beyond all former conceptions as to the era of humanity in this country. The idea, however, met with no support, and I was subsequently led to retract it in some measure, as being then disposed to allow greater scope for possible inundations than formerly, chiefly in consequence of a discovery subsequently made in the Carse of Gowrie. In that remarkable plain, which is generally twenty feet above the adjacent Firth of Tay, at a spot near the Errol station of the Perth and Dundee Railway, and on the property of Lord Kinnaird, there had been found, eight feet below the surface, in what appeared a small water-laid gravel, *an iron boat-hook*, of the ordinary form and appearance. Here was what, to superficial observation, would have appeared an important geological discovery. An article of iron was necessarily modern, for we know of a time in Britain when no iron implements existed. Yet this boat-hook was imbedded in a gravel which we could not readily suppose to have been laid down later than the time when the Carse was the bed of an estuary. On close examination, however, it was observed that a ditch-like rivulet-channel ran along within a few yards of the site of the discovery. The boat-hook might have been lost at no remote date by some people conducting a wherry from the firth along that channel. A freshet in the rivulet might have afterwards covered it over with gravel. Here

* *Ancient Sea-Margins, as Memorials of Changes in the Relative Level of Sea and Land.* 8vo.

was a possible, nay very probable history for it, taking it of course entirely out of the category of geological objects. Seeing how great a liability there was in this case to an erroneous conclusion, I deemed it necessary, for perfect candour, to admit some possible circumstances in the Clyde valley, which had caused the canoes to be entombed, at a comparatively modern date, in a situation where certainly no inundation ever in our days occurs. I remember the admission proved uncomfortable to my friend Dr Daniel Wilson, who, in his admired work, *The Prehistoric Annals of Scotland*, persisted in holding up the Clyde canoes as of a date antecedent to the last geological changes—which I now think they very probably were.

About the time when these discoveries were making in Scotland, there were some of a similar character made in America. In the Mississippi delta at New Orleans, excavations for a gas-work revealed, in succession, below the surface, ten different beds composed of the débris of so many cypress forests, each of which had been overwhelmed by a dip into the sea, and each of which spoke of a considerable space of time as necessary to its existence. Below all, was a bed composed of aquatic grasses, speaking of a still earlier era. On the surface, there was in like manner a stratum of débris of the present forest growth, which was calculated as requiring for its formation not less than fifteen hundred years. At the depth of sixteen feet in this excavation, and underneath the *fourth* bed of cypress moss, there was found burnt wood and the skeleton of a man, the cranium being evidently of the same type as those of the aboriginal tribes of America. Dr Bennett Dowler, in his work, *Tableaux of New Orleans*, published in 1852, indulged in some speculations as to the era of this remarkable deposit, and made it out to be about fifty-seven thousand six hundred years ago. In a speculation so vague, few on this side of the Atlantic will be disposed to follow him; but, assuming the facts to be truly reported, they certainly argue for a very remote date to humanity in that part of the globe.

Passing over several other ancient relics of man in America, as liable to be explained away or challenged, and therefore involved in some degree of doubt—though, perhaps, erroneously so—we may return to Europe, where a very considerable number of instances have been reported within the last few years.

I copy from a popular work the following statement: 'Dr Schmerling has examined a large number of localities in France and Liege, particularly the "caverne d'Engihoul," where bones of man occurred, together with those of animals of extinct species:

the human fossils being found, in all respects, under the same circumstances of age and position as the animal remains. Near these relics, works of art were sometimes disclosed; such as fragments of ancient urns and vases of clay, teeth of dogs and foxes pierced with holes, and doubtless worn as amulets. Tiedemann exhumed, in caverns of Belgium, human bones mixed with those of bears, elephants, hyænas, horses, wild boars, and ruminants. These human relics were precisely like those they were associated with, in respect to the changes each had undergone in colour, hardness, degree of decomposition, and other marks of fossilisation. In the caves of France and Belgium, we often find, in the deepest and most inaccessible places far remote from any communication with the surface, human bones buried in the clayey deposit, and cemented fast to the sides and walls. On every side we may see crania imbedded in clay, and often accompanied by the teeth and bones of hyænas. In breccias containing the bones of rodents and the teeth of horses and rhinoceroses, we also meet with human fossils.' *

I accept this as a summary of facts reported, without pretending to judge of their soundness. On this point we may be better enabled to decide, when certain discoveries connected with bone-caves in England shall have been more clearly elucidated. These consist in the finding of what are represented as flint implements in a cave at Brixham, near Torquay, and in another named Kent's Hole in the same district. We are told that the mouth of the former cave is in the side of a small valley at a considerable elevation. Its floor is covered with a bed containing bones of the rhinoceros, ox-tribe, cave-bear, and hyæna, of the usual extinct species, covered over with what appears as the gravel of a rivulet channel, as if a stream had passed through this cave, at a time subsequent to the deposition of the bones, though this would require arrangements of the neighbouring surface wholly different from what now exist. Among the bones there have been found numerous examples of what are considered as flint weapons or implements. Here the great question is as to the character of the so-called flint implements. They certainly do not very closely resemble the well-defined spear-heads and other flint implements with which antiquaries are familiar—all of which exhibit clear markings of repeated and careful chippings on all sides, designed to reduce the article to a certain shape, and undeniably traceable

* Dr William Usher of Mobile, U.S., in Nott and Gliddon's work on the *Types of Mankind*. 8vo. London, 1854.

to the hand of man. They are only—so to speak—slips or chips of flint, such as might be struck off from a large piece by a dexterous blow, but otherwise wholly undressed. At the first sight of any single one, we might be little disposed to regard it as a work of man's hand: the forming of it would seem to be not beyond the reach of accident. But when we see a number that have been found together, we must admit that the views presented by the gentlemen who have examined the bone-caves acquire some plausibility. According to Dr Falconer, 'the great majority of them present definite forms—namely, long, narrow, and thin—having invariably a smooth conchoidal surface below, and above a longitudinal ridge bevelled off right and left, or a concave facet replacing the ridge—in the latter case presenting three facets on the upper side. The author is of opinion that they resemble, in every detail of form, obsidian knives from Mexico, and flint knives from Stonehenge, Arabia, and elsewhere, and that they appear to have been formed by the dislamination, as films, of the long angles of prismatic blocks of stone.'

When we further learn that similar slips of flint are found in more caves than one, and in different parts of Europe, we must acknowledge that their verity as human works becomes still more admissible. It so happens that, while the Devonshire bone-caves were under examination, the eminent naturalist just quoted was exploring others of a like kind which occur along the northern coast of Sicily. One—the Grotto di Maccagnone, about twenty-four miles to the west of Palermo—opens in a cliff, at a point two hundred feet above the sea, and fifty above a tertiary plain intervening between the cliff and the sea-coast. A breccia resting on its floor, and covered with an earthy soil, is full of bones of the extinct mammalia, hippopotamus, elephant, hyæna, a felis, and several deer. There was also, in patches along the roof, remains of a stalagmitic breccia, which had once filled up the whole space above the earthy covering of the bone-bed; and in this breccia, cemented together by a calcareous paste, were entire land-shells of large size finely preserved, splinters of bone, teeth of ruminants, and of the horse, together with bits of carbon, specks of argillaceous matter resembling burnt clay, together with 'fragments of shaped silicious objects of different tints, varying from the milky or smoky colour of chalcedony to that of jaspery hornstone.' Of these last objects, Dr Falconer gave the description which I have just quoted as being equally applicable to the similar articles found in the Brixham cave. He regarded all the deposits above the bone-breccia to have been accumulated up to the roof by

materials washed in from above through crevices in the limestone rock. Calcareous infiltrations had subsequently fused the upper part of this deposit into a connected mass, which stuck fast to the roof. The loose materials below had been subsequently washed out, in consequence of 'a great physical alteration of the contour, altering the flow of superficial water and of the subterranean springs.' Thus it clearly appeared to Dr Falconer that, previous to some great geological change, which was again antecedent to the records of history, there had been a human population in that part of the world sufficiently advanced to use flint implements.

While it is just within reason to entertain a doubt of the flints of Brixham and Maccagnone, the same licence can scarcely be extended with regard to the articles of apparent human workmanship discovered in the Devonshire cave, called Kent's Hole. To adopt the description given by Dr Mantell—'Every one knows that near Torquay there is a chasm or fissure in the limestone strata, named Kent's Hole, which has long been celebrated for the quantities of fossil bones belonging to extinct species of bears, hyænas, lions, tigers, &c., that have from time to time been dug up from its recesses. These remains occur in a bed of reddish sandy loam, which covers the bottom of the chasm or cavern, to a thickness of twenty feet. The teeth and bones are for the most part in an excellent state of preservation. The principal chasm is 600 feet in length; and there are several lateral fissures of less extent. A bed of hard solid stalagmite, from one to four feet thick, is spread over the ossiferous loam, and covered with a thin layer of earth, with here and there patches of charcoal, mixed with human bones and coarse earthen vessels.

'On breaking through the sparry floor, the red loam containing teeth and bones is brought to view; and *imbedded in it, and at a depth of several feet, and intermingled with remains of extinct bears and carnivora*, there have been discovered several flint knives, arrow and spear heads, and fragments of pottery. The stone implements are of the kind usually found in early British tumuli, and doubtless belong to the same period; yet here they were unquestionably collocated with fossil bones of immense antiquity, and beneath the impermeable and undisturbed floor of the cavern, which was entire till broken through by the exploration that led to the exhumation of these relics.'

So far the learned geologist's description. He added, that 'the discovery gave rise to many curious speculations, because it was supposed to present unequivocal proof that man and the extinct carnivora were the contemporary inhabitants of the dry land, at

the period when the ossiferous loam was deposited.' He proceeded to express his belief, that, in this and all similar cases, the limbs and carcasses of the animals had been floated into the cave by currents, while it was submerged by shallow water, 'for the bones, though broken, are very rarely water-worn, and consequently must have been protected by the muscles and soft parts.' 'If,' said he, 'when Kent's Hole first became accessible, and while the floor was in a soft state, and before the formation of the stalagmitic covering, some of the wandering British aborigines prowled into the cave, or occasionally sought shelter there, the occurrence of stone instruments, pottery, bones, &c., in the ossiferous loam may be readily explained; for any hard or heavy substances, even if not buried, would quickly sink beneath the surface to a depth of a few feet, and afterwards become hermetically sealed up, as it were, by the crust of stalagmite that now forms the solid pavement.'

It is scarcely necessary to remark how unsatisfactory is this view of the matter. All suppositions as to the floating in of the bones by diluvial action had been refuted by Dr Buckland in regard to the Kirkdale Cave, by reference to the broken condition of the bones, their great number, the disproportion of teeth, and other particulars, to the entire satisfaction of the scientific world. Professor Owen, in his work on *British Fossil Mammalia*, expressed his full belief that the remains of the young mammoths in Kent's Hole 'were introduced into the cave by the carnivora which co-existed with them.'* Such a supposition as Dr Mantell's could never have been revived, except under an unusual anxiety to explain away one much more feasible. It is even less possible to receive Dr Mantell's theory as to the association of the human works with the bone-bed, for surely it is a very violent supposition that objects so small as arrow heads and fragments of pottery could sink several feet into a mud-floor which was sufficiently firm to sustain human beings. These objects he admits to have been 'intermingled' with the bones, and it seems much more fair to assume contemporaneity in this case, as is usually done in others where objects are associated in one bed.

Whatever may be the upshot of these questions about human relics in bone-caves, it cannot affect in any way certain other alleged discoveries of similar objects in the alluvial gravels of France.

It is not to a geologist, but to an antiquary, M. Boucher des

* Owen's *British Fossil Mammalia*, p. 259.

Perthes, that we have been indebted for an account of these remarkable fossils. It appeared in 1849, in an elaborate work, entitled *Antiquités Celtiques et Antediluviennes—Mémoire sur l'Industrie Primitive, et les Arts à leur Origine.* Here he carefully described and figured a vast number of primitive implements, ornaments, &c., taken from ancient graves, chiefly throughout the department of the Somme, and which had been the result of ten years' labour among quarries and engineering sections of the surface. These results were, of course, purely archæological, referring to man as hitherto supposed—namely, a recent inhabitant of the earth. But along with them were given articles which M. des Perthes stated himself to have obtained at considerable depths in gravel, manifestly of date anterior to the last geological changes.

'In our various excavations,' says he, 'we become acquainted with successive periods of civilisation which correspond with the written history of the country. Thus, after passing through the first stratum of the soil, we come to relics of the middle ages; and then, in regular order, meet with traces of the Roman, the Gallic, the Celtic, and the diluvian epochs. It is always in the neighbourhood of lakes and rivers that we find vestiges of the most numerous and ancient people. If their banks were not the earliest seats of human habitations, they were probably the most constant, and when once settled, were seldom afterwards deserted. This was owing to water, the first necessary of life, and surest pledge of fertility; and to the abundance of fish and game, so indispensable to a hunting-people. . . . . On the banks of their rivers, they deposited the ashes of chiefs and relatives, and there they desired to be buried themselves. The possession of these banks was, therefore, an object of general ambition, and became the continual subject of war and conquest. This explains the accumulation of relics which sometimes covers them, and which, on the banks of the Somme and the Seine, conducts us from the middle ages, through the Roman and Gaulish soils, back to the Celtic period.'

Even this so-called Celtic period M. des Perthes assumes to be represented by the monoliths and stone circles which still appear upon the surface. It is far below what a geologist would call the *zone* of these objects, that the others with which we have now to deal have been found.

At Portelette, on the Somme, an excavation was made which first cut through ten feet of vegetable soil; then through six and a half of calcareous tufa; then, again, through ten feet of blue muddy sand; and, finally, through ten feet of moss or turf, in

which last, and rather below its middle part, were found a variety of flint axes, with some objects described as axe-cases of deer's horn. Near these articles was a coarse vase of black pottery, very much broken, along with remains of other pieces of pottery, and a large quantity of 'wrought bones,' animal and human. There were also entire bones of the urus, boar, dog, and horse, but not of man. The zone of the articles found seems to have been nine or ten feet below the level of the neighbouring river.

Another section at Menchecourt shewed, first a few feet of recent alluvium, containing remains of still existing indigenous animals, and human remains, with relics of the works of man; below this, a set of beds less regularly stratified, and which, from the appearances of disturbance in their deposition, have been set down as diluvian, or the results of a violent flood. 'Here,' it is said, 'different sands, gravels, marls, broken and rolled flints, everywhere scattered in disturbed beds, and repeated at irregular distances, announce the movement of a great mass of water, and the devastating action of a furious current. Indeed, it is scarcely possible to be deceived in the diluvial character of these formations, or to confound them with a posterior deposit.' We are also called on to observe 'the total absence of modern relics, and of any remains of recent animals; the large lumps of silex; the scattered boulders; the pure sands (yellow, green, and black), sometimes in distinct layers, at other times mixed with the silex, whose *couches*, descending to a great depth, rise again immediately to the surface of the soil.' At the depth of thirteen feet in one instance, and twenty-seven in another, in these deposits, were found flint axes, mixed and associated with bones of elephants and rhinoceroses, and in such circumstances and conditions, as enforced the belief that the human implements had been placed there contemporaneously with the fossilised bones, and that the ground had since been the scene of various geological changes.

These discoveries of M. des Perthes, and others of a like nature by some of his countrymen, had been several years before the world, and were treated by English geologists in an unbelieving spirit, when at length, in 1858, the discoveries made in the Brixham Cave, under circumstances giving assurance of scientific accuracy, induced several gentlemen to think that the alleged French discoveries were worthy of some attention. To this they were further led by the preliminary report, which Dr Falconer presented in 1858 to the Royal Society, regarding his discoveries in Sicily. Accordingly, Mr Joseph Prestwich, F.G.S., who has

given much attention to the superficial beds in England, proceeded in May 1859 to Amiens, and immediately commenced an examination of the district on the banks of the Somme, in which the flint implements were reported to have been discovered. It is important to state, that he undertook the inquiry with a mind full of doubt (his own expression), and that the fact is in accordance with the whole treatment of this class of discoveries by the English geologists, because this school of scientific men are sometimes thought to be too ready to advance facts that seem to make for a novel class of opinions, while the fact is that they are exactly the reverse.

On the right bank of the Somme, about a mile south-east from Amiens, is a low chalk-hill, capped by gravel-beds, the whole rising to about a hundred feet above the river, and at a considerable distance from all higher ground. In what are called the gravel-beds of St Acheul, on this spot, the late Dr Rigollot of Amiens had recently reported his finding flint implements, as M. des Perthes had previously done. When Mr Prestwich came to the spot, he heard from the workmen of their frequently finding flint weapons, called by them cats' tongues (*langues de chat*); but none were discovered while he remained upon the ground. He was subsequently recalled to the place by a message stating that a worked flint had been found, and was left sticking in its bed for his inspection. He returned to the spot, taking with him his friend Mr Evans, and there accordingly the two gentlemen found a fashioned flint in the gravel section—'truly *in situ*,' Mr Prestwich says, and seventeen feet below the surface of the ground. The better to give the like assurance to others, he had a photographic sketch of the section taken, with a workman pointing to the flint —also another photograph representing the flint and its matrix on a larger scale.

With this verification of the phenomenon in his own experience and immediate observation, Mr Prestwich found no difficulty in accepting M. des Perthes's discoveries, of which he found ample results stored up at Abbeville. Some of these were the product of the same beds of St Acheul, in which he had seen the as yet undisturbed flint. Others had been gathered from similar beds of flint gravel, similarly situated on a low hill at Moulin Quignon, to the south-east of Abbeville. There, towards the bottom of the bed, which is from twelve to fifteen feet deep, M. des Perthes had found fragments of the bones of elephants associated with the flint weapons. Some, again, were from gravel-beds at Menchecourt, a suburb to the north-west of Abbeville. This deposit,

which Mr Prestwich considered as the most interesting, is 'patched on the side of a chalk-hill, which commands it to the northward, and it slopes down under the peat-beds of the valley of the Somme to the southward.' Here, in a bed of light-coloured sandy clay, from eight to twenty-five feet below the surface, along with land-shells of recent species, there were both flint implements and remains of the *Elephas Primigenius* or mammoth, the ancient rhinoceros and hippopotamus, the cave bear, the cave hyæna, together with the ancient stag, horse, and bos. Nay, even in a thin bed below this, it was affirmed that such relics had been found, and in connection with a few marine shells.

Mr Prestwich, in his communication on this subject to the Royal Society, after stating that there was a concurrent testimony about it from all the workmen at the different pits, which, after careful examination, he saw no reason to doubt, proceeds to remark that 'the flint implements ("*haches*") bear upon themselves internal evidence of the truth of M. des Perthes's opinion. It is,' says he, 'a peculiarity of fractured chalk flints to become deeply and permanently stained and coloured, or to be left unchanged, according to the nature of the matrix in which they are imbedded. In most clay-beds they become, outside, of a bright opaque white or porcelainic; in white calcareous or silicious sand their fractured black surfaces remain almost unchanged; whilst in beds of ochreous and ferruginous sands, the flints are stained of the light yellow and deep brown colours so well exhibited in the common ochreous gravel of the neighbourhood of London. This change is the work of very long time, and of moisture before the opening out of the beds. Now, in looking over the large series of flint implements in M. des Perthes's collection, it cannot fail to strike the most casual observer that those from Menchecourt are almost always white and bright, whilst those from Moulin Quignon have a dull yellow and brown surface; and it may be noticed that whenever (as is often the case) any of the matrix adheres to the flint, it is invariably of the same nature, texture, and colour as that of the respective beds themselves. In the same way at St Acheul, where there are beds of white and others of ochreous gravel, the flint implements exhibit corresponding variations in colour and adhering matrix; added to which, as the white gravel contains chalk débris, there are portions of the gravel in which the flints are more or less coated with a film of deposited carbonate of lime; and so it is with the flint implements which occur in those portions of the gravel. Further, the surface of many specimens is covered with fine dendritic markings. Some

few implements also shew, like the fractured flints, traces of wear, their sharp edges being blunted. In fact, the flint implements form just as much a constituent part of the gravel itself—exhibiting the action of the same later influences, and in the same force and degree—as the rough mass of flint fragments with which they are associated.'

There has been some discussion about Mr Prestwich's admissions, and the additional facts which he has brought forward; and those who hesitate to adopt his conclusions, may be said to have presented objections of two different kinds. First, it has been questioned if the so-called flint implements are not naturally fractured flints, with which primitive man has had nothing to do. Second, it has been strongly urged that the superincumbent gravels may have been placed where they are through some simple accident at a modern date. It has appeared, however, to most of the English geologists, and many of them have since gone over the same ground, that no reasonable doubt can be entertained either of the artificial origin of the flints in their present form, or of the beds being of the ordinary alluvial character, apparently, indeed, the same set of flint gravel-beds which we see in the neighbourhood of London, and on which the metropolis itself is built. Amongst those who corroborate Mr Prestwich's report, is Mr T. W. Flower of Croydon, who published a letter on the subject in the *Times* of 18th November 1859. After stating that he himself excavated two of the implements in the St Acheul pit, twenty feet from the surface, in the middle of a compact mass of gravel, he gives us the important information, that the beds containing the flints form the *capping* of that hill, 100 feet above the Somme, formerly described. They crop out or terminate at a few hundred yards' distance to the east, and, after an interval, are continued in the hill of St Roch. Now this interval or gap, isolating the flint-bearing beds, is the result of another and subsequent diluvial action, throwing the deposition of the implements still further back amongst geological occurrences. In connection with the whole matter of these discoveries, it is proper now to recall the numerous instances of alleged discovery of human works in connection with pleistocene deposits—such as the Glasgow canoes, the Carse-of-Stirling whales, with horn-knives, and the flints of the Devonshire and Sicilian caves, all of which speak to a like conclusion. Nor is this all—for we find that, upwards of sixty years ago, there was a well-observed and scientifically recorded discovery of flint weapons, in England, in precisely such a formation as that at Amiens. From the report of it by Mr John

Frere, F.R.S., in the thirteenth volume of the *Archæologia*, it appears that, at Hoxne, in Suffolk, after penetrating, first, one and a half feet of vegetable earth, then seven and a half feet of argill —by which we may understand brick-earth—and one foot of a sandy deposit containing shells, they came to a two-feet bed of gravel, containing numerous flint weapons, along with large bones not described. 'The ground,' we are told, 'does not lie at the foot of any higher ground, but does itself overhang a tract of boggy earth, which extends under the fourth stratum'—that is, the bed containing the human works—for that such they were the portraits given of them leave us no room for doubt.

Sir Charles Lyell, after remarking that upwards of a thousand flint implements have now been found in the chalk-gravels of the Somme, in an area of fifteen miles, says: 'I infer that a tribe of savages, to whom the use of iron was unknown, made a long sojourn in this region; and I am reminded of a large Indian mound which I saw in St Simond's Island in Georgia—a mound ten acres in area, and having an average height of five feet, chiefly composed of castaway oyster-shells, throughout which arrow-heads, stone-axes, and Indian pottery are dispersed. If the neighbouring river, the Alatamaha, or the sea, which is at hand, should invade, sweep away, and stratify the contents of this mound, it might produce a very analogous accumulation of human implements, unmixed perhaps with human bones. Although,' he adds, 'the accompanying shells are of living species, I believe the antiquity of the Abbeville and Amiens flint-instruments to be great indeed, if compared to the times of history or tradition. I consider the gravel to be of fluviatile origin; but I could detect nothing in the structure of its several parts indicating cataclysmal action, nothing that might not be due to such river floods as we have witnessed in Scotland during the last half century. It must have required a long period for the wearing down of the chalk which supplied the broken flints for the formation of so much gravel at various heights, sometimes 100 feet above the present level of the Somme, for the deposition of fine sediment, including entire shells, both terrestrial and aquatic, and also for the denudation which the entire mass of stratified drift has undergone, portions having been swept away, so that what remains often terminates abruptly in old river-cliffs, besides being covered by a new unstratified drift. To explain these changes, I should infer considerable oscillations in the level of the land in that part of France—slow movements of upheaval and subsidence, deranging, but not wholly displacing, the course of the ancient rivers. Lastly,

the disappearance of the elephant, rhinoceros, and other genera of quadrupeds now foreign to Europe, implies, in like manner, a vast lapse of ages, separating the era in which the fossil implements were framed and that of the invasion of Gaul by the Romans.'

It has, on the other hand, been remarked by Professor Phillips, that the positive evidence afforded by these discoveries amounts simply to this, that man and his works co-existed with the large extinct mammals, antecedent to the deposition of these gravel-beds. It may, in other words, be said that the human race had entered upon the theatre of the world before the last great geological changes. How long ago it is since these implements were made, we cannot tell. In short, we have not an absolute, but only a relative date for them. In giving man, however, a date prior to the last geological changes, it must be admitted that we extend very considerably all popular conceptions of his antiquity.

One general remark is strongly suggested by the history of this question—namely, how little it is to the credit of geologists, that its progress should have been so slow. I own myself very much struck by the clearness with which Mr Frere, in 1797, laid down the relations of the flint implements found in such abundance at Hoxne: although he had been a regular geologist of the present day, he could not have stated these more scientifically. Why were they so entirely slighted and forgotten? Then the Kent's Hole relics shewed as clearly the contemporaneity of man with the extinct mammalia, and his priority to the last great submergence, as the Picardy flints have done. Why was a strained surmise allowed to set these facts aside? I pass over the case of the Glasgow canoes, as I happened to have so much concern in it. But how was it that the discoveries of M. des Perthes, first announced in 1847, were treated with so much indifference, or rather scepticism? The only explanation that can be given, is that geologists had formed an *opinion* that man and his works were only to be found in the vegetable soil, and deemed it more likely that any *evidence to the contrary* was false than that their preconceptions were unfounded. I have treated this subject more largely elsewhere, and will not enlarge upon it now.* But the ultra-scientific people may be assured, that there is much in the scientific world which would greatly surprise them, if it were fully revealed. The boldness of speculation is what we hear of on the outside.

* *Testimony, its Posture in the Scientific World.* Being another of the series of Edinburgh Papers.

In the inside, we should have to remark the unsatisfiable scepticism about facts reported by others—the consequent fears which individuals are constantly expressing as to the extent to which they can safely announce the whole of what they have observed—anxieties about reputation in the first place, and truth in the second—affectations of doubts on generalisations, where little or no doubt is really entertained—hypocrisies to please each other—hypocrisies to please the ignorant and prejudiced out of school—such are a few of the moral phenomena evolved amongst the Searchers, in this dawn of philosophy; for it is yet no more.

On the whole subject of the Superficial Formation, I am disposed to make one concluding remark. I desire to refer to the broad fact, that in the regions of the earth where soil can least be dispensed with, there should have been a peculiar agency at work which secured the very general diffusion of soft matters over the hard surface. The warm parts of the world have large growth from little soil; but if the parts north and south of the fortieth parallels had been left to only such influences as the air and water, they might have been so meagrely furnished with the needful matrix for vegetation, that little population could have there existed. As it is, we have clays, and sands, and gravels, and mixtures of all three, spread in deep beds very generally over the temperate regions, so as to insure ample material for the agriculturist to work upon. In the present state of the subject of final causes, I suppose it would be held as rash to say that all this was matter of design; but I feel at least inclined to say that, if it was not from a premeditated plan of the Almighty Creator of the worlds, it looks marvellously like one, just as the existence of coal and other minerals does, and I do not see that we can be far or fatally wrong if we feel thankful for it accordingly.

NOTES OF LOCAL EXAMPLES AND ILLUSTRATIONS.

If any of my hearers be desirous of examining the objects connected with the glacial operations in the neighbourhood of our own city, he will find them very palpable to observation. A map of the district will shew him the alternating ridges and troughs, including the hill of Dun Edin itself, the long broad ridge of the New Town, and the valley between, all lying in a line pointing to 15° north of east, as do the streets subsequently erected upon them. If he takes an afternoon-walk by the Craig-Leith quarry to Granton, he will find that he passes over, first, a hollow a little beyond Stewart's Hospital; then a ridge on which is perched Blinkbonny farm-stead; then another hollow beyond the quarry; then a ridge on which the house of Drylaw is situated; then a third hollow. The hollows are all in a direction identical with that just described, and each points westwards to a cut or cleft in the crest of the Corstorphine Hill. It seems as if a flood, pouring over that eminence, had come with greater force through the three clefts or gaps, and hollowed out the ground for several miles to the east, by virtue of the greater force which it would have at those points; or perhaps we should rather suppose that the intermediate ridges, which are long masses of boulder-clay, lower and upper, were the result of accumulations produced by their being in the lee of the higher parts of the hill.

Another afternoon's walk would enable one to examine the western slope of the Corstorphine Hill, where, fifty years ago, Sir James Hall found what he called *dressings;* namely, grooves or channels on the exposed trap surfaces, arguing, as he thought, a water-flood by which the hills of the district were left generally precipitous to the west, and sloping to the east. In reality, these dressings are glacialised surfaces, slightly decayed by weathering.

The mouldings or flutings on the north face of the Pentland Hills can be readily observed from Edinburgh, on any sunny afternoon. The late Professor Fleming discovered clear glacial surfaces on the south front of those hills, at a place called *Thomson's Wa's*, at the height of fourteen hundred feet above the sea, the striæ pointing eastward.

Arthur's Seat and Salisbury Crags form a fine illustration of glacial phenomena. The ice-flood has come against the Crags, and poured over them, carrying along with it blocks, some of which are scattered down the slope behind, while others are carried on to places on Arthur's Seat of five or six hundred feet elevation. In like manner, blocks have been carried along Arthur's Seat to eastward, and are now found scattered along the

slopes above Duddingston. The abrading effects of the ice are well seen, on a part of the back slope of Salisbury Crags, near the edge of the cliff, and about two hundred yards from the eastern extremity. The rock is there smoothed down, with channellings and scorings pointing to 15° north of east, being the usual direction throughout Mid-Lothian and East Lothian; but there is here, also, another and later set of scorings, which pass across the swellings left by the agent in the first place, and point to 20° *south* of east. There has evidently here been a change in the direction of the abrading power, giving it a turn to the extent of 35°; and it has only been light and temporary. Such cross-markings, it may be remarked, are not unprecedented. I observed some upon a hill-face above the seaport of Drammen, in Norway; and there is a fine example at Stroncrubie, in Sutherlandshire.

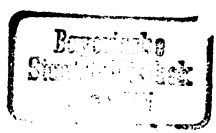
When the Queen's Drive was formed in 1846, the workmen laid bare the rock in the hollow pass above Samson's Ribs; and it was found to be polished and striated from end to end, in a manner which left no doubt as to the agent. At the urgency of the Royal Society, a piece of the side of this pass has been left exposed as a specimen of ancient ice-work. I remember observing in the bottom of this hollow a narrow chink—certainly it was not more than six inches wide at top, while it was perhaps eight or ten inches deep—and it was polished in the sides down to a point less than an inch from the angular base, leaving the sides concave. More recently, when the road was formed through Windygowl, there were similar polishings found along the pass, but not on the whole so perfect. At St Margaret's, likewise, at the north base of the hill, the operations of the North British Railway have laid bare a finely glacialised piece of rock, with groovings and striæ in the normal direction. On the north shoulder of the hill, beside a hollow called the Egg Pond, but which is generally dry, there is a small projecting platform of rock, presenting the glacial markings. Many of the exposed surfaces on the eastern mass of the hill have the roundedness which betrays ice-work, to an eye experienced in this class of observations.

The whole mass of unequal ground forming the Holyrood Park may be said to form an admirably good example of the denuding power of the ancient glacial agent. Every hard bed is left prominent—Salisbury Crags the best example. At every set of soft sandstone-beds we have a hollow —the Hunter's Bog the principal one. The whole mould of this interesting tract of ground is due to ice in connection with the varying resistance powers of the several parts.

I should not omit to call your attention to such glacial markings as still exist on the Castle Rock. This mass of basaltic clinkstone is generally rough, in consequence of the breaking away of the exterior parts at or after the ice-period. But a few patches of the glacialised surface still can be seen on the north side, about fifty feet above the gardens. They are well polished, and exhibit horizontal striæ, the memorials of a lateral sweeping.

On the sea-side, a hundred yards west of Granton Pier, there is a platform of sandstone laid bare by the sea, though not always covered by the tide; and on this surface the glacial-markings are very manifest. There is a similar surface in precisely similar relative circumstances, about fifty yards west of Joppa Pans.

The Boulder Clay can at present be studied to great advantage, in the deep sections lately made by the branch-railway to Granton. It is permanently presented to view at several places along the coast of the Firth of Forth, particularly at Leith Fort, at Seafield, and at Wellington Place, near the Maitland Burn. At all of these places the sea has cut it down, leaving it to form the floor of the beach, with a cliff towards the land. The boulders once settled in the clay which has been removed, lie scattered on the beach, and, when examined, are often found to betray the characteristic markings. At Seafield there is a greenstone, one of prodigious bulk—about ten feet high—and of a shape which has caused the boys to apply to it the jocular name of the Penny Bap. It is well worth notice, as a proof of the power of the agent concerned in the Drift. Close beside it, Mr Hugh Miller discovered a curious novelty in glacial matters, which has already been adverted to. Along the bared beach we can here readily trace a range of flattened boulders sticking in the subjacent bed of clay, and many of them unmistakably marked with polishings and scorings all pointed in one direction, and that 15° north of east. I was afterwards fortunate enough to detect a similar phenomenon at Wellington Place. It has evidently been produced, in both cases, by a force proceeding over that bed of the boulder-clay, in the same direction, and with the same abrading effects, as that which wore down the rock-surfaces below.



Special Writings on the same Subject, By the same Author.

ANCIENT SEA-MARGINS, as MEMORIALS of CHANGES in the RELATIVE LEVEL of SEA and LAND. Edin. 8vo, pp. 338. 1848.

TRACINGS of the NORTH of EUROPE: series of Papers in *Chambers's Edinburgh Journal*, 2d Series, vols. xii. and xiii. 1849–50.

PERSONAL OBSERVATIONS on TERRACES and other Proofs of CHANGES in the RELATIVE VALUE of SEA and LAND in SCANDINAVIA. *Edin. New Philosophical Journal*, October 1849.

OBSERVATIONS on GLACIAL PHENOMENA around EDINBURGH. Read at the British Association, 1850. *Edin. New Philosophical Journal*, October 1850.

ON GLACIAL PHENOMENA in SCOTLAND and PARTS of ENGLAND. *Edin. New Philosophical Journal*, April 1853.

FURTHER OBSERVATIONS on GLACIAL PHENOMENA in SCOTLAND and the NORTH of ENGLAND. *Edin. New Philosophical Journal*, January 1855.

ON GLACIAL PHENOMENA in PEEBLES and SELKIRKSHIRES. *Edin. New Philosophical Journal*, July 1855.

ON DENUDATION and other EFFECTS usually attributed to WATER. Read to British Association at Glasgow, 1855. (This paper has not been printed; but its leading doctrines are here reproduced in brief.)