hand will doubtless be elaborated in its details, and may perhaps here and there be somewhat modified. But we shall all feel that Alfred Russel Wallace is the architect whose designs we are carrying out.

---

## V. ON THE LOESS OF THE RHINE AND THE DANUBE.

By Thomas Belt, F.G.S.

THE sides of the valleys of the Rhine and the Danube, as well as those of their tributaries, are covered with a yellowish grey calcareous clay up to a height of several hundred feet above the rivers. This clay is often of great depth, is unstratified, and contains land and fresh-water shells scattered throughout it. It also contains the bones and the stone implements of palæolithic man, and the remains of the mammoth, the woolly rhinoceros, and other Mammalia. This clay has been named the Loess, and respecting its origin and its relation to the excavation of the great valleys there is much difference of opinion.

Sir Charles Lyell, in commencing an able summary of the facts respecting the distribution of this deposit, states that skilful geologists peculiarly well acquainted with the physical geography of Europe have styled the loess the most difficult geological problem.* It is certainly curious to contrast the ease with which some philosophers map out the world in former geological periods, showing with confidence which areas have been beneath the sea and which remained dry land, with the difficulty that is experienced in getting any idea of what was the condition of the continents during the formation of the latest deposits, after man had penetrated into Europe, and all the species of animals and plants now living had come into existence. And yet, until we understand the youngest of the geological formations, it is almost idle to speculate on the more ancient conditions of the earth's surface. Whilst, for instance, it is held by many that much of northern Europe and America was depressed below the level of the sea in post-tertiary times, and rose

* Antiquity of Man, 4th edition, p. 372.

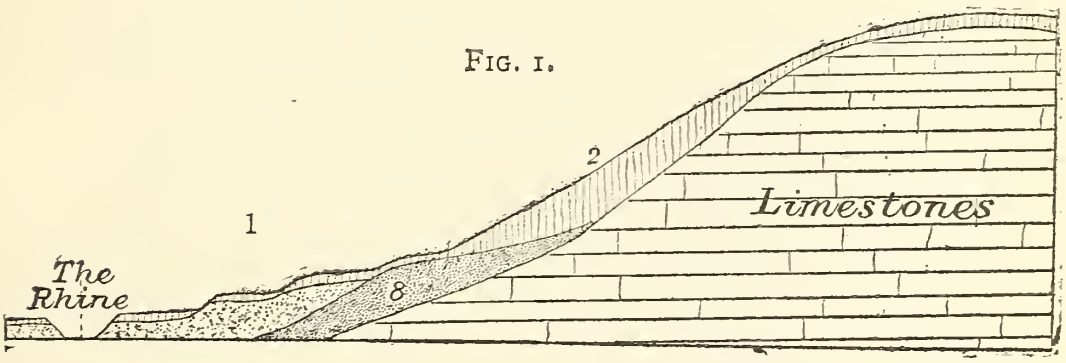
again to its former and present level, yet that the deposits formed beneath the waters of that ocean contain no marine organisms over thousands of square miles, what confidence can we feel in those theories that map out the continents in older geological periods according to the presence or absence of the remains of the inhabitants of the sea. The uncertainty felt respecting the latest formations fully justifies the large share of attention now paid to them and the efforts that are being made by many minds to bring the facts within the range of some consistent theory. This is not a case where the facts are unknown. No other formation has been so much studied as the quaternary. What is needed is a consistent theory of origin which shall violate no natural laws, be in harmony with the older geological record, ask for the aid of no unknown force, and in which every fact shall fall into its natural place and find its full explanation.

Impressed with the importance of the question, I have during the last twelve years endeavoured to make myself thoroughly acquainted with the facts, and have had unusual facilities for studying them in both hemispheres. When known, they appear to marshal themselves into a certain order, and to suggest a theory of origin that I have supported in the pages of this journal and elsewhere, but for which I have not yet obtained much consideration from geologists. My business occupations not leaving me sufficient time to prepare a general treatise, in which the various questions might be fully worked out and their relations to each other shown, I have been obliged to present my theory in short essays on distinct groups of facts, and in the present paper I propose to take into consideration the difficult question of the distribution of the loess, and to show that it is explained by the theory that at the culmination of the Glacial period the ice principally occupied the ocean depressions, and blocked up the drainage of the continents as far as it extended.

The loess, in the valleys of the Rhine, the Danube, and their tributaries, is found up to a great height above the present rivers. That of the Rhine is well illustrated around Basel, and the following section (Fig. 1) is one of many that may be seen in that neighbourhood. It is taken on the right bank, where a low range of vine-clad hills comes down nearly to the river, about 2 miles east of the city. Quarries of limestone are worked in the hill-side, and fine sections of the loess exposed. It is here a grey calcareous clay, of such a firm consistency that the workmen have excavated a chamber in it to keep their tools in; and this is its general

character wherever it is seen. Land shells are scattered throughout it, and I found them up to a height of about 1110 feet above the sea, which was as high as there were good sections of it exposed; but above this I traced it to the top of the hill, or to a height of about 1470 feet above the sea and 660 feet above the river. I took my altitudes by means of an aneroid barometer, calculating from the known height of the river at the bridge at Basel (803 feet), and though not absolutely correct they may be relied on to within a few feet, as I returned to my starting-point and found that only a small change had occurred in the barometric pressure in the meantime. Besides the land shells, small angular pieces of the local limestones and calcareous concretions are distributed throughout the loess. At the base of the hill it rests on a bed of gravel that has been

FIG. 1.




SECTION NEAR BASEL.

1 Terraced gravels. 2. Loess. 3. Old gravels.

cemented into a conglomerate by calcareous infiltrations. This gravel is composed of pebbles of crystalline rocks, rounded and subangular, and ranging in size from 1 inch up to 4 inches in diameter. With these are mixed angular and subangular fragments of the local limestones, of greater size. The highest point at which I noticed this old gravel-bed was 960 feet above the sea. It rests against the old valley bank, and the loess is distinctly superimposed upon it, and contains in its lowest part many pebbles derived from it. The importance of this fact will be recognised when I come to the discussion of the question of the origin of the loess.

Between the base of the hill and the river there are three terraces of gravel capped with clay, at the heights respectively of 923, 860, and 830 feet above the sea, the lowest being about 25 feet above the river. I think that these may have been of more recent origin than the loess, and that the

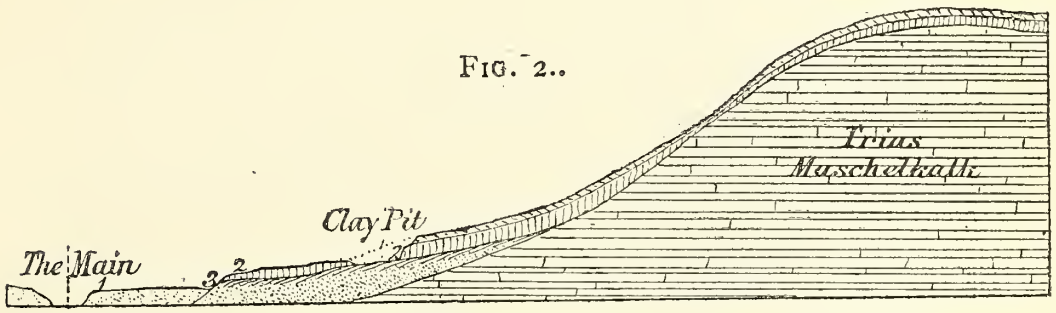
clay with which they are covered may have been washed down from the hills above them.

The loess may be traced all round the flanks of the hills that surround the great plain between Basel and Bingen, and also on the hills that in some places rise up like islands in its midst. Thus Sir Charles Lyell notes that it covers, up to a height of 1600 feet above the sea, the Kaiserstuhl, —a volcanic hill which stands in the middle of the great valley of the Rhine, near Freiberg, in the Brisgau. It is also spread over the volcanic hills of the Lower Eifel. Dr. Samuel Hibbert, in his "History of the Extinct Volcanoes of the Basin of Neuwied on the Lower Rhine," published in 1832, gave many instances of the intercalation of the loess with beds of volcanic ashes near Andernach. Much white pumice is spread over the loess, and it seems to be well ascertained that both during its deposit and afterwards the volcanoes were active. The veteran geologist, Herr Henry von Dechen, has mapped out these deposits, and described them in his "Geognostischer Fichrer zu dem Laacher." He has informed me that one of the highest patches of the loess on the volcanic hills lies south of Andernach, near the hill of Korrets, at an altitude of about 620 feet. Dr. Hibbert appears to have found it higher, for he states that on the Mahlsberg the loess attains an elevation of 800 feet above the sea, or 600 feet above the river, and is sometimes 60 feet thick. With regard to the pumice that is abundantly spread out on the top of the loess between Andernach and Coblentz, and which Herr von Dechen informed me indicated that the volcanoes were active at the time of the close of the deposition of the loess, it may be worth remarking that the *Challenger* explorations have shown that great quantities of pumice are spread over the bed of the ocean, proving it to be a common product of submarine volcanoes; so that it is quite in accordance with our knowledge of its production to suppose that the volcanoes of the Eifel at the time of its eruption may have been submerged beneath the waters from which the loess was deposited.

The loess extends up the valleys of the tributaries of the Rhine. The basin of the Neckar is, according to Sir Charles Lyell, filled with it. It is of great thickness, and at Canstadt, near Stuttgart, overlies a bed of gravel, and contains bones of the mammoth and the woolly rhinoceros. There are thick deposits of loess in the valley of the Main. I had the great advantage of examining it near Wurzberg, in the company of the celebrated geologist Dr. Sandberger. It has been principally preserved, from the effects of great

floods that appear to have swept down the valley, in bays and recesses, and at these points bones of the mammoth and its associates have been found. I took the following section (Fig. 2) at Blosenberg, near Heidingsfeld, where the loess is extensively dug for brick-making. At the clay-pit the lowest bed seen is one of subangular quartzose gravel, with pebbles of crystalline rocks from the mountains at the sources of the Main. This is covered with clean false-bedded sands, containing lines of small angular and subangular pebbles, mostly of quartz. The sands are covered by loess, which at the base is sandy and a little stratified, but soon graduates upwards into unstratified calcareous loess with vertical joints. It is divided into two beds by a clear line of division, the upper one of which is of a lighter colour than the lower. In another section, in a small valley to the

FIG. 2.




SECTION NEAR WURZBURG.

1. Alluvial plain. 2. Loess, with rubble and reconstructed loess on top.
3. Gravels and false-bedded sands underlying loess.

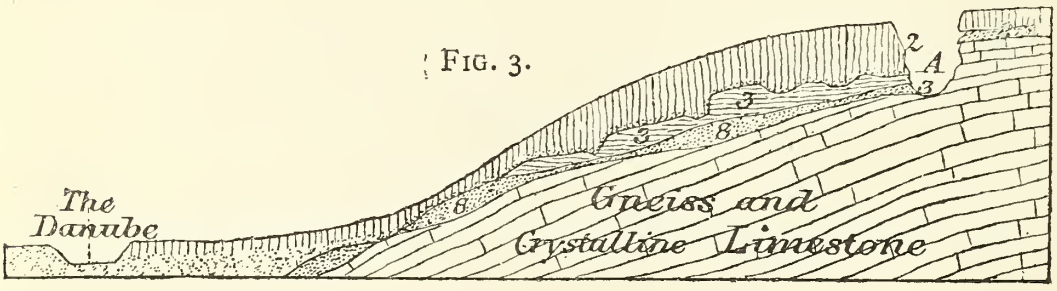
south of Marianberg, the division line is irregular, and is strongly marked by the occurrence along it of angular fragments of limestone.

At Blosenberg the loess conforms to the configuration of the ground, and in all the sections I saw, the different divisions were inclined with the slope of the hill, and had not been deposited in horizontal strata that had been afterwards denuded, but rather as a mantle on the slopes of a pre-existing valley. Shells of land mollusks are very abundant at Blosenberg, particularly on the slopes of the hill, where there are continuous sections by the sides of the deeply-cut paths that lead up through the vineyards. They occur here mostly in lines that give a sort of stratification to the loess. These lines of shells rise with the slope of the hill. I traced them up to a height of about 670 feet above the sea, and the loess up to 714 feet. From thence upwards the steep slope is mostly covered with limestone *débris* until we get to the summit, which is again covered with

loess. On the northern slope of the hill I found a thin layer of characteristic loess, beneath local *débris*, up to a height of 880 feet above the sea. On the hill-tops it occurs to 1100 feet or more, and Dr. Sandberger informed me that it is sometimes thick on the hill-tops, and contains the characteristic loess shells, though not so abundantly as lower down in the valley. I am inclined to think that it was originally deposited continuously over the slope up to the tops of the hills, but has since been removed by denudation, as the places where it is absent are just those where it would be most likely to be washed off, and it appears to be present wherever the ground becomes flatter.

In the basin of the Danube the loess is more generally and thickly spread out than even in the watershed of the Rhine. Prof. Edward Suess has kindly furnished me with much information respecting its distribution. It is found up to a height of at least 1300 feet above the sea in the upper part of the valley of the Danube. Where the river issues from the narrow gorges that it has cut through the crystalline rocks that range southwards from Bohemia, and again through the northern prolongation of the Alps above Vienna, the loess is heaped up as if deposited at the head of a lake, and just as the mud of the Rhone is now being deposited at the upper end of the Lake of Geneva. I visited Krems, where the valley—greatly contracted above where the river passes through gneiss and other crystalline rocks—widens out into a great plain, and there I found, as Prof. Suess had before informed me, the loess heaped up in a cone around the expanding mouth of the gorge. A little below the town of Krems, on the left bank of the Danube, I got the following section :—

FIG. 3.




SECTION NEAR KREMS.

2. Loess, with gravel and boulders at base and reconstructed loess on top. 3. Stratified sands and clays. 8. Old gravels, Miocene. A. Ravine showing pre-diluvial cliff.

The low hills bounding the valley are all covered with loess, and sections are exposed showing a thickness of over

60 feet without its base being seen. Many bones of the mammoth have been found in it, and it is related that when in the thirty years' war the Swedes were besieging Krems they found in one of their trenches the skeleton of a monstrous animal, and that besiegers and besieged ceased from their warfare for a time to gaze on the huge teeth of the giant that had been dug up.* Some bones were shown to me at the Imperial Museum, by Prof. Fuchs, which bore cuts and indentations apparently produced by a cutting instrument, and which are supposed to have been made by man. There is no reason to question this inference, as a few palæolithic implements have also been found; and that man was a contemporary of the mammoth is now fully established.

In ascending one of the many roads leading up the vine-covered slopes I found deep sections of the loess exposed, and it often rises like a wall on each side to a height of from 20 to 40 feet. The roads appear to have been purposely cut down deep, to allow not only wine-cellars but dwelling-houses to be excavated in them. The loess at Krems is compact, and almost like chalk in its homogeneous consistency, without the joints and fissures of the latter. It contains patches and seams of gravel, and pebbles of quartz are irregularly scattered throughout it. It is unstratified, but occasionally lines of division are seen separating portions of slightly different colour and composition. At its base I saw much gravel, and some boulders resting on the denuded top of stratified sands and clays. At one point I found that it had been banked up against a pre-diluvial precipice, as shown at A in Fig. 3.

In some parts patches of miocene gravels lie below the stratified sands or clays, and in these the remains of *Mastodon longirostris* have been found. Prof. Suess informed me that he had determined that these gravels were heaped up in Miocene times in the same parts of the valley where in the Quaternary times the loess was most thickly deposited, and he thinks that at that early period the valley had assumed in a great measure its present configuration.

The loess is by no means confined to the valleys of the great rivers and their tributaries. Sir Charles Lyell† and Mr. Godwin-Austen‡ both follow the Belgian geologists in identifying it with the "Limon de Hisbaya," which covers much

* I am indebted to Prof. Edward Suess for this anecdote.
† Antiquity of Man, p. 329.
‡ Quarterly Journ. Geol. Soc., vol. xxii., p, 251.

of Belgium, enveloping Hainault, Brabant, and Limburg like a mantle. It extends into France, and covers the high plains between the rivers, and is most likely the same as the upland loams of the valleys of the Seine and the Somme, which occupy positions often independent of the present lines of drainage. It is even probable that it once covered the south-east of England, but has since been denuded, as Prof. Morris has shown to me some of its characteristic shells which he had gathered in patches of loess, preserved in fissures of the chalk, near Maidstone.

There is also much evidence tending to prove that the loess is the equivalent in the river valleys of the northern drift that covers so much of Northern and Central Europe. Thus in ascending, from Vienna, the valley of the March, I found all the flanks of the hills covered with a loess like clay, which as I travelled northward changed to a redder colour. This clay covered the low watershed between the Danube and the Oder, to a depth of 20 feet in some places. The watershed is only about 1000 feet above the sea, and the clay covers it and follows along the flanks of the hills on either side. On the northern flanks of the range, Scandinavian blocks, that must have been carried from the far north, are found up to heights of over 1200 feet. These occur all along the northern side of the Carpathians. The diluvial clay extends much higher. According to Prof. Stur it fills the valleys on the north slope, and I have always found it extending to much higher levels than the northern blocks. This is what we might expect, for the icebergs that brought the blocks from the far north must have required a considerable depth of water to float them.

In 1875, at Wolochisk, in the province of Volhynia, near the Russian frontier, whilst detained for the examination of luggage and passports, I found, in the clay that had been thrown out of a well, shells of *Succinea oblonga* and *Pupa muscorum*, two mollusks that have left their shells in the loess almost everywhere where it occurs. This was not in a valley, but on the top of the flat plateau that forms the steppes of Southern Russia. I was much impressed with the occurrence of these characteristic loess shells at this place, as no higher ground overlooks the plain, and the clay may be followed continuously for hundreds of miles, and to the north contains transported Scandinavian rocks. On my return from a visit to Southern Russia, during the present year, I determined to examine this clay, which is "the diluvium" of the Russian geologists, nearer to the mountains, and for that purpose stayed twelve hours at Podwolochisk,

in Galicia. I was greatly gratified by finding loess shells in abundance, and thus adding another link to the chain of evidence that connects the loess with the northern drift. This northern drift and the clay that accompanies it is the Upper Boulder clay of the east of England; and in 1864 Mr. Searles-Wood, jun., was led—simply from the description of the loess of Belgium—to suggest the identity of the latter with the Upper Glacial clay.*

Prof. Suess has found, in the basin of the Danube, some important evidence pointing to the Glacial age of the loess. He showed me pieces of green Hornblendic rock that had been broken from large erratic blocks found in the loess near Vienna. This rock is not known to occur in place nearer than the Wechsel, at the Styrian frontier, and he thinks it must have been carried on and dropped from ice floating over the water from which the loess was deposited. At Wurflach there is the terminal moraine of a glacier that once came down from the Schneberg. This moraine contains many scratched and polished blocks of limestone. Many of these have been carried across the Steinfeldt and deposited on the flanks of the range of hills near Pitten, where the local rocks are mica-schists. They lie at a height of about 1100 feet from the sea, and at a distance of 9 miles from the terminal moraine at Wurflach, which is the nearest point from which they can have been brought. They were noticed by M. Morlot, who did not know, however, from whence they had been derived. Prof. Suess traced them to their source, and thinks they must have been carried by floating ice.

The animal remains found in and below the loess also indicate its Glacial age. I have spoken of the gravels that underlie it and belong to an earlier period, in the basin of the Rhine. Some of these gravels appear to be of the same age as the Cromer Forest beds and the Durnten lignites, being characterised by the presence of *Rhinoceros etruscus*, Falc., which has been identified by M. Lartet with the *R. Merkii* of the German and Swiss geologists. The deposits containing this characteristic mammal are well developed at Mosbach, near Biebrich, in the valley of the Main; they consist of sands and gravels overlaid by the loess. Besides the *Rhinoceros etruscus* they contain bones of *Elephas antiquus*, *E. primigenius*, *Cervus tarandus*, *C. megaceros*, and *Hippopotamus major*—a curious mixture of northern species with those that are supposed to have had a more southern range. Probably

* Ann. of Nat. Hist., vol. xiii., p. 185.

the southern mammals came northward in summer and retreated to the south in winter. This explanation of the mingling of the remains of northern and southern mammals in the same deposit was first given by Sir Charles Lyell, and has been since advocated with great ability by Mr. Boyd Dawkins. That this is correct—and not that we have here the mixture of the remains of animals belonging to two periods, one warm and the other cold, as urged by Mr. James Geikie—is evidenced by the land and fresh-water shells that accompany the remains of the Mammalia. These could not, like the southern mammals, retreat to the south on the approach of winter, and they are all of a northern character, fitted to withstand great cold. Dr. Sandberger informs us that many of them still live in the higher parts of the Main valley above Bamberg. Others, such as *Valvata naticina* and *Hyalina viridula*, are only now found in the north and north-east of Europe. *Pupa columella* is still living in the north of Russia, in Lapland, and on the Gemmi. *Patula solaria* is now found on the Eastern Alps and the Silesian hills, and others attain their southern limits at Frankfort.* From a consideration of these facts Dr. Sandberger comes to the conclusion that the climate must have been much colder than at present. It would appear to have been so if we take the evidence of the shells only, but when we add that of the mixture of the remains of northern and southern mammals we are rather led to the opinion held by Sir Charles Lyell and Mr. Boyd Dawkins,† that the winters were colder and the summers perhaps warmer than now; that, in fact, the climate was more continental, in consequence of the western coast of Europe having then embraced the whole of the British Isles and other lands now submerged below the sea. If, as has been advocated by Mr. James Geikie, the mingling together of the bones of the northern and southern mammals was not due to the range of their summer and winter migrations overlapping, but to the remains belonging to widely different periods having been afterwards mixed together,‡ it is inexplicable that mollusks denoting a warmer climate should not have accompanied the southern mammals in the valley of the Main. On the other hand, such a fact is fully explained if the winters were colder and the summers warmer, for the slow crawling mollusks could not retreat southward on the approach of winter along with the southern mammals,

* Geological Magazine, 1874, p. 220.
† *See* Cave Hunting, p. 397.
‡ Great Ice Age, p. 467.

and only those that could withstand the severe winters would survive.

The Dürnten lignites, which, like the Cromer Forest bed and the Mosbach beds, are characterised and have their geological horizon fixed by the presence of *Elephas antiquus* and *Rhinoceros etruscus*, have been shown by Prof. Heer—from a study of the flora preserved in them—to have certainly been formed in as cold and possibly a colder climate than the present. I may remark that Prof. Heer himself correlates the lignites with the Mosbach gravels and the Cromer pre-glacial beds;* and if the arguments that have been used to prove, from the existence of the former, that there have been interglacial warm periods, are of any weight, which I do not admit, then the glacial period that is supposed to have prevailed before the formation of the Dürnten lignites is one of which we have no traces in the British Islands, as it belongs to an epoch anterior to the growth of the Cromer Forest, which is older than any of our English glacial deposits.

Resting on the Mosbach sands and gravels, as well as on gravels of more recent age, and everywhere distinctly superimposed upon them, lies the loess. We have seen that in the gravels of more ancient date the climate was probably colder, or at any rate the winters were more severe than now. The fauna of the loess indicates a still colder climate. The hippopotamus, the southern elephant, and the southern rhinoceros are no more found. The mammoth abounds, and is now accompanied by the woolly rhinoceros. The reindeer and the Canadian elk are much more abundant than in the earlier period. Fresh-water shells occur but rarely, and belong to species such as *Lymnæus truncatalus* (the only one found near Wurzberg), which probably lived not in the water from which the loess was deposited, but in marshy spots above it. River shells are unknown: I have never seen even a fragment of one in the loess. The most abundant land shells are either those now ranging far to the north, or which, from their wide distribution, must be able to accommodate themselves to extremely varying circumstances. Thus the most characteristic of all the shells—the *Succinea oblonga*, which I have gathered in the loess of the Rhine, the Main, the Danube, and the Steppes of Southern Russia, and which Prof. Morris finds in the patches of loess preserved in fissures of the chalk near Maidstone—is, though widely ranging, essentially a northern

* The Primæval World of Switzerland (Eng. ed.), pp. 171 and 176.

species, being at present rare in the basin of the Rhine, but abounding much farther north, in Scandinavia and Northern Russia. The little *Pupa muscorum*, which nearly everywhere accompanies the last mollusk in the loess, ranges throughout Europe from Iceland and Lapland to the Mediterranean. The minute *Helix pulchella*, which I have also found very generally distributed in the loess, has a still wider range, being found from Siberia to Corsica, throughout Canada, and even in the Azores. *Helix hispida*, a common loess shell, and *H. sericea*, which replaces it near Wurzberg, range from Siberia to the Mediterranean.

The fauna of the loess is the same in the basins of the Danube and the Rhine, and in Southern Russia; it belongs entirely to the period of the mammoth and the woolly rhinoceros. Neither the highest nor the lowest patches of it contain the remains of any other fauna. It is one fitted to endure a cold climate. It is the culmination of a series showing a gradual refrigeration of the northern hemisphere from early tertiary times. The tropical forms of the Eocene strata are succeeded by the semi-tropical ones of the Miocene; these by the more temperate species of the Pliocene; then comes in the fauna of the Mosbach gravels, the Dürnten lignites, the Cromer Forest and the oldest Thames brick-earths, when palæolithic man first appears on the scene in Northern Europe, and when the mean temperature was probably about the same as now, though the winters were colder and the summers warmer. Then, distinctly superimposed upon the Mosbach sands and gravels, comes the last fauna of all before the present,—that which is found in the newer gravels and the loess resting on them,—the fauna of the mammoth and the woolly rhinoceros, along with which we find the latest remains of palæolithic man in Northern Europe. That that fauna belongs to the Glacial period is evidenced not only by the fact that it is composed of species best able to withstand extreme cold, but that in the valley of the Danube large boulders occur in the loess that must have been transported on icebergs whilst it was being deposited.

No more arctic fauna is known in the basins of the Danube and the Rhine than that of the loess. Above it, as elsewhere, at this stage, there is a great break in the succession of life; the mammoth, the woolly rhinoceros, and palæolithic man disappear; and after that interruption the next forms that appear are those of the recent period. Neolithic man now takes possession of the land, and with him comes a number of animals that still remain with us, with the exception of

the Irish elk in Europe and the mastodon in America, which have perished since the commencement of neolithic times.

I have now given all the most important facts that I know of respecting the position and distribution of the loess, and we may proceed to consider the theories that have been proposed to account for its origin. First of all we shall have to determine, as well as we may from the facts before us, whether the loess was deposited in previously formed valleys which were as deep or deeper than they are now, or that it was laid down in the process of the excavation of the valleys. The former view was that held by Sir Charles Lyell, who had studied the loess both of the Rhine and the Danube, and who in his "Antiquity of Man" has given —with the logical force and clearness that characterise all his writings—a most able summary of the facts that influenced his judgment. These are, briefly, that the loess encircles some of the modern cones of loose pumice and ashes of the Lower Eifel; that it rests on gravel near the bottoms of the present valleys; and that there is evidence that before it was deposited there existed steep slopes, as between Darmstadt and Heidelberg, where loess 200 feet thick and reaching up to 800 feet above the river is banked up against an old valley slope composed of granitic rocks.

Prof. Ramsay, on the contrary, favours the opinion that the loess of the Rhine has been deposited by the river, which, as it gradually lowered the level of the plain, left its finer *detritus* at various heights above it.* The memoir in which this opinion is expressed is an essay to prove that the valley of the Rhine has been excavated by the river,—an opinion not likely to be disputed by any geologist. The question of the deposition of the loess is only incidentally mentioned, and no explanation is offered of the many facts advanced by Dr. Hibbert, Sir Charles Lyell, and others, to prove that before such deposition commenced the valley had been excavated to at least its present depth. The authority of the Director of the Geological Survey of England is so great that it is necessary to insist here upon the cogency of the arguments that have been urged against the theory he espouses, and it is a pity that he has not met them or even alluded to them in his memoir. We have already seen that the loess rests on previously deposited beds of gravel. At Wurzberg this gravel lies at only a slight elevation above

* Quart. Journ. Geol. Soc., vol. xxx., p. 89.

the level of the river, and Dr. Sandberger informed me that it goes down to at least 50 feet below it. Here, then, the valley must have been excavated below its present depth to allow of the deposition of the gravel which preceded that of the loess. Near Basel, as I have shown in Fig. 1, the older gravel rests directly against the steep slopes of the rocks bounding the valley, proving again that the latter had been excavated long before the deposition of the loess commenced. At Mosbach the gravels, containing an older fauna than that of the loess, though above the level of the river, are yet several hundred feet below the altitude the loess attains to, and that the latter has all been deposited since, is proved by it everywhere containing a younger fauna. The Mosbach gravels belong to the time of *Rhinoceros etruscus*, the loess to that of *R. tichorinus*.

These facts are very strongly in favour of the pre-diluvial origin of the great valleys, and there are others still more difficult to explain on any other theory. As already mentioned, the loess extends far up the flanks of the recent volcanic cones of the Lower Eifel, and at Mahlsberg attains an elevation of 600 feet above the Rhine. The most ardent advocate of the theory that the loess has been left by the river whilst it ran at higher levels will not, I think, suggest that the volcanic cones have been carved out by it, and yet excepting on that supposition their theory falls to the ground. Another most serious objection to it is that it requires that the whole of the great valleys of the Danube and the Rhine have been excavated in one comparatively short period, namely, that of the mammoth and woolly rhinoceros. The upholders of the theory may say—"Not excavated, but re-excavated through the gravels and clays that were deposited in them in Miocene times;" but the loess extends far higher up the sides of the valleys than we have any evidence that the Miocene deposits ever reached to.

In the whole of the long Pliocene period it would appear that the land was above the level of the ocean, and we are to suppose, on the theory against which I am contending, that the rivers did not then wear down their channels, but waited for the mammoth period before they commenced doing so. Both in the valleys of the Danube and the Rhine the Pliocene epoch is unrepresented by fossil remains. I asked Prof. Suess what was the meaning of this great hiatus? and he replied that during Pliocene times the rivers were re-excavating their channels through the Miocene accumulations, and that periods of destruction are not periods of deposition in the same areas. At first, the new river

channels would probably be cut out with precipitous sides, and it was not until these sides had been sloped down by the action of rain that the loess was deposited.

Adding to the arguments already urged the fact that nowhere in the loess have any river shells been found, whilst they abound in the beds of all our large rivers, we have a case so strong against the theory, that, until its upholders offer some explanation of the facts arrayed against them, we may fairly refuse to receive it. And if we are forced to conclude that the loess has not been deposited by the rivers, and that the excavation of the valleys took place at an earlier time, we must believe that in some way or other these valleys were again filled with water up to the height to which the loess reaches. This is the conclusion of the Austrian geologists with regard to the valley of the Danube, and that of Sir Charles Lyell with regard to that of the Rhine also; and the next question we have to consider is whether the waters were pounded up through oscillations of the surface of the land, or in some other way.

The valleys of the Danube and the Rhine were in existence in early tertiary times, and we find two great accumulations of fossiliferous strata in them,—one miocene, the other post-tertiary. Both appear to be due, not to deposits from rivers wearing down their channels, but to interruptions to their drainage so that their channels were raised. The first of these interruptions is known to be due to the great volcanic disturbances during which the Alps were partly elevated; the second I hope to show was caused by the ice of the Glacial period blocking up the drainage of the continent.

I have already alluded to the transported boulders in the loess, and to its fauna, indicating its glacial age. Along the northern flanks of the Carpathians, the Scandinavian drift rises to heights of from 1000 to 1200 feet; considerably higher than the low passes that lead into the basin of the Danube. General Helmerson has done me the honour to inform me that the transported northern blocks in Russia also range up to heights of from 1000 to 1200 feet above the sea. As the Russian diluvial clay can be traced continuously up to and around the Carpathians into the basin of the Danube, we may reasonably conclude that the water over which the northern drift was floated was the same as that in which the loess was deposited.

But it will be urged that "the northern drift is a marine deposit." It is so stated in most works on geology; but excepting around the southern border of the Baltic, and just so far as, and no farther than, the Scandinavian glaciers

reached and carried up fragmentary shells from the arms of the sea they had crossed, the northern drift does not contain sea shells or any other marine organism. For thousands of square miles, south of the irregular line I have indicated, up to and around the Carpathians, the northern drift is spread out, and not a trace of marine life—not even a diatom—has been recorded from it, whilst at its base, between the Oder and the Elbe, fresh-water shells abound. To believe that Europe gradually sank down below the level of the sea until the latter had its shore line more than 1000 feet up the flanks of the mountains, and that it rose again without the sea leaving behind it any traces of life excepting fresh-water shells, is such an extreme hypothesis, and so contrary to all we know respecting the composition of existing sea-bottoms, that it is probable that its present acceptance is simply a survival from the time when there was no other way of explaining the existence of water up to such heights.

The usual explanation of the facts of the Glacial period is one continued appeal to the hypothesis of great oscillations of the earth's surface at that time. It may well be questioned whether geologists have not been too ready to call in the aid of these movements. There is much evidence to show that vast continental areas were never below the sea-level from the close of the Palæozoic period up to the end of the Tertiary period. Yet after this stability of surface over such an immense period of time no hesitation is felt, in the comparatively insignificant Glacial period, of sending the surface of the land thousands of feet higher, that ice may accumulate on the now low ranges, and thousands of feet lower, that icebergs may float over the submerged lands; and no difficulty is experienced in believing that it should finish its wonderful oscillations by regaining the level it had before the Glacial period commenced. It seems a burlesque on Science that such theories should be prevalent amongst our geologists, and if they were not held by philosophers they would be ridiculed as unphilosophical. Those who advocate the former existence of these oscillations of the surface are those who urge that we should not call in the aid of any but existing agencies; yet where do they now find a shore-less and a shell-less sea? Put down a dredge anywhere in the ocean within depths of less than 2000 feet, and in the small quantity of clay, mud, sand, or gravel scraped up, it will be scarcely possible to take out a tea-cupful that shall not teem with marine organisms; yet we are taught that an immense area in Europe and America has been a sea-bottom, and every part of it a sea-beach as

the land rose again, without any evidence of marine life having been left behind.

But is there really no other way of getting water up to the heights we require without resorting to this extreme hypothesis? I have in former papers urged that there is—that the ice of the Glacial period flowed principally down the ocean depressions and blocked up the drainage of the continents as far as it extended, causing immense lakes of fresh or brackish water. I was first led to believe that the ice had effected this in studying the glaciation of North America, and in 1866 I advanced the opinion that the drainage of the St. Lawrence had been blocked up by the ice moving down from the north, and that thus a great inland fresh-water sea had been formed, over which icebergs floated.* I next, in 1874, applied the theory to explain the formation of the Steppes of Siberia, after I had crossed them and found that they contained fresh-water shells, and I further suggested that the ice that descended from the mountains of Scandinavia must have dammed back all the rivers of Northern Europe.† Mr. Croll informs us‡ that before this Prof. Geikie had suggested to him that if the Straits of Dover were not then cut through, or were they blocked up by land ice, "say by the great Baltic glacier crossing over from Denmark, the consequence would be that the waters of the Rhine and Elbe would be dammed back and would inundate all the low-lying tracts of country to the south; and this might account for the extraordinary extension of the loess in the basin of the Rhine, and in Belgium and the north of France."

Very soon after my paper was published in the "Transactions of the Geological Society" I became dissatisfied with the explanation I had offered, because I found that in Devonshire there were drift pebbles and transported boulders up to heights of 1200 feet above the sea, and also that the ice of Scandinavia had actually retired before the boulder clay was spread out; as in Sweden, the latter overlies the glaciated rocks and the till left by the land ice. This is also the case on the north-east coast of England, as shown several years ago by Mr. Richard Howse. The Scandinavian drift of the coasts of Durham and Northumberland was deposited after the land ice, that had scored and grooved the rocks below, had melted back, and when the land was

* Trans. Nova Scotian Institute of Natural Science, 1866, p. 91.
† Quart. Journ. Geol. Soc., 1874, p. 490.
‡ Climate and Time, p. 452.

covered with water over which icebergs floated, carrying the erratic blocks.

During a visit I made to North America, in 1874, I found many more proofs that the drainage of the north-eastern part of that continent was blocked up by ice that flowed down the bed of the Atlantic from the direction of Greenland, and I learnt from Prof. James Hall that Cape Cod was a huge terminal moraine. Knowing, also, that on the European side of the Atlantic Mr. Robert Chambers had been led to the conclusion that Scotland had been glaciated from the north-west, that Mr. Thos. Jamieson had shown that Caithness had been overflown from the same direction, and that there was much other evidence pointing to the same conclusion,* I was led to believe that the drainage of Europe had been blocked up—not by Scandinavian ice, but by that which occupied the bed of the Atlantic and had reached to our western shores.

If we try to picture in imagination what would happen if the Glacial period were to return again, the continents keeping their present form, we shall not find it so improbable as it seems at first sight that the ice should advance down the ocean beds and be thicker there than on the land. The first effect would probably be a great increase of the ice on areas such as Scandinavia and the Alps, where it exists at present, but especially on Greenland, which lies at the northern end of the great evaporating basin of the Atlantic. For the ice would accumulate fastest where the frozen precipitation was greatest, and without great evaporation there could not be great precipitation. We need not carry on in imagination what happened in Scandinavia and the Alps, for we know what did occur, and can trace the great extension of the ice by the marks it has left on the rocks it passed over. We need only, for the present, try to follow the progress of the far greater accumulation of ice that was taking place in Greenland. When it there reached to such a height that it intercepted all the moisture of the currents of air travelling over it northwards, the precipitation would be confined to its northern slope, just as the Atlantic slopes of Central America drain the north-east trades of their moisture, so that they are dry winds on the Pacific side. But as the precipitation would not, as in Central America, run down immediately to the sea, but be retained on the southern slope of the frozen mass in the shape of snow and

* See Quart. Journ. Geol. Soc., vol. xxxii., p. 85, where a portion of the evidence I laid before the Society has been published.

ice, the effect must have been that that southern slope would advance southward; so that the ice would progress not only by flowing southward as a glacier, but by the area of frozen precipitation being moved southward. Let us suppose that a ridge of ice 6000 feet high, on Greenland, would intercept all the moisture of the southern winds; then, if the precipitation every year on its southern slope was greater than what it lost by melting and evaporation, it must have advanced southward, and no depth of the ocean bed would prevent it doing so, so long as the excess of frozen precipitation continued.

Some geologists urge as an objection to the theory of the great advance of circumpolar ice, that it cannot be pushed up a slope by a force acting from a distance. In the words of the most eminent of these, the Duke of Argyll, "the theory assumes that masses of ice lying upon the surface of the earth more than mountain deep would have a proper motion of its own, capable of overcoming the friction not only of rough level surfaces, but even of the steepest gradients, for which motion no adequate cause has been assigned, and which has never been proved to be consistent with the physical properties of the materials on which it is supposed to have acted."* If this was a fair statement of the views of glacialists a very strong case would be made out against them, for it is evident to any one having a moderate knowledge of mechanics and of the physical properties of ice that it could not be moved in such a manner; and Prof. James Forbes proved many years ago that, even when flowing down the steep slopes of the Alps, the bottom layers of the ice are so retarded by the friction of the rocks beneath them that the upper ones slip over them, producing the structure he named "frontal dip." But it is not a fair statement of their views. Mr. Thos. Jamieson, one of the greatest authorities on the glaciation of Scotland by land ice, showed, in 1865, that if snow was heaped up it would spread out at the base, and flow off "not so much on account of the inclination of the bed on which it rested as owing to the internal pressure exerted by the immense accumulation of snow,"† and he further compared its movement to that of a heap of grain which flows off when poured down on the floor of a granary, the grains flowing over each other and spreading out with a very small pitch or slope. Prof. Dana, too, has entered very fully into the question of the

* Nature, vol. xiv., p. 436. Report of Address to Brit. Assoc. at Glasgow.
† Quart. Journ. Geol. Soc., vol. xxi., p. 166.

motion of land ice, and has shown that no slope of the land beneath is necessary so long as there is a slope of the upper surface of the ice itself down which it moves, and he has likened its motion to that of heaped-up pitch—a simile that Prof. James Forbes had also used.* There may be some geologists who believe that ice is pushed along as a solid, but certainly no such opinion has been advocated by leading glacialists, who only claim that if ice be heaped up it will flow outwards. The margin of the ice would, however, be pushed forward by the ice behind and above it in summer, when its fluidity was increased, just as in a railway-cutting we often see, in wet weather, clay slip down and push up the earth at its base.

In my theory I assume that when ice in Greenland was heaped up high enough to intercept all the moisture of the winds blowing northwards, the snow would be heaped up on the southern slope, and that, if the frozen precipitation exceeded the liquefaction and evaporation, the icy mass would move southward, and the highest portion of its crest would reach to lower and lower latitudes. It would be a ridge of ice and snow gathering to itself the moisture of the atmosphere, its very growth supplying a basis for future extension, like an invading army gathering its supplies from the country it was adding to its domain. From this ridge, as from a mountain chain, the ice would flow down, chilling the atmosphere as far as it reached, and carrying with it its own wintry climate. There are tree-less districts in America where there is not sufficient rain to support forest life. Yet if a small extent of country be planted, and sustained until the trees grow up, they will cause a greater rainfall. For the rain that does fall will not be allowed to run off the land to the sea, but much of it will be retained and returned again to the atmosphere by evaporation; and as the amount of rain depends primarily upon the amount of moisture in the air, precipitation must be increased by increased evaporation. Thus a small forest may cause sufficient moisture to fall and to be retained, so as gradually to increase its limits and change a nearly tree-less country into one covered with forests. And so at the present time the ice is prevented from advancing into the temperate regions by a nice balance between the amount of frozen precipitation and of liquefaction; but if that balance were only a little shaken in favour of the accumulation of the ice, it would obtain powers of

* *See* Dana's Manual of Geology, p. 536, for an excellent account of the motion of land ice.

self-sustenance and growth that might cause it to spread like a living organism.

The height of the ridge of ice and snow would increase as it advanced southward, for it would depend upon that to which the moisture would be raised before it was precipitated, and this would be greater in low latitudes than in high.

I believe it is essential in any explanation of the facts of the Glacial period to bear in mind that from its commencement to its culmination the zone of frozen precipitation was gradually advanced southward in the northern hemisphere. On the Continent of Europe it was moved from Scandinavia and the Swiss Alps to the Pyrenees and the Maritime Alps, and when the ice was highest on the latter ranges that on the former must have shrunk back on account of the precipitation being intercepted further south, just as there are no glaciers now on the Altai Mountains because the moisture is intercepted by the Himalayas. As the ice gathered on the Maritime Alps, the Pyrenees, and probably on the Cantabian Range, the glacial ridge of the Atlantic was gradually advancing southward, and at last I suppose it coalesced with the ice of the Pyrenees or of the Cantabian Range. I thought, up to a recent period, that the Atlantic ice might have reached the coast of Europe near Brest, and so blocked up the drainage of the northern part of the continent, but I obtained proof during a visit to the valley of the Rhone this year, that it also was included within the area of the Great European Lake. This would be effected by the ice of the Atlantic glacier and that of the Pyrenees or of the Cantabian Range meeting on one side, and that of Pyrenees and of the western prolongation of the Maritime Alps on the other. Or the ice on the Cevennes may have met that of the western Maritime Alps and that of the Pyrenees; or the ice of the Atlantic glacier may have flowed across the low stretch of country north of the Pyrenees. How, precisely, this gap was blocked up I do not yet know, as I have not been able to examine it for myself, and I have had to work out the whole problem of the advance of the Atlantic ice and its interception of the European drainage, alone and unaided.

The Atlantic ice has left traces of its progress on every island and coast of the western side of Scotland and Ireland. The glaciers of the Pyrenees have been traced down unto the low plains to the north of that range,* and with regard to those of the Maritime Alps Mr.

* C. MARTINS, Revue de deux Mondes, 1867.

Moggridge states that he has found abundant proofs that they descended to the level of the present Mediterranean, near Mentone.*

If, at the time the Atlantic ice and that of the southern ranges I have mentioned blocked up the drainage of Europe, the upper end of the Northern Pacific was also filled with ice, or only so far as the mountains of Kamtchatska, a great continental basin of water would be formed, rimmed in on its southern side by the ranges of mountains that extend from the extreme north-east of Asia to the Alps. The only break now existing in that rim is through the Bosphorus, and both physical geographers and naturalists have come to the conclusion, on independent grounds, that the Black Sea did not communicate with the Mediterranean until after the close of the Tertiary period, and the excavation of the channel that connects them must have been effected about the time of the Glacial period. Probably it was made when the whole drainage of northern Europe and Asia was intercepted and turned in that direction. That the waters of the Great Lake flowed that way is indicated by the Scandinavian drift having been carried far over the plains of Russia, and by the vast extent of diluvial clay spread out around the north-western shores of the Black Sea.

In this way I consider the waters were raised, over which floated icebergs from the north carrying the Scandinavian drift, and into this great lake the Danube and the Rhine, or the upper portions of them above its level, brought down fine mud from the glacier-capped Alps, which was deposited as loess. The waters everywhere were muddy, for glaciers were still triturating the mountains of Scandinavia, and thus the fine clay was spread over Europe as far as the lake extended. The very fact that the glacial waters carried fine mud in suspension to such great distances is another proof that they were fresh, for it has been abundantly proved by Dr. Sterry Hunt† and others that in salt water mud is quickly precipitated, whilst in fresh it remains a long time in suspension.

I think there is evidence that the lake reached a height of 1700 feet above the sea, and that it remained for a long time at about 1200 feet. It was once completely drained; at first gradually, but from about 500 feet above the present level of the sea suddenly and tumultuously by the breaking away of the icy barrier, and thus was produced a great deluge or debacle that swept over the lower lands and

* Proc. Geol. Soc., London, 1876, p. 127.
† Proc. Boston Soc. Nat. Hist., February, 1874.

covered them with a mantle of false-bedded sands and gravel. The evidences of this debacle were insisted upon by the last generation of geologists, and they are to be found everywhere over the south of England; but of late years they have been almost ignored, Prof. Prestwich being, I think, the only one who still advocates the old theory.

After being thus broken, the icy barrier soon closed up again, and the great lake was reformed, and this time was much more permanent, and probably existed until the communication between the Black Sea and the Mediterranean was cut through.

The areas with which this paper has had especially to deal are at an altitude of more than 500 feet, and no traces of the debacle could be expected, though I think there is evidence of the more gradual lowering of the upper part of the first lake in the separation of the loess into two divisions, as at Wurzberg. It is to the first rising of the waters that I attribute the destruction of the mammoth and the woolly rhinoceros, and probably of palæolithic man in Europe. The evidence is perhaps not so conclusive with regard to palæolithic man, but as concerns the two great quadrupeds it is clear and decisive. I can find nowhere in Europe a trace of their existence after the first rise of the waters. In the great debacle their bones were carried and spread out over the low grounds along with the lowland gravel, and doubtless often carried unto the top of low-lying patches of boulder clay, but in these cases they are broken, single, or rolled. And in the valley of the Rhone, as the great advance of the Alpine glaciers preceded by a long time the culmination of the ice of the Atlantic and Pyrenees, and the destruction of the great mammals did not take place until the approach of the latter event, there are apparent proofs of their post-glacial existence, but the evidence only shows that they lived after the culmination of the Alpine ice, not after that of the Glacial period. The evidence of the latter is not the glaciation of the rocks of the Rhone above Lyons, but the gravels and clays spread out in the same area by the great lake when there was a high ridge of ice to the southward and that of the Alps had shrunk back.

Probably palæolithic man, the mammoth, and the woolly rhinoceros survived through the culmination of the Glacial period in Asia, though the two quadrupeds soon afterwards became extinct. Mr. Boyd Dawkins and Sir John Lubbock have given cogent reasons for supposing that the Eskimos are the descendants of palæolithic man, and they still survive in north-eastern Asia. I found evidence when I crossed

Siberia in 1873 that the high lands to the north of the Altai had not borne glaciers even in the Glacial period, and they would thus afford a refuge from the great flood. But in western Europe most of the land that was not submerged was covered with ice, and there were few places of safety to flee to. What few there were, were in the east of Europe, and therefore it is, I think, that after the Glacial period passed away the animals that survived mostly spread from the south-east across Europe again, and only a few had reached England, and still fewer Ireland, before the waters of the ocean resumed their old channels, and cut off the communication with the Continent.

After the Glacial period, neolithic man, who had probably lived to the south and south-east for ages before that time, found central and northern Europe open to him. Not only the mammoth and the woolly rhinoceros had been destroyed, but, what was of much greater importance to him, the great Carnivora—the cave bear, the lion, and the tiger. The whole of northern Europe had also been covered by the fertile mud deposited from the Great Lake, and thus in every way the conditions of existence had been made more suitable for him.

The Glacial period is thus invested with a double interest; it is the first step backward in geology, the first forward in archæology, and in neither sciences can we make our footing secure until we clear away the doubts that beset us here. I claim for my theory that it shirks none of the difficulties and embraces all the facts. I have only dealt with a few of the problems in this and other papers, but I hope to find time to show in future communications that the theory affords a key to all. I can only trust that through time the faith of geologists in great upheavals and depressions of the earth's surface within a comparatively short period, in the possibility of the ocean having covered vast continental areas and retired without leaving any marine remains behind it, and in a succession of glacial periods having alternated with inter-glacial warm ones, will be shaken, and that they may look more favourably upon a theory that explains all the phenomena by one great advance southwards of the ice of a single glacial period.