Geological Sketches

by Louis Agassiz

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GLACIAL PERIOD

IN the early part of the summer of 1840, I started from Switzerland for England with the express object of finding traces of glaciers in Great Britain. This glacier-hunt was at that time a somewhat perilous undertaking for the reputation of a young naturalist like myself, since some of the greatest names in science were arrayed against the novel glacial theory. It was not strange that it should be at first discredited by the scientific world, for hitherto all the investigations of geologists had gone to show that a degree of heat far greater than any now prevailing characterized the earlier periods of the world's history. Even Charpentier, my precursor and master in glacial research, who first showed the greater extent of Swiss glaciers in former times, had not thought of any more general application of his result, or connected their former boundaries with any great change in the climatic conditions of the whole continent. His explanation of the phenomena rested upon the assumption that the Alps formerly rose far beyond their present height; their greater altitude, he thought, would account for the existence of immense glaciers extending from the Alps across the plain of Switzerland to the Jura. Inexperienced as I then was, and ignorant of the modes by which new views, if founded on truth, commend themselves gradually to general acceptation, I was often deeply depressed by the scepticism of men whose scientific position gave them a right to condemn the views of younger and less experienced students. I can smile now at the difficulties which then beset my path, but at the time they

prove correct, and even then he recalled phenomena of his own country, which, under the new light thrown upon them by the glacial phenomena of Switzerland, gave a promise of success to my extraordinary venture. We then resolved to pursue the inquiry together on the occasion of my next visit to England; and after the meeting in Glasgow of the British Association for Advancement of Science, we started for the mountains of Scotland in search of traces of the glaciers, which, if there was any truth in the generalizations to which my study of the Swiss glaciers had led me, must have come down from the Grampian range, and reached the level of the sea, as they do now in Greenland. On the 4th of November of that year, I read a paper before the Geological Society of London, containing a summary of the scientific results of that excursion, which I had extended with the same success to Ireland and parts of England. This paper was followed by one from Dr. Buckland himself, containing an account of his own observations, and another from Lyell on the same subject. Since that time, the investigation of glaciers in regions where they no longer occur has been carried to almost every part of the globe. Before giving a more special account of this expedition, I will say a word of the mass of facts which I had brought from my Alpine researches, on which my own convictions were founded, and which seemed to Buckland worthy of careful consideration. To explain these more fully to my readers, I must leave the Scotch hills for a while, and beg them to return with me to Switzerland once more. Thus far I have spoken chiefly of the advance of glaciers, and very justly, since they are in constant onward motion, being kept within their limits only by a waste at their lower extremity proportionate to their advance. But in considering the past history of glaciers, we must think of their changes as retrograde, not progressive movements; since, if the glacial theory be true, a great mass of ice, of which the present glaciers are but the remnants, formerly spread over the whole northern hemisphere, and has gradually disappeared, until now no traces of it are to be found, except in the Arctic regions and in lofty mountain-ranges. Every terminal moraine is the retreating footprint of some glacier, as it slowly yielded possession of the plain, and betook itself to the

valley, the investigations here recorded have contributed. something to the results of modern geology.

~ THE END ~

1. The atlas in Martius's Journey to Brazil, or the sketch accompanying Bates's description of these hills in his Naturalist on the Amazons, will give an idea of their aspect.

2. Water-path in the forest.

3. Bohn's edition of Humboldt's Personal Narrative, p.134. Humboldt alludes to these formations repeatedly: it is true that he refers them to the ancient conglomerates of the Devonian age, but his description agrees so perfectly with what I have observed along the banks of the Amazons, that there can be no doubt he speaks of the same thing. He wrote at a time when many of the results of modem geology were unknown, and his explanation of the phenomena was then perfectly natural. The passage from which the few lines in the text are taken shows that these deposits extend even to the Llanos.

4. I am aware that Bates mentions having heard, that at Obydos, calcareous layers, thickly studded with marine shells, had been found interstratified with the clay, but he did not himself examine the strata. The Obydos shells are not marine, but are fresh-water Unios, greatly resembling Aviculas, Solens, and Arcas. Such would-be-marine fossils have been brought to me from the shore opposite to Obydos, near Santarem, and I have readily recognized them for what they truly are, fresh-water shells of the family of Naiades. I have myself collected specimens of these shells in the clay beds along the banks of the Solimoens, near Teffe, and might have mistaken them for fossils of that formation had I not known how Naiades burrow in the mud. Their resemblance to the marine genera mentioned above is very remarkable, and the mistake as to their true zoological

far down as the village;. such was the glacier of Aletsch, when it added its burden of ice to that coming from the upper valley; such was the glacier of the Simplon, whose moraines, of less antiquity, may now be seen by the roadside leading over the Alps to Italy; such were the two gigantic twin glaciers that drained the northern slopes of the mountain-colosses around Monte Rosa and Matterhorn, united at Stalden, and thence, losing their independence, became simply lateral tributaries of the great glacier of the Rhone; such were, farther on, the glaciers coming down from all the side-valleys opening into the Rhone basin; such were the glaciers of the St. Bernard, and even those of Chamouni, which in those early days crossed the Tete Noire to unite below Martigny with those that filled the valley of the Rhone. 1. Thus the outlines of this glacier may be followed from its present remnant, at the summit of the Valais, where the Rhone now springs forth from the ice, to the very shores of the Lake of - Geneva, where, near the mouth of the river, on both banks of the valley, the ancient moraines may be traced to this day, thousands of feet above the level of the water, marking the course the glacier once followed. It is evident that here the remains of the glacier mark a process of retrogression; for had these successive walls of loose materials been deposited in consequence of the advance of the glacier, they would have been pushed together in one heap at its lower end. That such would have been the case is not mere inference, but has been determined by direct observation in other localities. We know, for instance, by historical record (see Gruner's "Natural History of the Glaciers of Switzerland"), that in the seventeenth century a number of successive moraines existed at Grindelwald, which have since been driven together by the advance of the glacier, and now form but one. Indeed, we have ample traditional evidence of the oscillations of glacier-boundaries in recent times. When I was engaged in the investigation of this subject, I sought out all the chronicles kept in old convents or libraries which might throw any light upon it. Among other records, I chanced upon the following, which may have some interest for the historian as well as the geologist. , During the religious wars of the sixteenth century, when the Catholics gained the ascendancy

harbor of Para, all these islands have the same geological structure as the continent, and were evidently continuous with it at some former period. All the rocky islands along the coast of Maine and Massachusetts exhibit the glacial traces wherever their surfaces are exposed by the washing away of the drift; and where the drift remains, its character shows that it was once continuous from one island to another, and from all the islands to the mainland. It is difficult to determine with precision the ancient limit of the glacial drift, but I think it can be shown that it connected the shoals of Newfoundland with the continent; that Nantucket, Martha's Vineyard, and Long Island made part of the mainland; that, in like manner, Nova Scotia, including Sable Island, was united to the southern shore of New Brunswick and Maine, and that the same sheet of drift extended thence to Cape Cod, and stretched southward as far as Cape Hatteras;-in short, that the line of shallow soundings along the whole coast of the United States marks the , former extent of glacial drift. The ocean has gradually eaten its way into this deposit, and given its present outlines to the continent. These denudations of the sea no doubt began , as soon as the breaking up of the ice exposed the drift to its invasion; in other words, at a time when colossal glaciers still poured forth their load of ice into the Atlantic, and fleets of icebergs, far larger and more numerous than those now floated off from the Arctic seas, were launched from the northeastern shore of the United States. Many such masses must have stranded along the shore, and have left various signs of their presence. In fact, the glacial phenomena of the United States and elsewhere are due to two distinct periods: the first of these was the glacial epoch proper, when the ice was a solid sheet; while to the second belongs the breaking up of this epoch, with the gradual disintegration and dispersion of the ice. We talk of the theory of glaciers and the theory of icebergs in reference to these phenomena, as if they were exclusively due to one or the other, and whoever accepted the former must reject the latter, and vice versa. When geologists have combined these now discordant elements, and consider these two periods as consecutive,- part of the phenomena being due to the glaciers, part to the icebergs and to freshets consequent On their breaking

considerably beyond them. 2. But to return to the glacier of the Rhone. We can detect the sequence and relative age of its ancient moraines, not only by their position with reference to each other and to the present glacier, but also by their vegetation. The older ones have a mature vegetation; indeed, some of the largest trees of the valley stand upon the lower moraines, while those higher up, nearer the glacier, have only comparatively small trees, and the more recent ones are almost bare of vegetation. Moreover, we do not lose the track of the great glacier of the Rhone even when we have followed its ancient boundaries to the shores of the Lake of Geneva; for along its northern and southern shores we can follow the lateral moraines marking the limits of the glacier which once occupied that crescent-shaped depression now filled by the blue waters of the lake. M. de Charpentier was the first geologist who attempted to draw the outlines of the glacier of the Rhone during its greatest extension, when it not only filled the basin of the Lake of Geneva, but stretched across the hilly plain to the north, reached the foot of the Jura, and even rose to a considerable height along the southern slope of that chain of mountains. At that time, the colossal glacier spread at its extremity like a fan, extending westward in the direction of Geneva and east- ward towards Soleure. The very minute and extensive investigations of Professor A. Guyot upon the erratic boulders of Switzerland have not only confirmed the statements of M. de Charpentier, but even shown that the north-eastern boundary of the ancient glacier of the Rhone was more extensive than was at first supposed. Other researches upon the ancient moraines along the shores of the Lake of Geneva, and in other parts of Switzerland, in the which most geologists of the day took an active part, have made us as fully conversant with the successive outlines and varying the extent of the principal glaciers ranging from the Alpine summits to the surrounding low-lands as we are with the glaciers in their present circumscription. But no one has the done as much as Professor Guyot to add precision to these investigations. The number of localities, the level of which he has determined barometrically, with the view of fixing the ancient levels of all these vanished glaciers, is almost incredible.

from the reports of Mr. St. John respecting the formations in the valley of the Paranahyba, it is my belief that the changes I have been describing are but a small part of the destruction wrought by the sea on the northeastern shore of this continent. I think it will be found, when the coast has been fully surveyed, that a strip of land not less than a hundred leagues in width, stretching from Cape St. Roque to the northern extremity of South America, has been eaten away by the ocean. If this be .so, the Paranahyba and the rivers to the northwest of it, in the province of Maranham, were formerly tributaries of the Amazons; and all that we know thus far of their geological character goes to prove that this was actually the case. Such an extensive oceanic denudation must have carried away not only the gigantic glacial moraine here assumed to have closed the mouth of the Amazonian basin, but the very ground on which it stood. During the last four or five years, I have been engaged in a series of investigations, in the United States, upon the subject of the denudations connected with the close of the glacial period there, and the encroachments of the ocean upon the drift deposits along the Atlantic coast. Had these investigations been published in detail, with the necessary maps, it would have been far easier for me to explain the facts I have lately observed in the Amazonian Valley, to connect them with facts of a like character on the continent of North America, and to show how remarkably they correspond with facts accomplished during the -same period in other parts of the world. While- the glacial epoch itself has been very extensively studied in the last half-century, little . attention has been paid to the results connected with the breaking up of the geological winter and the final disappearance of the ice believe that the true explanation of the presence of a large part of the superficial deposits lately ascribed to the agency of the sea during temporary subsidences of the land, will be found in the melting of the ice-fields. To this cause I would refer all those deposits which 1 have designated in former publications as remodelled drift. When the. sheet of ice, ex- tending from the Arctic regions over a great part of North America and coming down to the sea, slowly melted away, the waters were not distributed over the face of the country as they

of Zurich. Professor Escher von der Linth has shown that the lovely city of Zurich is built upon a moraine, like Berne. The imagination shrinks from the thought that all the beautiful scenery of those countries should once have been hidden under masses of ice, like those now covering Greenland. The easternmost ancient glacier of Switzerland; was that of the Rhine. It had its sources in all the valleys from which now descend the many tributaries of that stream, and must have spread over the northeastern Cantons, filling the Lake of Constance, and terminating at the foot of the Suabian Alp. Next to the glacier of the Rhone, this was once the largest of those descending from the range of the Alps. West of Mont Blanc, Professor Guyot has traced the boundaries of two other distinct ancient glaciers. One of these, the glacier of the Arve, followed chiefly the course of the Arve, and, though discharging the icy accumulations from the western slope of Mont Blanc, was, as it were, only a lateral affluent of the great glacier of the Rhone. The other, the glacier of the Isere, occupied, to the south and west of the preceding, the large triangular space intervening between the Alps arid the Jura, in that part of Savoy where the two mountain-chains converge and become united. It would lead me too far, were I to describe also the course of the great ancient glaciers which descended from the southern slopes of the Alps into the plain of Northern Italy. Moreover, these boundaries are not yet ascertained with the same degree of accuracy as those of the northern and western slopes; though very accurate descriptions of some of them have been published, with illustrations on a large scale, by MM. Martins and Gastaldi, -and of others by Professor Ramsey. I have myself examined only the upper part of that of the valley of Aosta. The evidence concerning the ancient glaciers of the Alps, especially within the limits of Switzerland, is already so full that it affords ample means for a comprehensive general view of the subject. When a stretch of time or space lies between us and a matter we have once studied more closely, we often see it as a whole more vividly than when our nearness to it forced all its details upon our observation. In my present position, separated by the lapse of many years from my personal investigation of the ancient and

present position of the island of Tupinambaranas, just at the junction of the Madeira with the Amazons. It is a question among geographers whether the Tocantins is a branch of the Amazons, or should be considered as forming an independent river system. It will be seen that, if my view is correct, it must formerly have borne the same relation to the Amazons that the Madeira River now does, joining it just where Marajo divided the main stream, as the Madeira now joins it at the head of the island of Tupinambaranas. If in countless centuries to come the ocean should continue to eat its way into the Valley of the Amazons, once more transforming the lower part of the basin into a gulf, as it was during the cretaceous period, the time might arrive when geographers, finding the Madeiraemptying almost immediately into the sea, would ask themselves whether it had ever been indeed a branch of the Amazons, just as they now question whether the Tocantins is a tributary of the main stream or an independent river. But to return to Marajo, and to the facts actually in our possession. The island is intersected, in its southeastern end, by a considerable river called the Igarape Grande. The cut made "through the land by this stream seems intended to ,serve as a geological section, so perfectly does it display the three characteristic Amazonian formations above described. At its mouth, near the town of Soure and at Salvaterra, on the opposite bank, may be seen, lowest, the well-stratified sandstone with the finely laminated clays resting upon it, overtopped by a crust; then the cross-stratified, highly ferruginous sandstone, with quartz pebbles here and there; and, above all, the well-known ochraceous, unstratified sandy clay, spreading over the undulating surface of the denudated sand-stone, following all its inequalities, and filling all its depressions and furrows. But while the Igarape Grande has dug its channel down to the sea, cutting these formations, as I ascertained, to a depth of twenty-five fathoms, it has thus opened the way for the encroachments of the tides, and the ocean is now, in its turn, gaining upon the land. Were there no other evidence of the action of the tides in this locality, the steep cut of the Igarape Grande, contrasting with the gentle slope of the banks near its mouth, wherever they have been modified by the invasion of the

see that the glaciers to which these ancient moraines owe their origin must have been retreating gradually, while the moraines were accumulating. But a glacier while uniformly retreating forms no high walls of loose materials around its edges and at its lower extremity; as it melts away, it only drops the burden of angular rocky fragments carried upon its back over the loose fragments above which it moves, and which it grinds to powder, or to sand, or to rounded pebbles, in its progress. It is only where the glacier remains stationary for a longer or shorter period that large terminal moraines can accumulate; and they are generally found in such places in the valleys of the Alps as would naturally determine the lower limit of a glacier for the time being. We cannot escape the conclusion that the ancient glaciers must have begun that series of oscillations to which the accumulation of the moraines is to be ascribed, at a time when ice-fields already occupy the whole area which they have covered during their greatest extension. After we shall have seen how many centres of dispersion of erratic boulders, similar to that of the Alps, existed in the northern hemisphere, we may perhaps be able to form some idea of the manner in which these ice-fields originated and gradually vanished. Some investigators have been inclined to explain the presence of boulders, moraines, drift, and the like phenomena by the action of water. But even if we could believe that rivers had brought along with them such masses of rock, and deposited them where they are now found, the regularity in the distribution of the materials disproves any such theory. In the lateral moraines of the Lake of Geneva we have a striking illustration of this apparently systematic division of the loose materials. The northeastern moraines of that glacial basin contain rocks belonging exclusively to the northern side of the valley of the Rhone, while the moraines on the southern shore of the lake consist of rocks belonging to its southern side. Indeed, rivers, so far from building up moraines, have often partially destroyed them. We find various instances of moraines through which a river runs, having worn for itself a passage, on either side of which the form of the moraine remains unbroken. In the valley of the Rhone there are villages, as, for instance,

rains, and also by the filling of the basin with loose materials, would overflow, and thus contribute to destroy the moraine. However this may be, it follows from my premises that, in the end, these waters obtained a sudden release, and poured seaward with a violence which cut and denuded the deposits already formed, wearing them down to a much lower level, and leaving only a few remnants standing out in their original thickness, where the strata were solid enough to resist the action of the currents. Such are the hills of Monte Alegre, of Obydos, Almeirim, and Cupati, as well as the lower ridges of Santarem. This escape of the waters did not, however, entirely empty the whole basin; for the period of denudation was again followed by one of quiet accumulation, during which was deposited the ochraceous sandy clay resting upon the denudated surfaces of the underlying sandstone. To this period I refer the boulders of Errere, sunk as they are in the clay of this final deposit. I suppose them to have been brought to their present position by floating ice at the close of the glacial period, when nothing remained of the ice-fields except such isolated masses, ice-rafts, as it were; or perhaps by icebergs dropped into the basin from glaciers still remaining in the Andes on the edges of the plateaus of Guiana and Brazil. From the general absence of stratification in this clay formation, it would seem that the comparatively shallow sheet of water in which it was deposited was very tranquil. Indeed, after the waters had sunk much below the level which they held during the deposition of the sandstone, and the currents which gave rise to the denudation of the latter had ceased, the whole sheet of water would naturally become much more placid. But the time came when the water broke through its boundaries again, perhaps owing to the further encroachment of the sea and consequent destruction of the moraine. In this second drainage, however, the waters, carrying away a considerable part of the new deposit, furrowing it to its very foundation, and even cutting through it into the underlying sandstone, were, in the end, reduced to something like their present level, I , and confined within their present beds. This is shown by the fact that in this ochre-colored clay, and penetrating to a greater or less depth the sandstone below, are dug, not only the great

the Alps, are barred in the same way, as are f also the lakes of Norway and Sweden, and some of our own ponds and lakes. Strange as it may seem to the traveller who sails under an Italian sky over the lovely waters of Como, Maggiore, and Lugano, it is, nevertheless, true, that these depressions were once filled by solid masses of ice, and that the walls built by the old glaciers still block their southern outlets. Indeed, were it not for these moraines, there would be comparatively few lakes either in Northern Italy or SwItzerland. The greater part of them have such a wall built across one end, and, but for this masonry of the glacier, there would have been nothing to prevent their waters from flowing out into the plain at the breaking up of the ice-period. We should then have had open valleys in place of all these sheets of water which give such diversity and beauty to the scenery of Northern Italy and Switzerland, or, at least, the lakes would be much fewer and would occupy only the deeper depressions in the hard rocks. Such being the evidences of the former extent of the glaciers in the plains, what do the mountain-summits tell us of their height and depth? for here, also, they have left their handwriting on the wall. Every mountain-side in the Alps is inscribed with these ancient characters, recording the level of the ice in past times. Here and there a ledge or terrace on the wall of the valley has afforded support for the lateral moraines, and wherever such an accumulation is left, it marks the limit of the ice at some former period. These indications are, however, uncertain and fragmentary, depending upon projections of the rocky walls. But thousands of feet above the present level of the glacier, far up towards their summits, we find the sides of the mountains furrowed, scratched and polished in exactly the same manner as the surfaces over which the glaciers pass at present. These marks are as legible and clear to one who is familiar with glacial traces as are hieroglyphics to the Egyptian scholar; indeed, more so, -for he not only recognizes their presence, but reads their meaning at a glance. Above the line at which these indications cease, the edges of the rocks are sharp and angular, the surface of the mountain rough, unpolished, and absolutely devoid of all marks resulting from glacial action. On the Alps these traces are visible to a height of

glaciers, which, in the course of time, accumulated at their lower end a wall of loose materials. These walls still remain, and serve as dams to prevent the escape of the waters. But for their moraines, all these lakes would be open valleys. In the roads of Glen Roy, in Scotland, we have an instance of a fresh-water lake, which has now wholly disappeared, formed in the same manner, and reduced successively to lower and lower levels by the breaking down or wearing away of the moraines which originally prevented its waters from flowing out. Assuming then, that, under the low temperature of the ice-period, the climatic conditions necessary for the formation of land-Ice existed in the Valley of the Amazons, and that it was actually filled with an immense glacier, it follows that, when these fields of ice yielded to a gradual change of climate, and slowly melted away, the whole basin, then closed against the sea by a huge wall of debris, was transformed into a vast fresh-water lake. The first effect of the thawing process must have been to separate the glacier from its foundation raising it from immediate contact with the valley bottom, and thus giving room for the accumulation of a certain amount of water beneath it; while the valley as a whole would still be occupied by the glacier. In this shallow sheet of water under the ice, and protected by it from any violent disturbance, those finer triturated materials always found at a glacier bottom, and ground sometimes to powder by its action, would be deposited, and gradually transformed from an unstratified paste containing the finest sand and mud, together with coarse pebbles and gravel, into a regularly stratified formation. In this formation the coarse materials would of course fall to the bottom, while the most minute would settle above them. It is at this time and under such circumstances that I believe the first formation of the Amazonian Valley, with the coarse, pebbly sand beneath, and the finely laminated clays above, to have been accumulated I shall perhaps be reminded here of my fossil leaves, and asked how any vegetation would be possible under such circumstances. But it must be remembered, that, in considering all these periods, we must allow for immense lapses of time and for very gradual changes; that the close of this first period would be very different from its beginning; and that a rich vegetation springs

over, planted them with trees, sown his seed and gathered in his harvests upon them, until at last they make a part of the undulating surface of the country. Were it not for anticipating my story, I could point out many a green billow, -rising out of the fields and meadows immediately about us, that had its origin in the old ice-time. Thus disguised, they are not so evident to the casual observer; but, nevertheless, when once familiar with the peculiar form, character, and position of these rounded ridges scattered over the face of the country, they are easily recognized. Of course the ancient glaciers of Great Britain were far more difficult to trace than those of Switzerland, where the present glaciers are guides to the old ones. Nevertheless, my of expectations were more than answered. The first valley I entered in the glacial regions of Scotland was barred by a terminal moraine; and throughout the North of England, as well as in Scotland and Ireland, I found the hill-sides covered with traces of glacial action, as distinct and unmistakable as those had left in my native land. Not only was the surface of the country polished, grooved, and scratched, as in the region of existing glaciers, presenting an appearance corresponding exactly to that described elsewhere, but we could track the path of the boulders where they had come down from the hills above and been carried from the mouth of each valley far down into the plains below. In Scotland and Ireland the phenomena were especially interesting. I had intended to give in this article some account of the "parallel roads" of Glen Roy, marking the ancient levels of glacier-lakes, so much discussed in this connection. But the reminiscences of old friends, and the many associations - revived in my mind by recurring to a subject which I have long looked upon as a closed chapter so far as my own researches are concerned, have constantly led me beyond the limits I had prescribed to myself in these papers upon glaciers; and as the story of Glen Roy and the phenomena connected with it is a long one, I shall reserve it for another article.

1. It is desirable that the reader should look up these localities upon a map of Switzerland, that he may be impressed with the

suppose that an ocean basin of this size, which must have been submerged during an immensely long period in order to accumulate formations of such a thickness, should not contain numerous remains of the animals formerly inhabiting it. 4. The only fossil remains of any kind truly belonging to it, which I have found in the formation, are the leaves mentioned above, taken from the lower clays on the banks of the Solimoens at Tonantins; and these show a vegetation similar in general character to that which prevails there to-day. Evidently, then, this basin was a fresh-water basin; these deposits are fresh-water deposits. But as the Valley of the Amazons exists to-day, it is widely open to the ocean on the east, with a gentle slope from the Andes to the Atlantic, determining a powerful seaward current. When these vast accumulations took place, the basin must have been closed; otherwise the loose materials would constantly have been carried down to the ocean. It is my belief that all these deposits belong to the ice-period in its earlier or later phases; and to this cosmic winter, which, judging from all the phenomena connected with it, may have lasted for thousands of centuries, we must look for the key to the geological history of the Amazonian Valley. I am aware that this suggestion will appear extravagant. But is it, after all, so improbable that, when Central Europe was covered with ice thousands of feet thick; when the glaciers of Great Britain ploughed into the sea, and when those of the Swiss mountains had ten times their present altitude; when every lake in Northern Italy was filled with ice, and these frozen masses extended even into Northern Africa; when a sheet of ice, reaching nearly to the summit of Mount Washington in the White Mountains (that is, having a thickness of nearly six thousand feet), moved over the continent of North America, -is it so improbable that, in this epoch of universal cold, the Valley of the Amazons also had its glacier poured down into it from the accumulations of snow in the Cordilleras, and swollen laterally by the tributary glaciers descending from the table-lands of Guiana and Brazil? The movement of this immense glacier would be eastward, and determined as well by the vast reservoirs of snow in the Andes as by the direction of the valley itself. It must have ploughed the valley bottom over

and the matter still remains a mooted point; but the one of all these theories which shall stand the test of time and repeated examination and be eventually accepted will explain many a problem besides the one it was meant to solve, and lead to further progress in other directions. I propose here to reconsider the facts of the case, and to present anew my own explanation of them, now more than twenty years old, but which I have never had an opportunity of publishing in detail under a popular form, though it appeared in the scientific journals of the day. Before considering, however, the phenomena of Glen Roy, or the special glacial areas scattered over Scotland and the other British Isles, let us see what general evidence we have its that glaciers ever existed at all in that realm. The reader will pardon me, if, at the risk of repetition, I sum up here the facts which, from their identity with those produced by on present glaciers, must be admitted, wherever they are found, as proof of their former existence. Such a summary may serve also as a guide to those who would look for glacial traces where they have not hitherto been sought. In the first place, we have to consider the singular abrasion of the surfaces over which in the glacier has moved, quite unlike that produced by the action of water. We have seen that such surfaces, wherever the glacier-marks have not been erased by some subsequent action, have several unfailing characteristics: they are highly polished, and they are also marked with scratches or fine striae, with grooves and deeper furrows. Where best preserved, the smooth surfaces are shining; they have a lustre like stone or marble artificially polished by the combined friction and pressure of some harder material than itself until all its an inequalities have been completely levelled and its surface has become glossy. Any marble mantel-piece may serve as an example of this kind of glacier-worn surface. The levelling and abrading action of water on rock has an entirely different character. Tides or currents driven powerfully and constantly against a rocky shore, and bringing with them hard materials, may produce blunt, smooth surfaces, such as the repeated blows of a hammer on stone would cause; but they never bring it to a high polish, because the grinding materials are not held steadily down in firm permanent contact

sandstone deposits retain their original thickness, as in the hills of Monte Alegre and Almeirim, the red clay is not found on their summits, but occurs only in their ravines and hollows, or resting against their sides. This shows that it is not only posterior to the sandstone, but was accumulated in a shallower basin, and consequently never reached so high a level. The boulders of Errere do not rest on the stratified sand- stone of the serra, but are sunk in the un- stratified mass of the clay. This should be remembered, as it will presently be seen that their position associates them with a later period than that of the mountain itself. The unconformability of the ochraceous clay and the underlying sandstones might lead to the idea that the two formations belong to distinct geological periods, and are not due to the same agency, acting at successive times. One feature, however, shows their close connection. The ochraceous clay exhibits a remarkable identity of configuration with the underlying sandstones. An extensive survey of the two in their mutual relations, shows clearly that they were both deposited by the same water-system within the same basin, but at different levels. Here and there the clay formation has so pale and grayish a tint, that it may be confounded with the mud deposits of the river. These latter, however, never rise so high as the ochraceous clay, but are everywhere confined within the limits of high and low water. . The islands also in the main course of the Amazons consist invariably of river-mud, while those arising from the intersection and cutting off of portions of the land by diverging branches- of the main stream always consist of the well-known sandstones, capped by the ochre-colored clay. It may truly be said that there does not exist on the surface of the earth a formation known to geologists resembling that of the Amazons. Its extent is stupendous; it stretches from the Atlantic shore, through the whole width of Brazil, into Peru, to the very foot of the Andes. Humboldt speaks of it "in the vast plains of the Amazons, in the eastern boundary of Jaen de Bracamoros," and says," This prodigious extension of red sandstone in the low grounds stretching along the east of the Andes is one of the most striking phenomena - I observed during my examination of rocks in the equinoctial regions." 3. When the great natural

the iceberg. It has also been urged, that, without admitting any general glacier- period, icebergs and floating ice from more northern latitudes might account for the extensive transportation of the loose materials scattered in a continuous sheet over a large portion of the globe. There can be no doubt that debris of all sorts are carried to great distances by floating ice; where their presence is due to this cause, however, they are every-where stranded along the shore or dropped to the sea-bottom. Large boulders are frequently left by the ice along the New England coast, and we shall trace them hereafter among the sand-dunes of Cape Cod. But before it can be admitted that the drift-phenomena, and the polished and engraved surfaces with which they are everywhere intimately associated, are owing to floating Ice or Icebergs, It must be shown that all these appearances have been produced by some agency moving from the sea-board towards the land, and extending up to the very summits of the mountains, or else, that all the countries exhibiting glacial phenomena have been sunk below the ocean to the greatest height at which glacier-marks are found, and have since gradually emerged to their present level. Now, though geologists are lavish of immersions when something is to be accounted for which they cannot otherwise explain, and a fresh baptism of old Mother Earth is made to wash away many obstacles to scientific theories, yet the common-sense of the world will hardly admit the latter assumption without positive proof; and all the evidence of the kind we have, at the period under consideration, indicates only a comparatively slight change of relative level between sea and land within a narrow belt along the shores; and even this is shown to be posterior, not anterior, to the glacial phenomena. As to the supposition that the motion proceeded from the sea towards the land, all the facts are against it, since the whole trend of these phenomena is from inland centres toward the shore, instead of being from the coast upward. Certainly, no one familiar with the facts could suppose that floating ice or icebergs had abraded, polished, and furrowed the bottom of narrow valleys as we find them worn, polished, and grooved by glaciers. And it must be remembered that this is a theory founded not upon hypothesis, but upon the closest

only genuine erratic boulders I have seen in the whole length of the Amazonian Valley, from Para to the frontier of Peru, though there are many detached masses of rock, as, for instance, at Pedreira, near the junction of the Rio Negro and Rio Branco, which might be mistaken for them, but are due to the decomposition of the rocks in place. The boulders of Errere are entirely distinct from the rock of the serra, and consist of masses of compact hornblende. It would seem that these two ranges skirting a part of the northern and southern banks of the Lower Amazons are not the only remnants of this arenaceous formation in its primitive altitude. On the banks of the Japura, in the serra of Cupati, Major Coutinho has found the same beds rising to the same height. It thus appears, by positive evidence, that over an extent of a thousand miles these deposits had a very considerable thickness in the present h direction of the valley. How far they extended in width has not been ascertained by direct observation, for we have not seen how they sink away to the northward, and towards the south the denudation has been so complete that, except in the very low range of hills in the neighborhood of Santarem, they do not rise above the plain. But the fact that this formation once had a thickness of. more than eight hundred feet within the limits where we have had an opportunity of observing it, leaves no doubt that it must have extended to the edge of the basin, filling it to the same height throughout its whole extent. The thickness of the deposits gives a measure for the colossal scale of the denudations by which this immense accumulation was reduced to its present level. Here, then, is a system of high hills, having the prominence of mountains in the landscape, produced by causes to whose agency inequalities on the earth's surface of this magnitude have never yet been ascribed. We may fairly call them denudation mountains. At this stage of the inquiry we have to account for two remarkable phenomena. First, the filling of the Amazonian bottom with coarse arenaceous materials and finely laminated clays, immediately followed by sandstones rising to a height of more than eight hundred feet above the sea; the basin meanwhile having no rocky barrier towards the ocean on its eastern side. Second, the wearing away and reduction of these formations

separated by deep indentations wide enough to be filled up by large glaciers, overtopping the summits of the intervening prominences, and passing over them like a river, or like tide-currents flowing over a submerged ledge of rock. It is evident that water rushing over such sunken hills or ledges, adapting itself readily to all the inequalities over which it flows, and forming eddies against the obstacles in its course, will scoop out tortuous furrows upon the bottom, and hollow out rounded cavities against the walls, acting especially along pre-existing fissures and upon the softer parts of the rock. The glacier, on the contrary, moving as a solid mass, and carrying on it~ under side its gigantic file set in a fine paste, will in course of time, abrade uniformly the angles against which it strikes, equalize the depressions between the prominent masses, and round them off until they present those smooth bulging knolls known as the roches moutonntees in the Alps, and so characteristic everywhere of glacier-action. A comparison of any tide-worn hummock with such a glacier-worn mound will convince the observer that its smooth and evenly rounded surface was never produced by water. Besides their peculiar form, the roches moutonees present all the characteristic features of glacier-action in their polished surfaces accompanied with the straight lines, grooves, and furrows above described. There are two circumstances connected with these knolls deserving special notice. They frequently present the glacial marks only on one side, while the opposite side has all the irregularities and roughness of a hill-slope not acted upon by ice. It is evident that the polished side was the one turned towards the advancing glacier, the side against which the ice pressed in its onward movement, -while it passed over the other side, the lee side as we may call it, without coming in immediate contact with it, bridging the depression, and touching bottom again a little farther on. As an additional evidence of this fact, we frequently find op the lee side of such knolls accumulations of the loose materials which the glacier carries with it. It is only, however, when the knolls are quite high, and abrupt enough to allow any rigid substance to bridge over the space in its descent from the summit to the surface below, that we find these conditions; when

most numerous insects were the dragon-flies, -some with crimson bodies, black heads, and burnished wings; others with large green bodies, crossed by blue bands. Of land shells I saw but one creeping 'along the reeds; and of water shells I gathered only a few small Ampullarire. Having ascended the river to a point nearly on a line with the serra, I landed, and struck across the Campos on foot. Here I entered upon an entirely different region, -a dry, open plain, with scanty vegetation. The most prominent plants were clusters of cactus and curua palms, a kind of stemless, low palm, with broad elegant leaves springing vase-like from the ground. In these dry, sandy fields, rising gradually toward the serra, I observed in the deeper gullies formed by the heavy rains the laminated clays which are every- where the foundation of the Amazonian strata. They here presented again so much the character of ordinary clay slates, that I thought I had at last come upon some old geological formation. Instead of this I only obtained fresh evidence that, by baking them, the burning sun of the tropics may produce upon laminated clays of recent origin the same effect as plutonic agents have produced upon the ancient clays, that is, it may change them into metamorphic slates. After an hour's walk under the scorching sun, I was glad to find myself at the hamlet of Errere, near the foot of the serra, where I rejoined my companions. It was already noon, and they had arrived some time before. They had, however, waited breakfast for me, to which we all brought a good appetite. Break-fast over, we slung our hammocks under the trees, and during the heat of the day enjoyed I the rest which we had so richly earned. I Major Coutinho and myself passed three days in the investigation of the serra of Errere. We found it to consist wholly of the sandstone deposits described above, and to have exactly the same geological constitution. In short, the serra of Monte Alegre, and of course all those connected with it on the northern side of the river, lie in the prolongation of the lower beds forming the banks of the river, their greater height being due simply to the fact that they have not been worn to the same low level. The opposite range of Santarem, which has the same general outline and character, shares, no doubt, the same

which the ice ascended, have led to a mistaken view of the mode in which large boulders are transported by ice. It has been supposed by those who, while they accepted the glacial theory, were not wholly conversant with the mode or action of glaciers, that, in passing through the bottom of a valley, for instance, the glacier would take up large boulders, and, carrying them along with it, would push them up such a slope and deposit them on its summit. It is true that large boulders may sometimes be found in front of glaciers among the materials of their terminal moraines, and may upon any advance of the glacier be pushed forward by it. But I know of no example of erratic boulders being carried to considerable distances and raised from lower to higher levels by this means. All the angular boulders perched upon prominent rocks must have fallen upon the surface of the glacier in the upper part of its course, where rocky ledges rise above its surface and send down their broken fragments. The surface of any boulder carried under the ice, or pushed along for any distance at its terminus, would show the friction and pressure to which it had been subjected. In this connection it should be remembered that in the case of large glaciers low hills form no obstacle to their onward progress, especially when the glacier is thick enough to cover them completely, and even to rise far above them. The roches moutonnees about the Grimsel show that hills many hundred feet high have been passed over by the great glacier of the Aar, when it descended as far as Meyringen, without having seemingly influenced its onward progress. In enumerating the evidences of glacier action, we have to remember not only the effects produced upon the surface of the ground by the ice itself, but also the deposits it has left behind it. The loose materials scattered over the face of the earth may point as distinctly to the source of their distribution as does the character of the rocky surfaces on which they rest indicate the different causes of abrasion. In characteristic localities the loose materials deposited by glaciers may readily be recognized at first sight, and distinguished from water-worn pebbles; nor is it difficult to distinguish both from loose materials resulting from the decomposition of rocks on the spot, -the latter always agreeing with the rocks on which they rest, while the

started them up in pairs. Their flat, open nests generally contained five flesh-colored eggs, streaked in zigzag with dark brown lines. The other waders were a snow-white heron, another ash-colored, smaller species, and a large white stork. The ash-colored herons were always in pairs, the white one always single, standing quiet and alone on the edge of the water, or half hidden in the green capim. The trees and bushes were full of small warbler-like birds, which it would be difficult to characterize separately. To the ordinary observer they might seem like the small birds of our woods; but there was one species among them which attracted my attention by its numbers, and also because it builds the most extraordinary nest, considering the size of the bird itself, that I have ever seen. It is known among the country people by two names, as the Pedreiro or the Forneiro, -both names referring, as will be seen, to the nature of its habitation. This singular nest is built of clay, and is as hard as stone (pedra), while it has the form of the round mandioca oven (forno) in which the country people prepare their farinha, or flour, made from the mandioca root. It is about a foot in diameter, and stands edgewise upon a branch, or in the crotch of a tree. Among the smaller birds, I noticed bright Tanagers, and also a species resembling the canary. Besides these, there were the wagtails, the black and white widow finches, the hang-nests, or Jape, as they are called here, with their pendent bag-like dwellings, and the familiar "Bem ti vi." Humming-birds, which we are always apt to associate with tropical vegetation, were very scarce. I saw but a few specimens. Thrushes and doves were more frequent, and I noticed also three or four kinds of wood-peckers. Of the latter there were countless numbers along our canoe path, flying overhead in dense crowds, and, at times, drowning every other sound in their high, noisy chatter. These made a deep impression upon me. Indeed, in all regions, however far away from his own home, in the midst of a fauna and flora entirely new to him, the traveller is startled occasionally by the song of a bird or the sight of a flower so familiar that it transports him at once to woods where every tree is like a. friend to him. It seems as if something akin to what in our own mental experience we call reminiscence or association

distance over which they are carried, and the suddenness of the transportation, allow no time for the abrasion which produces the smooth surfaces of water-worn pebbles or the polished and scratched surfaces of glacier-worn ones. In the latter case, we have seen that the pebbles, being so set in the ice as to expose only one side, may be only partially polished, while others, more loosely held and turning in their sockets, may receive the same high polish on every side. In such a case the lines will intersect one another, in consequence of the different position in which the stone has been held at different times. No such appearances exist in the water-worn pebbles; their blunt surfaces, smoothed and rounded uniformly by the action of the water in which they have been rolled or tossed about, present everywhere the same aspect. The correlation between these different loose materials and the position in which they are found helps us also to detect their origin. The loose materials bearing glacier-marks are always found resting upon surfaces which have been worn, abraded, and engraved in the same manner, while the water-worn pebbles are everywhere found resting upon rocks the abrasion of which may be traced to water. It is true that in some localities, as, for instance, in the gravel-pit of Mount Auburn, near Cambridge, large masses of glacier-worn pebbles alternate with beach shingle; but it is easy to show that there was here a glacier advancing into the sea, crowding its front moraine and the materials carried under it over and into the shingle washed up by the waves upon the beach. Not infrequently also, river-pebbles may be found among glacial materials. This is especially the case where, after the disappearance of large glaciers, rivers have occupied their beds. Examples of this kind may be seen in all the valleys of the Alps. But, besides the special character of the individual fragments, the true origin of any accumulation of glacier-debris, commonly called drift, may be detected by the total absence of stratification, so essential a feature in all water deposits. This absence of stratification throughout its mass is, after all, the great and important characteristic of the drift; and though I have alluded to it before, I reiterate it here, as that which distinguishes it from all like accumulations under water. I may be pardoned for dwelling upon this point, because the great

canoe journey is somewhat longer. A two-hours ride across the Campos brings you to the foot of the mountain, whereas the trip by boat takes more than twice that time. But I preferred going by water, as it gave me an opportunity of seeing the vast variety of animals haunting the river-banks and lakes. As this was most the only occasion in my journey when I passed a day in the pure enjoyment of nature, without the labor of collecting, which in this hot climate, where specimens require such immediate and constant attention, is very great, I am tempted to interrupt our geology for a moment, to give an account of it. I learned how rich a single day may be in this wonderful tropical world, if one's eyes are only open to the wealth of animal and vegetable life. Indeed, a few hours so spent in the field, in simply watching animals and plants, teaches more of the distribution of life than a month of closet study; for under such circumstances all things are seen in their true relations. Unhappily, it is not easy to present the picture as a whole, for all our written descriptions are more or less dependent on nomenclature, and the local names are hardly known out of the districts where they belong, while systematic names are familiar to few. I started before daylight; but, as the dawn began to redden the sky, large flocks of ducks, and of the small Amazonian geese, might be seen flying towards the lakes. Here and there a cormorant sat alone on the branch of a dead tree, or a kingfisher poised himself over the water, watching for his prey. Numerous gulls were gathered in large companies on the trees along the river-shore; alligators lay on its surface, diving with a sudden plash at the approach of our canoe; and occasionally a porpoise emerged from the water, showing himself for a moment and then disappearing again. Sometimes we startled a herd of capivara, resting on the water's edge; and once we saw a sloth, sitting upon the branch of an a1mbauba (Cecropia) tree, rolled up in its peculiar attitude, the very picture of indolence, with its head sunk between its arms. Much of the river-shore consisted of low alluvial land, and was covered with that peculiar and beautiful grass known as Capim; this grass makes an excellent pasturage for cattle, and the abundance of it in this region renders the district of Monte Alegre very favorable for agricultural purposes. Here and there,

scarcely any angular boulders, while the drift is interspersed with larger fragments of this character, carried under the ice, instead of on its back. Another distinction between water- worn deposits and drift consists in the fact that the former are washed clean, while the latter always retains the mud gathered during its journey and spread throughout its mass. In summing up the glacial evidences, I must not omit the moraines, though I have described them so fully in a previous chapter that I need not do more than allude to them here; but any argument for the glacial theory which did not include these characteristic walls erected by glaciers would be most imperfect. We need hardly discuss the theory of currents with reference to the formation of terminal moraines, extending across the valleys from side to side. Any current powerful enough to bring the boulders and debris of all sorts of which these walls are composed to the places where they are found would certainly not build them up with such regularity, but would sweep them away or scatter them along the bottom of the valley. That this is actually the case is seen in the lower course of the valley of the Rhone, where there are no transverse moraines, while they are frequent and undisturbed in the upper part of the valley. This is no doubt owing to the fact, that, when the main glacier had already retreated considerably up the valley, the lateral glaciers from the chains of the Combin and the Diablerets still reached the valley of the Rhone at a lower point, and barred the outlet of the waters from the glaciers above. A lake was thus formed, which, when the lower glaciers retreated up the lateral valleys, swept away all the lower transverse moraines, and formed the flat bottom of Martigny. In this case, the moraines were totally obliterated; but there are many other instances in which the materials have been only broken up and scattered over a wider surface by cur- rents. In such remodelled moraines, the glacier-mud has, of course, been more or less washed away. We have here a blending of the action of water with that of the glacier; and, indeed, how could it be otherwise, when the colossal glaciers of past ages gradually disappeared or retreated to the mountain-heights? The wasting ice must have occasioned immense freshets, the action of which we shall trace hereafter, when examining the formation of our

in the lowermost beds, the whole mass is honeycombed, as if drilled by worms or boring shells, the hard parts enclosing softer sands or clays, Occasionally the ferruginous materials prevail to such an extent, that some of these beds might be mistaken for bog ore, while others contain a large amount of clay, more regularly stratified, and alternating with strata of sandstone, thus recalling the most characteristic forms of the Old Red or Triassic formations, This resemblance has, no doubt, led to the identification of the Amazonian deposits with the more ancient formations of Europe, At Monte Alegre, of which I shall presently speak more in detail, such a clay bed divides the lower from the upper sandstone. The thickness of these sandstones is extremely variable. In the basin of the Amazons proper, they hardly rise anywhere above the level of high water during the rainy season, while at low water, in the summer months, they may be seen everywhere along the river-banks. It will be seen, however, that the limit between high and low water gives no true measure of the original thickness of the whole series. In the neighborhood of Almeirim, at a short distance from the northern bank of the river, and nearly parallel with its course, there rises a line of low hills, interrupted here and there, extending in evident connection from Almeirim through the region of Monte Alegre to the heights of Obydos. These hills have attracted the attention of travellers, not only from their height, which, because they rise abruptly from an extensive plain, appears greater than it is, but also on account of their curious form, many of them being perfectly level on top, like smooth tables, and very abruptly divided from each other by low, intervening spaces. 1. Nothing has hitherto been known of the geological structure of these hills, but they have been usually represented as the southern- most spurs of the table-land of Guiana. On ascending the river, I felt the greatest curiosity to examine them; but at the time I was deeply engrossed in studying the distribution of fishes in the Amazonian waters, and in making large ichthyological collections, for which it was very important not to miss the season of low water, when the fishes are most easily obtained. I was, therefore, obliged to leave this most interesting geological problem, and content myself with examining the structure of the

termination; for the lowest of these terraces turns eastward into the valley of Glen Spean, following the whole curve of the eastern half of the valley, while, of the two upper terraces there is no trace whatever, nor is there any indication that either of the three ever existed in the western half of the valley. When I first visited the region, these phenomena had already been the subject of earnest discussion among English geologists. The commonly accepted explanation of the facts was that these terraces marked ancient sea-levels at a time when the ocean penetrated much farther into the interior, and Glen Roy and the adjoining valleys were as many fiords or estuaries. Though the present elevation of the locality made such an interpretation improbable at first sight, the first or highest of the terraces being eleven hundred and forty-four feet above the present sea-level, the second eighty-two feet below the first, and the third and lowest two hundred and twelve feet below the second, or eight hundred odd feet above the level of the sea, it was thought that the oscillations of the land, its alternate subsidences and upheavals, proved by the modern results of geology to have been so great and so frequent, might account even for so remarkable a change. There are, however, other objections to this theory not so easily explained away. There are no traces of organic life upon these terraces. If they were ancient sea-beaches, we should expect to find upon them the remains of marine animals, shells, crustacea, and the like. All the explanations given to lessen the significance of this absence of organic remains are futile. Again, why should the lower terrace alone be continued into the eastern end of the valley of Glen Spean, while there are no terraces at all in its western part, since both must have been as fully open to the sea as Glen Roy valley itself? This seemed the more inexplicable since all the terraces exist on the valley-wall opposite the outlet of Glen Roy, showing that this sheet of water, wherever it came from, filled the valley itself and the space between it and the southern wall of Glen Spean, but failed to spread, on either side of that space, into the eastern and western extension of Glen Spean. It is evident, that, at the time the water filled Glen Roy, some obstruction blocked the valley of Glen Spean, both to the east and west, leaving, however, that space in

have certainly destroyed a great part of the cretaceous deposit, they have never been observed in any part of the Amazonian basin. Whatever tertiary deposits are represented in geological maps of this region are so marked in consequence of an incorrect identification of strata belonging, in fact, to a much more recent period. A minute and extensive survey of the Valley of the Amazons is by no means an easy task, and its difficulty is greatly increased by the fact that the lower formations are only accessible on the river margins during the vas ante, as it is called, or dry season, when the waters shrink in their beds, leaving a great part of their banks exposed. It happened that the first three or four months of my journey, August, September, October, and November, were those when the waters are lowest, reaching their minimum in September and October, and beginning to rise again in November, so that I had an excellent opportunity in ascending the river to observe its geological structure. Throughout its whole length, three distinct geological formations may be traced, the two lower of which have followed in immediate succession, and are conformable with one another, while the third rests unconformably upon them, following all the inequalities of the greatly denudated surface presented by the second formation. Not- withstanding this seeming interruption in the sequence of these deposits, the third, as we shall presently see, belongs to the same series, and was accumulated in the same basin.

The lowest set of beds of the whole series is rarely visible, but it seems everywhere to consist of sandstone, or even of loose sands well stratified, the coarser materials lying invariably below, and the finer above. Upon this lower set of beds rests everywhere an extensive deposit of fine laminated clays, varying in thick- ness, but frequently dividing into layers as thin as a sheet of paper. In some localities they exhibit in patches an extraordinary variety of beautiful colors, -pink, orange, crimson, yellow, gray, blue, and also black and white. The Indians are very skilful in pre- paring paints from these colored clays, with which they ornament their pottery, and the bowls of various shapes and sizes made from the fruit of the Cuieira-tree. These clay deposits assume occasionally a peculiar appearance, and one which might mislead the observer to their

England, and in the valleys of Wales and Ireland. Following the glacial indications wherever we could find them in the country about Glen Roy, it became evident to me that the whole western range of the Grampian Hills had once been a great centre of glaciers, that they had come down toward Glen Spean through all the valleys on the mountain-slopes to the north and south of it, so that this valley had be- come, as it were, the great drainage-bed for the masses of ice thus poured into it laterally, and moving down the valley from east to west as one immense glacier. It is natural to suppose that, at the breaking-up of the great sheet of ice which, if my view of the case is correct, must have covered the whole country , at this time, the ice would yield more readily in a valley like that of Glen Roy, lying open to the south and receiving the full force of the sun, than in those on the opposite side of Glen Spean, opening to the north. At all events, it is evident that at some time posterior to this universal glacial period, when the ice began to retreat, Glen Roy became the basin of a glacial lake such as we now find in the Alps of Switzerland, where occasionally a closed valley becomes a trough, as it were, into which the water from the surrounding hills is drained. In such a lake no animals are found, such as exist in any other sheet of fresh water, and this would account for the absence of any organic remains on the terraces of Glen Roy. But at first sight it seemed that this theory was open in one respect to the same objection as the other. What prevented this sheet of water from spreading east and west in Glen Spean? If it not only filled Glen Roy, but extended to the southern side of Glen Spean immediately opposite the opening of Glen Roy, what pre- vented it from filling the whole of that valley also? In endeavoring to answer this question, I found the solution of the mystery. The bed of Glen Spean, through its whole extent from east to west, is marked, as I have said, by glacial action, in rectilinear scratches and furrows. This westward track of the main glacier is crossed transversely near the centre of the valley by two other glacier-tracks cutting it at right angles. Upon tracing these cross-tracks carefully, I became satisfied that, after the surrounding ice had begun to yield, after the masses of ice which descended from the northern and southern slopes of the

above alluded to from the f eastern borders of this ancient basin, I have had recently another evidence of its cretaceous character from its southern region. Mr. William Chandless, on his return from a late journey on the Rio Purus, presented me with a series of fossil remains of the highest interest, and undoubtedly belonging to the cretaceous period. They were collected by himself on the Rio Aquiry, an affluent of the Rio Purus. Most of them were found in place between the tenth and eleventh degrees of south latitude, and the sixty-seventh and sixty-ninth degrees of west longitude from Greenwich, in localities varying from 430 to 650 feet above the sea-level. There are among them remains of Mososaurus, and of fishes closely allied to those already represented by Faujas in his description of Maestricht, and characteristic, as is well known to geological students, of the most recent cretaceous period. Thus in its main features the Valley of the Amazons, like that of the Mississippi, is a cretaceous basin. This resemblance suggests a further comparison between the twin continents of North and South America. Not only is their general form the same, but their frame-work, as we may call it, that is, the lay of their great mountain-chains and of their table-lands, with the extensive intervening depressions, presents a striking similarity. Indeed, a zoologist, accustomed to trace a like structure under variously modified animal forms, cannot but have his homological studies recalled to his mind by the coincidence between certain physical features in the northern and southern parts of the Western hemisphere. Yet here, as throughout all nature, these correspondences are combined with a distinctness of individualization, which leaves its respective character not only to each continent as a whole, but also to the1different regions circum- scribed within its borders. In both, however, the highest mountain-chains, the Rocky Mountains and Coast Range with their wide intervening table-land in North America, and the chain of the Andes with its lesser plateaus in South America, run along the western coast; both have a great eastern promontory,- New-foundland in the northern continent, and Cape St. Roque in the southern; -and though the resemblance between the inland elevations is perhaps less striking, yet the Canadian range, the

Sidlaw Hills into the capacious bed of the valley which divides them. The glacial phenomena of this region present a striking resemblance in their general relations to those of the Alps and the Jura. The Grampian range on the northern side of Strathmore valley occupies the same position in reference to that of the Sidlaw Hills opposite, as does the range of the Alps to that of the Jura, while the intervening valley may be compared to the plain of Switzerland. As from the Bernese Oberland and from the valleys of the Reuss and Limmath gigantic glaciers came down and stretched across the plain of Switzerland to the Jura, scattering their erratic boulders over its summit and upon its slopes at the time of their greater extension, and, as they withdrew into the higher Alpine valleys, leaving them along their retreating track at the foot of the Jura and over the whole plain, so did the glaciers from Glen Prossen and parallel valleys on the Grampian Mountains extend across the valley of Strathmore, drop- ping their boulders not only on the slopes and along the base of the Sidlaw Hills, but scattering them in their retreat throughout the valley, until they were themselves reduced to isolated glaciers in the higher valleys. At the same time other glaciers came down from the heights of Schihallion on the west, and, descending through the valley of the Tay, joined the great masses of ice in the valley of Strathmore, thus combining with the eastern ice-field, just as the glacier from Mont Blanc and the valley of the Rhone formerly combined in the western part of Switzerland with those of the Bernese Oberland. The relations are identical, though the geographical position is reversed, -the higher range, or the Grampian Hills, lying to the north in Scotland, and the lower one, or the Sidlaw Hills, to the south, while in Switzerland, on the contrary, the higher range lies to the south and the lower to the north. I have alluded especially to Glen Prossen because the glacial marks in that valley are remarkably distinct, the whole bed of the valley being scratched, polished, al and furrowed by the great rasp which has moved over it, while the concentric moraines at its lower extremity are very striking. But these signs, so perfectly preserved in Glen Prossen, recur with greater or less intensity in all the corresponding valleys, leaving no doubt that the same

period, and considered by all travellers to be at least as old as the Tertiaries. The result, however, confirmed his report, at least so far as the component materials of the formation are concerned; but, as will be seen hereafter, the mode of their deposition, and the time at which it took place, have not been the same at the north and south; and this difference of circumstances has modified the aspect of a formation essentially the same throughout. At first sight, it would indeed appear that information, as it exists in the valley of the Amazons, is identical with that of Rio; but it differs from it in the rarity of its boulders, and in showing occasional signs of stratification. It is also everywhere under-laid by coarse, well-stratified deposits, resembling somewhat the recife of Bahia and Pernambuco; whereas the unstratified drift of the south rests immediately upon the undulating surface of whatever rock happens to make the foundation of the country, whether stratified or crystalline. The peculiar sandstone on which the Amazonian clay rests exists nowhere else. Before proceeding, however, to describe the Amazonian deposits in detail, I ought to say something of the nature and origin of the valley itself. The Valley of the Amazons was first sketched out by the elevation of two tracts of land; namely, the plateau of Guiana on the north, and the central plateau of Brazil on the south. It is probable that, at the time these two table-lands were lifted above the sea-level, the Andes did not exist, and the ocean flowing between them through an open strait. It would seem (and this is a curious result of modern geological investigations) that the portions of the earth's surface earliest raised above the ocean have trended from east to west. The first tract of land lifted above the waters in North America was also a long continental island, running from Newfoundland almost to the present base of the Rocky Mountains. This tendency may be attributed to various causes, to the rotation of the earth, the consequent depression of its poles, and the breaking of its crust along the lines of greatest tension thus produced. At a later period, the upheaval of the Andes took place, closing the western side of this strait, and thus transforming it into a gulf, open only toward the east. Little or nothing is known of the earlier stratified deposits resting against

the line of perpetual snow, they have disappeared as completely as in the Grampian Hills. It would lead me too far, were I to give here a special account of all the investigations I made in 1840 upon the distribution of glaciers in Great Britain. I will therefore only point out a few of the more distinct areas of distribution. The region surrounding Ben Wyvis formed such a centre of dispersion from which glaciers radiated, and we have another in the Pentland Hills about Edinburgh. In Northumberland, the Cheviot Hills present a glacial centre of the same kind, and in the West-moreland Hills we have still another. In the last-named locality, the glacial tracks can be followed in various directions, some of them descending toward the northwest from the heights of Helvellyn, others moving southward toward Ambleside. In Wales the same kind of glacial distribution has been observed; but, as Professor Ramsay has treated this subject in full, I would refer my readers to his masterly work for a further account of the ancient Welch glaciers. In Ireland I had also opportunities of extensive local investigations of glacial action. I observed the centres of distribution in the neighborhood of Belfast, in the county of Wicklow, and in Cavan. Nowhere are these phenomena more striking than in Fermanagh County about the neighborhood of Enniskillen, and more especially in the immediate vicinity of Florence Court, the seat of the Earl of Enniskillen. On the northern slope of Ben Calcagh are five valleys lying parallel with each other and opening into the valley of Loch Nilly, which runs from east to west at the base of the mountain. A road now passes through this valley, and where it crosses the mouth of either of the five valleys rising towards the mountain-slope; it cuts alternately through the two horns of a crescent-shaped wall which bars the lower end of everyone of them. These crescent-shaped mounds are so many terminal moraines, built up by the five glaciers formerly descending through these lateral valleys into the valley of Loch Nilly. They bore the same relation to each other as the glaciers De Tour and D' Argentiere, the Glacier des Bois with the Mer de Glace,-the Glacier des Bossons, the Glacier de Taconet, now bear to each other in the valley of Chamouni. Were it not for the smaller dimensions of the whole, anyone familiar with the

in the greater part of which travelling is easy and delightful, -an admirable line of diligences, over one of the finest roads in the world, being established as far as Juiz de Fora, -the drift may be seen along the roadside, in immediate contact with the native crystalline rock. The fertility of the land, also, is a guide to the presence of drift. Wherever it lies thickest over the surface, there are the most flourishing coffee-plantations; and I believe that a more systematic regard to this fact would have a most beneficial influence upon the agricultural interests of the country. No doubt the fertility arises from the great variety of chemical elements contained in the drift, and the kneading process it has undergone beneath the gigantic ice-plough, -a process which makes glacial drift everywhere the most fertile soil. Since my return from the Amazons, my impression as to the general distribution of these phenomena has been confirmed by the reports of some of my assistants, who have been travelling in other parts of the country. Mr. Frederick C. Hartt, accompanied by Mr. Copeland, one of the volunteer aids of the expedition, has been making collections and geological observations in the province of Spiritu Santo, in the valley of the Rio Doce, and afterwards in the valley of the Mucury. He informs me that he has found everywhere the same sheet of red, unstratified clay, with pebbles and occasional boulders, overlying the rock in place. Mr. Orestes St. John, who, taking the road through the interior, has visited, with the same objects in view, the valleys of the Rio San Francisco and the Rio das Vel has, and also the valley of Piauhy, gives the same account, with the exception that he found no erratic boulders in these more northern regions. The rarity of erratic boulders, not only in the deposits of the Amazons proper, but in those of the whole region which may be considered as the Amazonian basin, is account- ed for, as we shall see hereafter, by the mode of their formation. The observations of Mr. Hartt and Mr. St. John are the more valuable, because I had employed them both, on our first arrival in Rio, in making geological surveys of different sections on the Dom Pedro Railroad, so that they had a great familiarity with those formations before starting on their separate journeys. Recently, Mr. St. John and myself having met at Para on returning from our respective journeys, I

1. Having enumerated the characteristic features of the glacial phenomena in the preceding pages, I throw into this note some explanations which may render my views of the parallel roads more intelligible, not to interrupt again the exposition with details. It would be desirable, however, that the reader should first make himself thoroughly familiar with the localities concerned before proceeding any further. The woodcut on page 58 (Figure 1.) is taken from a small map, accompanying a paper of mine upon "The Glacial Theory and its Recent Progress," printed in the “Edinburgh New Philosophical Journal" for October, 1842. G. R. indicates the valley of Glen Roy, with the three parallel roads marked 1, 2, 3. Glen Spean is designated by G. S., and the river flowing at its bottom by S. Loch Laggan, out of which the river Spean rises, is marked L. G. indicates Glen Gloy, a little valley to the northwest of Glen Roy, with a single terrace. Loch Treig is designated by T., Loch Lochy by L. O., Loch Arkeig by A., and Moeldhu Hill by M., while E. indicates Loch Eli. The Great Glen of Scotland, through which the Caledonian Canal runs, extends in the direction of L. O. and E. , The position of Ben Nevis is designated by N. The dotted area between N. and M. marks the place occupied by the great glacier of Ben Nevis, when it extended as far as Moeldhu; while, the close continuous lines in front of Loch Treig indicate the direction of the glacial scratches left across Glen Spoon by the glacier of Loch Treig, when it extended as far as the eastern termination of the two upper terraces. It ought to be remembered, in this connection, that the bottom of the valley of the Spean, as well as that of Glen Roy, is occupied by loose materials, partly drift, that is, materials acted upon by glaciers, and partly decomposed fragments of rocks brought down by the torrents, greatly impeding the observation of the polished surfaces. The river-bed is cut through this deposit, and here and there through the underlying rock. Besides the parallel roads, there are also peculiar accumulations of loose materials in Glen Roy and Glen Spean, - more particularly connected with the lowest terrace, which Mr. Darwin and Professor Jamieson have shown to be little deltas formed during the existence of the lake of Glen Roy at the bottom of the gullies intersecting the shelves

unquestionably drift phenomena, they present in their wider extension, and especially in the northern part of Brazil, as will hereafter be seen, some phases of glacial action hitherto unobserved. Just as the investigation of the ice-period in the United States has shown us that ice-fields may move over open level plains, as well as along the slopes of mountain valleys, so does a study of the same class of facts in South America reveal new and unlooked-for features in the history of the ice-period. Some will say, that the fact of the advance of ice-fields over an open country is by no means established, inasmuch as many geologists believe all the so-called glacial traces, namely, striae, furrows, polish, etc., found in the United States, to have been made by floating icebergs at a time when the continent was submerged. To this I can only answer, that in the State of Maine I have followed, compass in hand, the same set of furrows, running from north to south in one unvarying line, over a surface of one hundred and thirty miles from the Katahdin Iron Range to the sea-shore. These furrows follow all the inequalities of the country, ascending ranges of hills varying from twelve to fifteen hundred feet in height, and descending into the intervening valleys only two or three hundred feet above the sea, or sometimes even on a level with it. I take it to be impossible that a floating mass of ice should travel onward in one rectilinear direction, turning neither to the right nor to the left, for such a distance. Equally impossible would it be for a detached mass of ice, swimming on the surface of the water, or even with its base sunk considerably below it, to furrow in a straight line the summits and sides of the hills, and the beds of the valleys. It would be carried over the depressions without touching bottom. Instead of ascending the mountains, it would remain stranded against any elevation which rose greatly above its own basis, and, if caught between two parallel ridges, would float up and down between them. Moreover, the action of solid, unbroken ice, moving over the ground in immediate contact with it, is so different from that of floating ice-rafts or icebergs, that, though the latter have unquestionably dropped erratic boulders, and made furrows and striae on the surface where they happened to be grounded, these phenomena will easily be distinguished

be more than a monotonous repetition of my statements respecting their existence in other regions; but the peculiar configuration of this continent, as compared with the more mountainous countries of Europe and Asia, has led to some modifications of the same phenomena here, worthy of special notice. Thus far, the traces of ancient glaciers in America have been studied only east of the Rocky Mountains; little is known of the glaciers still remaining in the high mountain- ranges dividing the eastern part of the continent from California, still less respecting any indications of their former extension. There can be little doubt that such traces exist, and as soon as the so-called parks between Pike's Peak and Long Peak are explored, we may hope for information on this point. Indeed, the investigation may be spoken of as already undertaken; for among the exploring parties now on their way to that region are some intelligent observers, who will not fail to make this point a subject of special study. But it is well known that the usual characteristic marks of glaciers extend over the whole surface of the land in the eastern half of the continent, from the Atlantic shores to the States west of the Mississippi, and from the Arctic Sea to the latitude of the Ohio, in its middle course, while within the range of the Alleghanies they stretch as far south as Georgia and Alabama. In no other region where these traces have been observed do they extend over such wide tracts of country in unbroken I continuity, this being of course owing to the level character of the land itself. The continent of North America, east of the Rocky Mountains, is, indeed, an immense uniform plain, intersected from east to west only by the ranges of low hills running in the direction of the St. Lawrence and the Canadian lakes, and from northeast to southwest by the Alleghany range stretching from Alabama to New England, where it trends towards the Canadian Hills in the ridges known as the Green and White Mountains. This coast-range has a short slope towards the Atlantic, and a long one in the direction of the great Mississippi Valley. With the exception of some higher points of the Alleghany range, the surface of this whole plain is glacier-worn from the Arctic regions to about the fortieth degree of northern latitude, the glacier-marks trending from north to

come to be accepted by geologists, so will the existence of like phenomena, both in North and South America, during the same epoch, be recognized sooner or later as part of a great series of physical events extending over the whole globe. Indeed, when the ice-period is fully understood, it will be seen that the absurdity lies in supposing that climatic conditions so intense could be limited to a small portion of the world's surface. If the geological winter existed at all, it must have been cosmic; and it is quite as rational to look for its traces in the Western as in the Eastern hemisphere, to the south of the equator as to the north of it. Impressed by this wider view of the subject, confirmed by a number of unpublished investigations which I have made during the last three or four years in the United States, I came to South America, expecting to find in the tropical regions new evidences of a bygone glacial period, though, of course, under different aspects. Such a result seemed to me the logical sequence of what I had already observed in Europe and in North America. On my arrival in Rio de Janeiro, -the port at which I first landed in Brazil, -my attention was immediately attracted by a very peculiar formation, consisting of an ochraceous, highly ferrnginous sandy clay. During a stay of three months in Rio, whence I made many excursions into the neighboring country, I had opportunities of studying this deposit, both in the province of Rio de Janeiro and in the adjoining province of Minas Geraes. I found that it rested everywhere upon the undulating surfaces of the solid rocks in place, was almost entirely destitute of stratification, and contained a variety of pebbles and boulders. The pebbles were chiefly quartz, sometimes scattered indiscriminately throughout the deposit, sometimes lying in a seam between it and the rock below; while the boulders were either sunk in its mass or resting loose on the surface. At Tijuca, a few miles out of the city of Rio, among the picturesque hills lying to the southwest of it, these phenomena may be seen in great perfection. Near Bennett's Hotel- a favorite resort, not only with the citizens of Rio but with all sojourners there who care to leave the town occasionally for its beautiful environs -may be seen a great number of erratic boulders, having no connection whatever with the rock in place, and also a bluff of

inequalities of the surface. Thus the peculiar physical character of the country gives a new aspect to the study of glacial evidences here. The polished surfaces stretch continuously over hundreds and hundreds of miles; the rectilinear scratches, grooves, and furrows are unbroken for great distances; the drift spreads in one vast sheet over the whole land, consisting of an indiscriminate medley of clays, sands, gravels; pebbles, boulders of all dimensions, so uniformly mixed together that it presents hardly any difference in its composition, whether we examine it in New England, New York, Pennsylvania, Ohio, Michigan, Indiana, Illinois, Wisconsin, in Iowa beyond the Mississippi, in the more northern Territories, or in Canada. In Europe, boulders of large dimensions do not often occur within the drift, but are usually resting above it with their sharp angles and rough surfaces unchanged, having travelled evidently upon the glacier and not under it. But such large boulders, polished and scratched like the smaller pebbles, are to be found everywhere imbedded in American drift, while the angular fragments of rock resting above these triturated masses are comparatively rare,- It is evident from this that the ice overtopped the rocky inequalities of the land, and that the detached fragments remaining beneath the icy covering underwent the same action from friction and pressure to which the whole mass of drift was subjected. 1. The distribution of the few angular boulders scattered over the country no doubt began when-some of the higher portions of the land had emerged from the mass of snow and ice; and they are most frequent in New England, where the mountain-elevation is greatest. The mineralogical character of the loose materials forming the American drift leaves no doubt that the whole movement, with the exception of a few local modifications easily accounted for by the lay of the land, was from north to south, all the fragments not belonging to the localities where they occur being readily traced to rocks in situ to the north of their present resting-places. The farther one journeys from their origin, the more extraordinary does the presence of these boulders become. It strikes one strangely to find even in New England fragments of rock from the shores of Lake Superior; but it is still more impressive to meet with masses of northern rock

and over a part of its length, in a narrow track some hundred miles in extent, from the Katahdin Iron Works to the southern shore of Mount Desert, where they are lost in the ocean. I have, however, suppressed a great amount of evidence which could not easily be presented without maps and sections. I may have an opportunity of publishing what has been omitted on some future occasion. Over this whole region, the glacial characters run due north and south, never deflected except by local causes, ascending, in undeviating rectilinear course, all the elevations, and descending into all the depressions. How is it possible to suppose that floating icebergs would advance over such an uneven country with this steadfast, straightforward march? Instead of ascending the hills, they would be caught between them in the intervening depressions, or, if the land were completely submerged, floated over them. The advocates of the iceberg theory forget also that an amount of floating ice, so much larger than is now annually spreading over the Northern Atlantic, implies a far lower temperature; and with it we have the conditions necessary to cover the mainland with glaciers, instead of simply increasing the field of icebergs. Equally impossible is it to suppose that anything so unstable as water has produced such straight and continuous lines. Assuming, then, that these phenomena were produced by ice, let me add, in conclusion, that the glacial traces over the State of Maine, and especially between Bangor and the seacoast, afford means of estimating approximately the thickness of the ice-sheet which once moved over the whole land, as well as its limitations during a later period, when it had begun to wane. In order to advance across a hilly country and over mountainous ridges rising to a height of twelve and fifteen hundred feet in the southern part of the State, and to a much higher level in its northern portion, the ice must have been several times thicker than the height of the inequalities over which it passed; otherwise it would have become r encased between these elevations, which would have acted as walls to enclose it. We are therefore justified in supposing that the ice-fields, when they poured from the north over New England to the sea, had a thickness of at least five or six thousand feet. On a future occasion I shall give an account of

moraine, and there are others in the neighborhood of the Blue Hills. In the southeastern parts of Maine, also, I have observed very well defined moraines. In Vermont, the valley of the Winooski River retains ample traces of the local glacier by which it was formerly filled; and, indeed, throughout the Alleghany range, in its north- eastern as well as its southern extension, we have various evidences of localized glaciers, which must have outlived the general ice- period for a longer or a shorter time. I am unwilling to weary my readers by dwelling upon appearances identical with those already described; but I may state, for the guidance of those who wish to investigate these traces for themselves, that any recently uncovered ledge of rock in our neighborhood, the surface of which has not been altered by atmospheric agencies, presents the glacier- worn surfaces with the characteristic striae and furrows. These marks may be traced everywhere, even to the sea-shore, not only down to the water's edge, but beneath it, wherever the harder rocks have resisted the action of the tides and retain their original character. In our granitic regions intersected by innumerable trap dikes, as, for instance, at Nahant, the smooth surface of many of the rocks, where sienite and trap have been evenly levelled, shows that the same inexorable saw, cutting alike through hard and soft materials, has passed over them. In the hills of pudding- stone in the neighborhood of Roxbury we have quartz pebbles cut down to the same level with the softer paste in which they lie imbedded with pebbles of sandstone, clay-slate, gneiss, and limestone. In the limestone regions of Western New York and Northern Ohio, about the neighborhood of Buffalo and Cleveland, the flat surfaces of the limestone are most uniformly polished, furrowed, and scratched, the furrows often exhibiting that staccato grating action described in a former chapter. I have observed the same traces in tl1e vicinity of Milwaukee and Iowa City, and we know, from the accounts given by Arctic travellers of their overland expeditions, that these peculiar appearances of the surface are characteristic of the rocks in those regions, wherever they are not disintegrating under the influence of the present atmospheric agents. Upon these surfaces, through the whole expanse of the country, rests the drift, having everywhere

characters also point to the north. At Seal Cove, however, on the southwestern shore, the marks have again a north-northwesterly direction. South of Seal Cove all the surface inequalities are moutonnees, the striae running north-northwest. We returned to Trenton Bridge by the western shore, having thus skirted the whole island. Before closing these remarks I wish to m allude, in passing, to some other facts connected with this investigation, which I could not easily notice at an earlier time without interrupting my narrative. East and south of Bangor there are considerable deposits of faintly laminated clays, used for the manufacture of bricks, in which striated pebbles and patches of sand are sparsely interspread. I take it for granted that the clays are morainic materials remodelled by the floods arising from the melting of the great glaciers, and that the pebbles and sands are the droppings of ice-bergs floating upon these waters. This is the more probable, since accumulations of irregularly stratified sand are always found in the vicinity of such masses of sifted clays, containing scratched pebbles. I have seen similar deposits in the Western States, for instance, near Milwaukee and Chicago. Between Bangor and Mount Desert the usual evidence of glaciation is very extensive. I would mention as particularly interesting the hills south of Holden and the hills about Dedham. On the route along Union Bay there are also extensive polished surfaces, especially in the vicinity of Bucksport. Near Ellsworth , they are beautifully preserved, and all the eminences are moutonnees. At Ellsworth Falls, on both sides of the bridge, there are splendid of polished surfaces, with scratches and furrows of pointing due north. Between Ellsworth and Trenton, and westward of that meridian, and the direction of Bucksport, there are several longitudinal moraines parallel to one another, running from north to south, composed of from large angular boulders, resting upon ground the moraines made up of rounded, scratched pebbles and sand mixed with clay. Such a superposition is utterly incompatible with the idea of currents passing over these tracks. Two n the miles west of Ellsworth a similar longitudinal moraine runs over the top of the hill, and are about one mile further west there is another, near chiefly composed of the coarse Dedham granite. The bottom deposit,

equally numerous, will be seen protruding at various heights from the sides, where they are imbedded in the general mass of the drift. As soon as the work progresses a little further, and the finer materials are removed, these boulders will also drop out, and lie as thickly scattered over the surface of the ground as they now do in that portion of the bottom where the pit has been completely opened and the gravel removed. We shall see hereafter how these boulders, derived from the land-drift and scattered along the coast, may be distinguished from those cast ashore by icebergs. Notwithstanding the number of facts thus far collected respecting glacial phenomena in America, certainly forming in their combination a very strong chain of evidence, the scientific world has, nevertheless, been slow to admit the possibility of the former existence of glaciers over such a wide, unbroken expanse of level land. This backwardness is, no doubt, partly due to the fact, that, as glaciers have hitherto been studied in mountainous countries, their presence has been supposed to imply the presence of mountains, this impression being strengthened by the downward and onward movement of existing glaciers, so long supposed to be exclusively due to the slopes along which all modern glaciers advance. Were it true that glaciers move solely or mainly on account of the sloping bottom on which they rest, and that they can advance only on an inclined plane, all the phenomena concerning drift, polished and furrowed surfaces, boulders, etc., in America, would hardly justify us in assuming a moving sheet of ice as their cause. But we have seen that the phenomena of glaciers, like those of currents, are in great part meteorological. The Gulf Stream does not flow toward the English shore because the ocean-bottom slopes eastward; nor does the cold current of Baffin's Bay run down hill when it pours its icy waters southward upon our northeast coast. Their course is determined by laws of temperature, and so have we also seen that the motion of glaciers is mainly determined by conditions of temperature, although, in this case, an internal mechanical action is combined with external influences; and while it is true that glaciers, as they now exist, are dependent upon the shape of the valleys in lofty mountain-chains, yet under different geographical conditions the

of Frenchman's Bay. On the following day, we crossed to the opposite side of the island, skirting Somes's Sound, and the next morning entered the sound in a small schooner. A stiff breeze from the north, which obliged us to tack constantly, and made our progress very slow, prevented us from exploring this singular inlet for its whole length; but short as it was, our sail gave me ample opportunity for observing the glacial phenomena along its shores. At the mouth of the sound, before entering the narrows, there are several concentric terminal moraines on both sides of the fiord. No doubt they once stretched across it, and were broken through by the sea. On either side, to the right and left, in ascending the sound, are little valleys running down to the water; and evidently they have all had their local glaciers, for there are terminal moraines at the mouth of each one. These facts only confirmed my anticipations. I had seen, on passing the head of the fiord, in our drive of the previous day, that it must from its formation afford an admirable locality for glacial remains, unless they had been swept away by the sea. The small town of Somesville is beautifully situated at the head of the sound. Approaching it from the east, I observed that the glacial marks which had been pointing due north began to point west-northwest, while on the western side of the settlement they pointed east-northeast. Evidently there is an action here similar to that by which the marks are deflected on the northern shore of the island about Frenchman's Bay and Union Bay. The mass of ice coming from the north had been gradually sinking into the fiord from opposite sides. Near Somesville church the marks run again due north. The extensive surfaces of polished and scratched rocks in this locality recall the celebrated Helle-Platten of the valley of Hasli. From Southwest Harbor we followed the shore to Bass Harbor and Seal Cove. There are frequent indications of glaciaction along this road, and one or two points of special interest. At Bass Harbor there is a large dike of green trap running at right angles with the tide current. Though regularly overflowed at high-water, the action of the sea has not affected the glacial characters, which are peculiarly distinct at this spot. Not only is the surface of the dike itself deeply scored with striae and furrows running due north, but,

falling upon it as rain or dew, the alternations of temperature being of course more frequent and greater along its outer limit. In proportion as, with the rising of the temperature, these alternations became more general, a packing of the mass would begin, corresponding to that observed in the glacial valleys of Switzerland, though here the action would not be intensified by lateral pressure; an internal movement of the whole mass would be initiated, and the result could be no other than a uniform advance in a southerly direction from the Arctic toward the more temperate latitudes in Europe, Asia, and North America, and from the Antarctic toward South America, the Cape of Good Hope, and Van Dieman's Land. But we need riot build up a theoretical case in order to form an approximate idea of the great ice-sheet stretching over the northern part of this continent during the glacial period. It would seem that man was intended to decipher the past history of his home, for some remnants or traces of all its great events are left as a key to the whole. Greenland and the Arctic regions hold all that remains of the glacial period in North America. Their shrunken ice-fields, formidable as they seem to us, are to the frozen masses of that secular winter but as the patches of snow and ice lingering on the north side of our hills after the spring has opened; let us expand them in imagination till they extend over half the continent, and we shall have a sufficiently vivid picture of this frozen world. And a temperature which would bring the climate of Greenland down to the fortieth degree of latitude would not only render the field of ice far more extensive, but thousands of feet thicker than it is at present. The physical configuration of Greenland also confirms the possibility of a glacial period in America, for there we have at this moment a wide expanse of land unbroken by mountains, over which a uniform sheet of ice moves southward, with occasional variations of its trend, according to the undulations of the surface. The interesting accounts of Dr. Rink show that in reality Greenland is a miniature picture of the ice-period. The immense number of icebergs breaking off and floating southward every summer gives us some idea of the annual waste and renewal of the ice. How can we doubt, that, when, under the same latitude, Norway,

depression half-way up the mountain-side. At the very entrance to the island, on passing over the toll-bridge of Trenton, there is an excellent locality for glacial tracks. The striae are admirably well preserved on some ledges at the Mount Desert end of the bridge. The trend of these marks is north-northeast, instead of due north as in most localities; and here is one of the instances where the slight deflection of the lines is evidently due to the lay of the land. The island is not only highest towards the centre, but narrows at its northern end as it sinks toward the shore, from which it is separated on either side by two deep fiords running up into the coast of Maine, and known as Frenchman's Bay on the east, and Union Bay on the west. It is evident that the mass of ice passing from the mainland over this arm of the sea sunk; eastward and westward into these two gorges, acquiring, no doubt, additional thickness thereby, and being, in consequence of this change in its normal course, slightly deflected from its usual direction in working its way up against the shore of Mount Desert. This is shown by the fact that the glacial marks on the northwest shore bear, as I have already said, slightly to the east, while those on the northeast shore bear slightly to the west. On approaching the centre of the island the marks converge towards each other, and regain their primitive direction due north and south, on its more elevated positions. I have often observed in Switzerland like instances, when from some local cause the direction of the movement was slightly deflected to the right and left, converging again at some little distance. In the valley of Hasli, between the hospice of the Grimsel and Guttanen, are several knolls which afford examples in point. On the upper side of these knolls, facing the higher part of the valley, from which large glaciers formerly came down, marks are carried directly up the slope on to the back of the knoll, while on either side they fall away slightly to the right and left, con- verging again to meet and continue their straight course over the lower slope; showing that, though such knolls, entirely buried beneath the mass of the ice, are no obstacle to r its advance, the inequalities of the bottom do affect in a slight degree the direction of the movement, and render the striae less even than over a level surface. Of course, where the ice is very thick, bottom

with the most recent river-deposits. One naturally asks, What was the use of this great engine set at work ages ago to grind, furrow, and knead over, as it were, the surface of the earth? We have our answer in the fertile soil which spreads over the temperate regions of the globe. The glacier was God's great plough; and when the ice vanished from the face of the land, it left it prepared for the hand of the husbandman. The hard surface of the rocks was ground to powder, the elements of the soil were mingled in fair proportions, granite was carried into the lime regions, lime was mingled with the more' arid and unproductive granite districts, and a soil was prepared fit for the agricultural uses of man. I have been asked whether this inference was not inconsistent with the fact that a rich vegetation preceded the ice-period, -a vegetation sufficiently abundant to sustain the tropical animals then living throughout the temperate regions. But the vegetation which has succeeded the ice-period is of a different character, and one that could not have flourished on a soil that would nourish a more tropical growth. The soil we have now over the temperate zone is a grain-growing soil,- one especially adapted to those plants most necessary to the higher domestic and social organizations of the human race. Therefore I think we may believe that God did not shroud the world he had made in snow and ice with- out a purpose, and that this, like many other operations of his providence, seemingly destructive and chaotic in its first effects, is nevertheless a work of beneficence and order.

1. The greater proportion of large, rounded boulders in the American drift, as compared with the European, is a singular fact not fully met by the above explanation; since, while the number of mountain-peaks rising above the ice in Europe If would account for the frequency of large, angular fragments transported upon its surface, there would seem to be no reason why the drift, carried along by a mass of ice having the same thickness in both continents, should not contain as many

from east to west, across the country, are not exactly at right angles with the normal direction of the glacier marks, though nearly so. It is this formation of the surface of the land which makes the glacial phenomena so interesting between Bangor and the sea, especially where one can connect them with like traces farther north. The road from Bangor to Mount Desert passes in succession over all these ridges, ascending to the heights and descending into the intervening depressions; thus rising three times from the bottom of a valley over the ridge intervening between it and the next valley, before reaching the southern coast of the large shore islands. Over all the elevations and in all the valley bottoms one may trace, in unbroken continuity, and almost at right angles with the direction of the mountains and of the valleys, the same set of lines or glacial marks that we have already traced to the north of Bangor, running due north and south until they disappear under the arm of the sea which separates Mount Desert from the coast. They reappear on the north shore of the island itself, passing over its higher summits to lose themselves finally under the level of the ocean. Not only are the characteristic marks to be followed along the entire length of the road, but the whole surface of the country is moutonnee; namely, worn into those rounded, knoll-like surfaces so frequently alluded to in this and previous chapters, and so well known in Switzerland as due to glacial action. Bald Mountain is a striking example of this kind of hill. This region is literally strewn with huge boulders, sometimes forty or fifty feet high. For the most part they seem to belong to the neighboring hills, and have not travelled a great distance. There are many of these boulders, however, which add their testimony to show that the path of the great ice-plough has been from north to south. This is especially the case with the granite rock of Dedham, so -well characterized by its large feldspar crystals -detached masses of which are frequently found to the south of that locality, but never to the north of it. Occasional boulders of a much more northern origin are not wanting. Another link in the evidence is that, wherever the marks are preserved on any abruptly rising ground, they occur on its northern side, and do not appear on the southern one. Evidently the abrading agent advanced from the

and had their origin in the Alps. Before they attracted the attention of scientific men, these dislodged masses were so generally recognized as strangers to the soil that in Germany, among the common people, they went by the name of Fundlinge, -homeless children. They are indeed the wandering Bohemians among rocks. The first interpretation of these phenomena, which very naturally suggested itself, when they began to be systematically studied, was that of their transportation by water. It was supposed that irruptions of the northern oceans had swept the loose masses of Scandinavian rock over adjoining countries, and that large lakes within the Alps had broken their natural barriers, and poured down into the plains, carrying with them debris of all sorts, and scattering them over the lowlands. But soon it was found that this theory did not agree with the facts; that the valleys of the Alps, for instance, had sent out boulders, not only northward, but southward and westward also, and that their distribution was often so regular, and their position so isolated, on high elevations, as to preclude the idea that immense tidal waves, freshets, or floods had so arranged them. Nature is so good a teacher that, the moment we touch one set of facts, we are instinctively, and almost unconsciously, led to connect them with other phenomena, and so to find their true relations. The boulders of the plains soon began to be compared with the boulders of the higher valleys; ice itself I was found to be a moving agent; and it was I presently ascertained that the transportation I of loose materials by existing glaciers, and their mode of distributing them, corresponded exactly with the so-called erratic phenomena of Central Europe and England. With these results were soon associated a great number of correlative facts; -the accumulation of loose materials under the glacier and upon its sides, as well as upon its surface, the trituration of the former until they were ground to a homogeneous paste, and the regular arrangement of the latter as they successively fell upon the glacier, and were borne along upon its back, retaining all the sharpness of their angles, because they were subjected to no pressure; the characteristic markings, furrowing, grooving, scratching, and polishing of the surfaces over which the glacier passed, as well as of the pebbles and stones held fast in its mass,

level of the slate beds, and upon its surface there is no trace of rectilinear lines and grooves, but simply the usual irregular, winding marks arising from the action of running water, and following all the structural inequalities. The valley as a I whole is a rather shallow depression, sinking a little more sharply toward the centre, and rising gradually east and west of the river-banks. The whole rock surface, with the exception of the river-bed, is glaciated, and it ,is impossible to overlook the fact that the same agent which has fashioned the bottom of the valley up to the adjoining hills has also grooved and scratched, at right angles with their structure, the upturned beds trending across it. The absence of angular ledges in a region exclusively composed of uplifted slaty rocks is very remarkable. Facts like these show that a careful survey may furnish the means of actually measuring the extent of denudation or abrasion resulting from the grinding power of glaciers. They may even settle the question as to the origin of lake-basins now under discussion among geologists. The extensive excavations made by the quarrying operations in these rocks give the most admirable chances for investigation. These slates are themselves of admirable quality, and are much used as roofing-slates. About a mile to the west of the quarries, near Merrill, there are large morainic accumulations of loose materials of the kind I have called bottom or ground moraines, though here they are not exactly in the form of horsebacks. Immediately above the quarries at Brownville, where the drift has been recently removed to facilitate the quarrying, there are good sections where these bottom moraines, trending in the direction of the hills to the east of the valley, may be easily studied. They rest immediately upon the edges of the upturned beds, the whole mass being a mixture of the most heterogeneous rocky materials uniformly mixed. Nowhere in this neighborhood have I seen anything like a distinct lateral moraine; but near the church, an un- mistakable terminal moraine, across which the liver has cut its bed, spans the valley. The exhibition of glacial phenomena is so complete here, that it seems superfluous to follow similar facts through localities where, owing to the character of the rocks and the lay of the land, they are less distinct. As, however,

the same time my reasons for believing that immense masses of ice would move over an open plain nearly as rapidly as in a slanting valley, and from the same causes as those which determine the advance of the Swiss glaciers down the Alpine valleys. This article appeared in June, 1864. I had intended to follow it with one upon the appearances of the drift in this country; and in September I went to Maine in order to examine the drift phenomena on the islands and coast of that State, and compare them with those of the Massachusetts shore. At Bangor I fell in with a friend, who, when he heard the object of my journey, proposed to me to pass a day or two in a drive with him northward along the "horsebacks," in the direction of Mount Katahdin. I desired nothing better; for a previous glimpse of one horseback in the neighborhood of Aurora had already shown me their morainic character, and they therefore were immediately connected with my present investigation. It would give me, besides, an opportunity of carrying out my survey on a much larger plan. As I had already satisfied myself, in this and previous journeys from Portland to Bangor, that the traces of glacial action occurred over all that region, this excursion would enable me to follow them north- ward to a considerable distance, while on my return I could track them down to the coast in continuous connection. I dwell upon the character of this investigation, because, numerous as have been the local observations of this kind, I am not aware that extensive tracts of land have been systematically surveyed, com- pass in hand, with the view of ascertaining the continuity of these marks in definite directions. I gladly accepted my friend's offer; and to this incident I owe some of the pleasantest days I have ever spent in travelling, and the knowledge of some important, and I believe novel facts in glacial phenomena. It was late in September, just at the turn of the leaf; the woods were in all their golden and crimson glory, with here and there a purple beech, or a background of dark green pines. Familiar as we all are with the brilliancy of the autumnal foliage in the neighbor- hood of our towns, one must see it in the unbroken forest, covering the country with rainbow hues as far as the eye can reach, in order to appreciate fully its wonderful beauty. A few words on this

Mount Desert, but on a former occasion. I then noticed, that, at intervals, between Bangor and Calais and over the whole track from Calais to Eastport, numerous polished surfaces are visible, with distinct scratches and furrows pointing due north. I may say, therefore, from my own personal observation, that the State of Maine, for nearly its whole width, that is, over four degrees of longitude, and between latitude 44° and 45°, bears all the characteristic indications of glacial action on its surface. But while many of these phenomena are perfectly simple and clear to one intimately acquainted with the effects produced by moving masses of ice, I have noticed near Bangor, and more especially in the neighborhood of Waterville, facts not so readily explained, though I believe I have found their true solution. Ordinarily all the glacial marks in a given locality run in one direction, and have certainly been produced simultaneously by one and the same agent, however opinions may differ as to the nature of that agent. But on Ledge Hill, five and a half miles from Bangor, faint striae may be seen pointing due north, while upon the same slab are other lines pointing northwest, forming an angle of forty-five degrees with the first. I believe that here we have two successive sets of lines, the later ones having partially obliterated the first. The height of the ridge may have determined a change in the course of the ice, when it had diminished in thickness, and no longer acted with the same undeviating force. At Waterville the facts are still more perplexing. On the road to Benton, near the house of G. W. Drummond, are slaty rocks striking northeast, upon the surface of which are again two sets of marks, -one consisting of large, distinct scratches and furrows trending due north, while the others are finer, less distinct, and point east-northeast. On the road to Winslow, near the house of Henry Gichell, the same two systems of scratches may be seen on flat slabs of rock along the roadside. From the formation of the land in this region, I am inclined to believe the second agent -namely, that to which the scratches bearing east should be ascribed -to have been icebergs. There is high land two or three miles beyond these rocky surfaces, in Benton township; and the flat over which the Sebasticook River flows extends to these heights. The ice is

ripening of the foliage alluded to above has also its counterpart in the fruits. Here and there a single apple or peach or pear ripens prematurely, while all the rest of the fruit remains green, or a separate branch brings its harvest to maturity in advance of all the surrounding branches. No doubt the brilliancy of the change in the United States, as compared with other countries, is partly due to the dryness of the climate; and indeed it has been observed that certain European flowers take on deeper hues when transplanted to America. But I believe the cause lies rather in the special character of certain American plants and trees. The Virginia-creeper, for instance, which is much cultivated now in France and Germany, turns to as brilliant a scarlet in a European garden as in its native woods. But let us return to our horsebacks. At the very beginning of our journey, we followed one of them for a considerable distance after leaving Bangor, on our way to Oldtown, besides which, we saw a number of similar ridges running parallel with it. 1. The name is somewhat descriptive, for they are shaped not unlike saddles with sloping sides and flattened summits. They consist of loose materials of various sizes, usually without marked -evidence of a regular internal arrangement, though occasionally traces of imperfect stratification are perceptible. Sometimes they follow horizontally, though not with an absolutely even level, the trend of a rocky ledge; again, they themselves seem to have built the foundation of their own superstructure, being composed of the same homogeneous elements which cover the extensive flats over which they run with as great regularity as upon a more solid basis. The longest of these horsebacks -and they sometimes stretch, as I have said, for many miles –trend mainly from north to south, though their course is somewhat winding, seldom following a perfectly straight line. They are unquestionably of a morainic nature, and yet they are not moraines in the ordinary sense of the term, but rather ridges of glacial drift heaped up in this singular form, as if they had been crowded together by some lateral pressure. Had they been accumulated and carried along upon the edge of the glacier, they could not be found in their present position. They differ also from moraines proper in their rounded materials, containing many scratched and polished

action of glaciers on the rocks over which they move-present the most varied outlines, sometimes flat, sometimes bulging, with inclined slopes. But whether more or less prominent, they are always rounded, dome shaped, and the larger furrows, like the smaller striae and grooves, are invariably straight. Never do we find winding, branching furrows determined by the inequalities in the hardness of the rock, or by pre-existing fissures, as is the case wherever rocks are worn by water, or rather by sand and pebbles set in motion by water. While upon the subject of glacial phenomena in general, and in order not to interrupt r too frequently the account of my own journey, I may here enumerate some of the localities in the State of Maine where glacial marks are most distinct. They are so numerous, that I must limit myself to those where the traces are most remarkable. To the east of Portland there are a number of ledges where they are well preserved, and they exist also upon some rocky surfaces in the islands of the bay. Rocky ledges occur frequently between Yarmouth and Lewiston, the surface of which is polished and scratched from north to south. These ledges are partly covered by morainic accumulations. West of Lewiston, along the Little Androscoggin, there is a coarse clay slate distinctly scratched in the same way. To the east of Lewiston, along Lake Winthrop, there are surfaces of clay slate intersected by greenstone dikes exhibiting also the characteristic markings; and an immense median moraine in the same locality cannot escape notice. A few miles to the west of West Waterville a terminal or front moraine is thrown across the neck of the lake, forming a barrier to which this sheet of water owes its existence. Half- way between Waterville and West Waterville are fine polished and striated surfaces. At Clinton, as also between Etna and Newport, the marks are very distinct. In all these localities the lines run due north and south. To the west of Bangor the country is rolling and rather flat. Here the roches moutonnees are numerous, with polished surfaces, upon which the scratches and grooves are very distinct, but bearing generally north-northwest, over beds of slaty rock striking northeast. These rocks are partially covered by drift, in which scratched pebbles are not rare, though it contains but few large boulders. In the immediate neighborhood

mounds. The most perfect one I have seen stretches through Lagrange town- ship, between Bangor and Mount Katahdin, its direction being mainly from north to south. Leaving the horsebacks and the open country on the second day of our drive, we entered upon a more wooded region, which brought us through the townships of Lagrange and Brownville, to the Ebeeme Mountains, at the foot of which the Katahdin Iron Works are situated. This is not only a very picturesque spot, but a most interesting locality with reference to glacial phenomena. To the north of the Iron Works there are two ranges of hills, one to the east, the more prominent masses l of which are respectively known by the names of Horseback and Spruceback, while to the west corresponding summits have been christened the Iron Mountain and Chairback. These two ranges are separated by a depression called the Gulf, at the foot of which, between Horse- back and Iron Mountain, there lies a little lake. Here a practiced eye will at once detect the unmistakable action of a glacier in two successive periods of its history. In the direction of Iron Mountain and the Chairback, one hundred feet and more above the level of the lake, may be seen old lateral moraines, more or less disintegrated, marking an ancient glacial level. At a much less height, indeed but little above the bottom of the valley, a magnificent crescent-shaped terminal moraine is thrown across the southern end of the lake. By this wall the waters drained from the whole valley are held back to form a lake, although the barrier is not perfectly impassable, for a little stream oozes through it, just in front. Evidently this moraine is an accumulation of loose materials, pressed forward by the great glacier once filling the Gulf, at the time when the ice was circumscribed within the limits of the valley itself. To the east and west of it there are, however, lateral moraines, resting on a much higher level, and showing the extraordinary thickness of the glacier at a still older period. This structure strikingly resembles that of the morainic accumulations in the trough holding the present glacier of the Upper Aar in Switzerland. At its extremity stands a large, crescent-shaped moraine, corresponding in size and form with that of the Katahdin Iron Works. The loose materials thrown on either side of the valley,

to the right and left, extending in advance of the front moraine, and resting far above the present surface of the ice, may be compared to the higher lateral moraines of this ancient Maine glacier. In short, were the ice suddenly to disappear from the Alpine valley in which the Aar glacier lies, the rocky frame- work of loose fragments it has built around" itself would be almost identical with that of the so-called Gulf at the Katahdin Iron Works. In both instances, the lateral moraines on a higher level indicate an earlier phase in the history of the glacier, when the ice was thicker; while the terminal moraine records the wasting of the glacier, until it occupied a much smaller area. As the Gulf is an interesting locality for the study of ancient glacial phenomena in Maine, I must point out its bearings with more precision, for the benefit of those who may care to verify my statements by personal observation. To the east of the hotel there is a knoll, on which stand the smelting-works. This knoll itself forms a part of the moraine; but its character may be more distinctly appreciated from the shore of the lake, looking toward the smelting-works. In this position, the abrupt inner side of the crescent-shaped wall faces the observer. The traces of this local glacier in two successive phases of its existence are not more distinct than are those of the great ice-sheet in which all lesser glaciers were once merged, over the whole region. And not here alone. I have tracked its footsteps on its southern march from the Katahdin Iron Works to Bangor, and thence to the sea-shore. Every natural surface of rock is scored by its writing, and even the tops of the mountains attest, by their rounded and polished summits, that they formed no obstacle to its advance. It has been assumed by some geologists, and especially by Sir Charles Lyell, that the ice-period was initiated by the spread of local glaciers from special centres. The particular character of the more extensive glacial phenomena satisfies me, on the contrary, that they must have preceded in course of time all mere local glaciers, and that the latter are but the remnants of the great ice-sheet lingering longer in higher and more protected valleys. From the evidence we have of its thickness and extent, such a mass of ice advancing over the country would have swept away all evidences of local glaciers, all morainic accumulations