Geological Sketches
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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 seemed serious enough. It is but lately, that, in turning over the leaves of a journal, published some twelve or fifteen years ago, to look for a forgotten date, I was amused to find a formal announcement, under the signature of the greatest geologist of Europe, of the demise of the glacial theory. Since then it has risen, phoenix-like, from its own funeral pile. Even when I arrived in England, many of my friends would fain have dissuaded me from my expedition, urging me to devote myself to special zoological studies, and not to meddle with general geological problems of so speculative a character. "Punch" himself did not disdain to give me a gentle hint as to the folly of my undertaking, terming my journey into Scotland in search of moraines a sporting-expedition after "moor-hens." Only one of my older scientific friends in England, a man who in earlier years had weathered a similar storm himself, shared my confidence in the investigations looked upon by others as so visionary, and offered to accompany me in my excursion to the North of England, Scotland, and Wales. I cannot recur to that delightful journey without a few words of grateful and affectionate tribute to the friend who sustained me by his sympathy and guided me by his knowledge and experience. For many years I had enjoyed the privilege of personal acquaintance with Dr. Buckland, and in 1834, when engaged in the investigation of fossil fishes, I had traveled with him through parts of England and Scotland, and had derived invaluable assistance from his friendly advice and direction. To him I was indebted for an introduction to all the geologists and paleontologists of Great Britain, with none of whom, except Lyell, had I any previous personal acquaintance. Through him I obtained not only leave to examine all the fossil fishes in public and private collections throughout England, but the unprecedented privilege of bringing them together for closer comparison in the rooms of the Geological Society of London. A few years later he visited Switzerland, when I had the pleasure of showing him, in my turn, the glacial phenomena of my native country, to the study of which I was then devoting all my spare time. After a thorough survey of the facts I had collected, he became satisfied that my interpretation of them was likely to 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 Scot- land 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 mountains; wherever we find one of these ancient semicircular walls of unusual size, there we may be sure the glacier resolutely set its icy foot, disputing the ground inch by inch, while heat and cold strove for the mastery. There may have been a succession of cold summers, or, if now and then a warmer summer intervened, a colder one followed, so that the glacier regained the next year the ground it had lost during the preceding one, thus continuing to oscillate for a number of years along the same line, and adding constantly to the debris collected at its extremity. Wherever such oscillations and pauses in the retreat of the glacier occurred, all the materials annually brought down to its terminus were collected; and when it finally disappeared from that point, it left a wall to mark its temporary resting-place. By these semicircular concentric walls we can trace the retreat of the ice as it withdrew from the plain of Switzerland to the fastnesses of the Alps. It paused at Berne, and laid the foundation of the present city, which is built on an ancient moraine; it made a stand again at the Lake of Thun, and barred its northern outlet by a wall which holds its waters back to this day. Other moraines, though less distinct, are visible nearer the base of the Bernese Alps, and, above Meyringen, the valley is spanned by one of very large dimensions. Again, on the other side of the first chain of high peaks, the glacier of the Rhone, descending the valley toward the Lake of Geneva, has everywhere left traces of its ancient extension. We find the valley crossed at various distances by concentric moraines, until we reach the lake. There are no less than thirteen concentric moraines immediately below the present termination of the glacier of the Rhone, the one nearest to the ice and the last formed, marking its present boundary. Others are visible half a mile, a mile, and two or three miles beyond, near the villages of Obergestelen and Munster. One of the largest and finest of these ancient moraines of the glacier of the Rhone stands at Viesch, and extends across the whole valley, while the Rhone, already swollen by many mountain-torrents, has cut .its way through it. Lower down, we meet with traces of other ancient glaciers, reaching laterally the main glacier, which occupied the centre of the valley. Such was the glacier of Viesch, when it extended as 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 in the Canton of Valais, the inhabitants of the upper valleys adhered to the Protestant faith. Shut out from ordinary communication with the Protestant churches by the Bernese Oberland, the account states that these peasants braved every obstacle to the exercise of their religion, and used to carry their children over a certain road by the valley of Viesch, across the Alps, to be baptized at Grindelwald, on the farther side of the glaciers of Aletsch and Viesch. I could not understand this statement, for no such road exists, or could be conceived possible at present; nor was there any knowledge of it among the guides, intimate as they are with every feature of the region. Impressed, however, with the idea that there must be some foundation for the statement, I carefully examined the ground, and, penetrating under the glacier of Aletsch, actually found, a number of feet below the present level of the ice, the paved road along which these hardy people traveled to church with their children, and some traces of which are still visible. It has been almost completely buried, although here and there it reappears; but at this day it is completely impassable for ordinary travel. Evidence of a like character is found in a number of facts cited by Venetz in his celebrated paper upon the variations of temperature in the Swiss Alps, drawn from the parish and commune registers of the Canton of Valais. Among these are acts concerning the right to roads which are now either entirely hidden by ice or rendered nearly useless by the advance of the glacier, a lawsuit respecting the use of a forest which no longer exists but the site of which is covered by a glacier, and other records of a similar character. The only document so far as I know, previous to this century, which furnishes the means of delineating with any accuracy the former boundary of a glacier, is a topographical plan of the environs of the Grimsel, including the extremity of the Aar, making a part of Altomann's work upon the Alps. In 1740, Kapeler, a physician of Lucerne, undertook a journey to the mountains of the Aar, to visit certain crystal grottos, now well known, but then recently discovered. He prepared a map it of these grottos and their vicinity, in which they are represented as being situated at some distance from the extremity of the glacier, in a the lower end of which is now 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. The result of all these surveys has been a distinct recognition of not less than seven gigantic glaciers descending from the northern and western slopes de of the Alps to the adjoining hilly plains of Switzerland and France. It is most interesting to trace their outlines upon a-recent map of those countries, but it requires that kind of intellectual effort of the imagination without which the most brilliant results of modern science remain an unmeaning record to us. Let us, nevertheless, try to follow. The glacier of the Rhone, occupying the whole space between the Bernese and Valesian Alps, filled to overflowing the valley of the Rhone; at Martigny it was met by a large tributary from Mont Blanc, by the side of which it advanced into the plain beyond, filling the whole Lake of. Geneva, and covering the beautiful Canton de Vaud and parts of Fribourg, Neuchatel, Berne, and Soleure, rising to the crest of the Jura, and in many points penetrating even beyond its outer range. To the east of this, the largest of all the ancient glaciers of Switzerland, we find the ancient glacier of the Aar, descending from the northern slope of the whole range of the Bernese Oberland. The glaciers that once filled the valley of Hasli, from the Grimsel to Meyringen, and those that came down from the Wetterhorner, the Schreckhorner, the Finster-Aarhorn, and the Jungfrau through the valleys of Grindelwald and Lauterbrunnen, united in a common bed, the bottom of which was the present basin of the lakes of Brientz and Thun. These were joined by the glaciers emptying their burden through the valley of the Kander. To these combined glaciers the formation of the terminal moraine of Thun must be ascribed. But before this had been formed, the glacier of the Aar, in its amplest extension, had also reached the foot of the Jura, without, however, spreading so widely as the glacier of the Rhone. Farther to the east Professor Guyot has traced the boundaries of three other colossal glaciers, one of which derived its chief supplies from the Alps of Uri, bringing with it all the tributaries which the main glacier coming down from the St. Gothard received right and left, in its course through the valley of the Reuss and the basins of the lakes of Lucerne and Zug. The second, born in the Canton of Glaris, followed mainly the present course of the Linth and the basin of the Lake 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 modern glaciers of Europe, I look back upon them from another continent, and it seems to me that I have, as it were, a bird's-eye view of their whole extent. I confess that this distant retrospect of the subject has been to me almost as fascinating as were the researches of my earlier years in the same direction. I wish that I could present it to the minds of my readers with something of the attraction it possesses for me. I trust, however, that I have made it plain to them that the great mountain-chain of the Alps has been a central axis from which immense glaciers at one time descended in every direction, not only to its base, beyond which the lowlands extend in flat undulations, but to a greater or less distance over the adjoining plains; while at present they are confined to the higher valleys. The first attempts at a generalization concerning their origin started from the assumption that they must have been formed between the high ridges from which they seem to flow down. My own theory was also at first, that the upheaval of the Alps must, in some way or other, have been connected with these phenomena. But it soon became evident to me that these views were inadequate to account for the former presence of extensive glaciers in other parts of Europe; and even within the range of the Alps there were insuperable objections to their final admission. If the ancient glaciers had been first formed among the highest mountains, and extended, downwards into the plains, the largest and highest moraines ought to be the most distant, and to be formed of the most rounded masses; whereas the actual condition of the detrital accumulations is the reverse, the distant materials being widely spread, and true moraines being found only in valleys connected with great chains of lofty mountains. Again, all these moraines are within one another, -the most distant from the glacier to which they owe their origin, encircling all those which are nearer and nearer to it within the same glacial basin. As no glacier could reach its farthest moraine without pushing forward all the intervening loose materials, it is self-evident that the outer moraines were first formed, while those nearer the glacier were built up subsequently, in the order in which they follow one another from the lower valleys to the higher levels at which alone glaciers exist at present. Thus we 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, Viesch, built on such moraines, with the river running through their centre. If we need further confirmation of the fact that these accumulations on either side of this and other Swiss lakes are ancient lateral moraines, we have it in their connection with the walls of a like nature at their lower end, where we find again transverse moraines barring their outlet, and also on the continuity of long trains of fragments of similar rocks extending side by side across wide plains for great distances without mixture. From the beginning of my investigations upon the

glaciers, I have urged these two points as most directly proving their greater extension in former times, and more recent researches constantly recur to this kind of evidence. All our lakes would be filled with loose materials, had their basins not been sheltered by ice against the encroachments of, well river-deposits during the transportation of the erratic boulders to the farthest limits of their respective areas. All the continuous trails of rocks derived from the same locality would have been scattered over wide areas, had they not been carried along in unyielding tracks like moraines. On a small scale the waters of the Rhone and of the Arve recall to this day such a picture. There are few travellers in Switzerland who have not seen these two rivers, where they flow side by side, at the southern extremity of the lake, meeting, but not mingling, the different color of their water marking the two parallel currents. In old times, when the glaciers filled all the valleys at the base of Mont Blanc, and to the east of it, uniting in the valley through which now runs the river Rhone, the glacier of the Arve came down to meet the ice from the valley of the Rhone, in the same manner as the river Arve now comes to meet the waters of the Rhone where they rush out from the southern end of the lake. This would be the proper place to consider the formation of the lakes of Switzerland, as well as their preservation by the agency of glaciers. But this subject is so intricate, and has already given rise to so many controversies which could not be overlooked in this connection, that I prefer to pass it over altogether in silence. Suffice it to say that not only are most of the lakes of Switzerland hemmed in by transverse moraines at their lower extremity, but the lakes of Upper Italy, at the foot of 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 nine thousand feet, and across the whole plain of Switzerland, as I have stated, one may trace the glaciers by their moraines, by the masses of rock they have let fall here and there, by the drift they have deposited, to the very foot of the opposite chain, where they have dropped their boulders along the base of the Jura. Ascending that chain, one finds the grooved, polished, and scratched surfaces to its summit, on the very crest of which bou1ders entirely foreign to the locality are perched. Follow the range down upon the other side and you find the same indications extending into the plains of Burgundy and France beyond. With a chain of evidence so complete, it seems to me impossible to deny that the whole space between the opposite chains of the Alps and the Jura was once filled with ice; that this mass of ice completely covered the Jura, with the exception of a few high crests perhaps, rising island-like above it, and mounted to a height of some nine thousand feet upon the Alps, while it extended on the one side into the northern plain of Italy, filling all its depressions, and on the other down

to the plains of Central Europe. The only natural inference from these facts is, that the climatic conditions leading to their existence could not have been local; they must have been cosmic. When Switzerland was bridged across from range to range by a mass of ice stretching southward into Lombardy and Tuscany, northward into France and Burgundy, the rest of Europe could not have remained unaffected by the causes which induced this state of things. It was this conviction which led me to seek the traces of glaciers in Great Britain. I had never been in the regions I intended to visit, but I knew the forms of the valleys in the lake-country of England, in the Highlands of Scotland, and in the mountains of Wales and Ireland, and I was as confident that I should find them crossed by terminal moraines and bordered by lateral ones, as if I had already seen them. The reader must not suppose, when I describe these walls formed of the debris of the glacier as consisting of boulders, stones, pebbles, sand, and gravel, a rough accumulation of loose materials indiscriminately thrown together, that we find the ancient moraines presenting any such appearance. Time, which mellows and softens all the wrecks of the past, has clothed them with turf, grassed them 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 growing grandeur of these ancient glaciers, even while they were retreating into the heart of the Alps. In proportion as they left the plain, the landscape must have gained in imposing effect in consequence of the isolation of these immense masses of ice, which in their united extension may have recalled rather the immensity of the ocean, than the grandeur of Alpine scenery.

2. This map, with all its details arid measurements, is reproduced (Pl V. fig. 1) in my "Systeme Glaciare," It was accompanied by an explanatory paper in the form of a letter to Altmann, then Professor at Berne.

THE PARALLEL ROADS OF GLEN ROY IN SCOTLAND.

THERE are phenomena in nature which give the clew to so many of its mysteries, that their correct interpretation leads at once to broad generalizations and to the rapid advance of science in new directions. The explanation of one very local and limited problem may clear up many collateral ones, when its solution includes the answer to a whole set of kindred inquires. The "parallel roads" of Glen, Roy offer such a problem. For half a century they have been the

subject of patient investigation and the boldest speculation. To them natural philosophers have returned again and again to test their theories, and until they are fully understood no steady or permanent advance can be made in the various views which they have suggested to different observers. The theory of the formation of lakes by barriers, presented by McCulloch and Sir T. Lauder-Dick, that of continental upheavals and subsidences, advocated by Sir Charles Lyell and Charles Darwin, that of inundations by great floods, maintained by Professor H. D. Rogers and Sir George Mackenzie, that of glacial action, brought forward by myself, have been duly discussed with reference to this difficult case; have found their advocates, all have met with warm opposition, 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 with the rocky surfaces against which they move, as is the case with the glacier. On the contrary, being dashed to and fro, they strike and rebound, making a succession of blows, and never a continuous, uninterrupted pressure and friction. The same is true of all the marks made on rocky shores against which loose materials are driven by water-currents. They are separate, disconnected, fragmentary; whereas the lines drawn by the hard materials set in the glacier, whether light and fine or strong and deep, are continuous, often unbroken for long distances, and rectilinear. Indeed, we have seen that we have beneath every glacier a complete apparatus adapted to all the results described above. In the softer fragments path ground to the finest powder under the incumbent mass we have a polishing paste; in the hard materials set in that paste, whether pebbles, or angular rocky fragments of different sizes, or grains of sand, we have the various graving instruments by which the finer or coarser lines are drawn. Not only are these lines frequently uninterrupted for a distance of many yards, but they are also parallel, except when some change takes place in the thickness of the ice, which may slightly modify the trend of the mass, or where lines in a variety of directions are produced by the intermittent action of separate glaciers running successively at different angles over the same surfaces. The deeper grooves sometimes present a succession of short staccato touches, just as when one presses the finger vertically along some surface where the resistance is sufficient to interrupt the action without actually stopping it, a kind of grating motion, showing how firmly the instrument which produced it must have been held in the moving mass. No currents or sudden freshets carrying hard materials with them, even moving along straight path down hillsides or mountain-slopes, have ever been known to draw any such lines. They could be made only by some instrument held fast as in a vice by the moving power. Something of the kind is occasionally produced by the drag of a wheel

grating over rocks covered with loose materials. It has been said that grounded ice or ice-bergs floating along a rocky shore might produce similar marks; but they will chiefly be at the level of high-water mark, and, if grounded, they will trend in various directions, owing to the rocking or rotating movement of 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 comparison. I have not become acquainted with these marks in regions where glaciers no longer exist, and made a theory to explain their presence. I have, on the contrary, studied them I where they are in process of formation. I have seen the glacier engrave its lines, plough its grooves and furrows in the solid rock, and polish the surfaces over which It moved, and I was familiar with all this when I found after-wards appearances corresponding exactly to those which I had investigated in the home of the present glaciers. I could therefore say, and I think with some reason, that this also is the work of the glacier acting in ancient times as it now acts in Switzerland. There is another character of glacial action distinguishing it from any abrasions caused by water, even if freighted with a large amount of loose materials. On any surface over which water flows we shall find that the softer materials have yielded first and most completely. Hard dikes will be left standing out, while softer rocks around them are worn away, -furrows will be eaten into more deeply, -fissures will be widened, -clay-slates will be wasted, -while hard sandstone or limestone and granite will show greater resistance. Not so with surfaces over which the levelling plough of the glacier has passed. Wherever softer and harder rocks alternate, they are brought to one outline; where dikes intersect softer rock, they are cut to one level with it; where rents or fissures traverse the rock, they do not seem to have been widened or scooped out more deeply, but their edges are simply abraded on one line with the adjoining surfaces. What-ever be the inequality in the hardness of the materials of which the rock consists, even in the case of pudding-stone, the surface is abraded so evenly as to leave the impression that a rigid rasp has moved over all the undulations of the land, advancing in one and the same direction and levelling all before it. Among the inequalities of the glacier-worn surfaces which deserve especial notice are the so-called roches moutonnees. They are knolls of a peculiar appearance, frequent in the Alps, and first noticed by the illustrious De Saussure, who designated them by that name, because, where they are numerous and seen from a distance, they resemble the rounded backs of a flock of sheep resting on the ground. These knolls are the result of the prolonged abrasion of masses of rocks 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 the knolls are low and slope gently downward in every direction, they present the characteristic glacier-surfaces equally on all sides. This circumstance should be borne in mind by all who investigate the traces of glacier-action; for the inequality in the surfaces presented by the opposite sides of any obstacle in the path of the ice is often an important means of determining the direction of its motion. The other characteristic peculiarity of these roches moutonnees consists in the direction of the glacier-scratches, which ascend the slope to its summit in a direct line on one side, while they deviate, to the right and left on the other sides of the knoll, more or less obliquely according to its steepness. Occasionally, large boulders may be found perched on the very summit of such prominences. Their position is inexplicable by the supposition of currents as the cause of their transportation. Any current strong enough to carry a boulder to such a height would of course sweep it on with it. This phenomenon finds, however, an easy explanation in the glacial theory. The thickness of such a sheet of ice is of course less above such a hill or mound than over the lower levels adjoining it. Not only will the ice melt, therefore, more readily at this spot, but, as ice is transparent to heat, the summit of the prominence will become warmed by the rays of the sun, and will itself facilitate the melting of, the ice above it. On the breaking up of the ice, therefore, such a spot will be the first to yield, and allow the boulders carried on the back of the glacier to fall into the hollow thus formed, where they will rest upon the projecting rock left uncovered. This is no theoretical explanation; there are such cases in Switzerland, where holes in the ice are formed immediately above the summit of hills or prominences over which the glacier passes, and into which it drops its burdens. Of course, where the ice is constantly renewed over such a spot by the onward progress of the glacier, these materials may be carried off again; but if we suppose such a case to occur at the breaking up of the glacier-period, in a locality from which the ice was disappearing forever, it is easy to account for the poising of these large boulders on prominent peaks or ledges. The appearances about the roches moutonnees, especially the straight scratches and grooves on the side up 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 decomposition to which they owe their separation from the solid rock is often still going on; Such debris are found everywhere about disintegrating rocks, and they constantly mingle with the loose fragments brought from a distance by various agencies. They are found upon and among the glacier-worn pebbles, especially where the latter have themselves been disturbed since their accumulation. They are also found among water-worn pebbles, wherever the rocky beds of our rivers or the rocky bluffs of our seashores crumble down. In investigating the character of loose materials transported from greater or less distances, either by the agency of glaciers or by water-currents, it is important at the very outset to discriminate between these deposits of older date and the local accessions mingling with them. Occasionally we may have also to distinguish between all these deposits and the debris brought down by land-slides, or by sudden, freshets transporting to a distance a vast amount of loose materials which are neither ice-worn nor water-worn. At Rossberg, for instance, in the Canton of Schwitz, the land-slide which buried the village of Goldau under a terrific avalanche, and filled a part of the Lake of Lauertz, spread an immense number of huge boulders across the valley, some of which even rolled up the opposite side to a considerable height. Many of these boulders might easily be mistaken for erratic boulders, were not the aggregate of these loose materials traceable to the hills from which they descended. In this case water had no part in loosening or bringing down this mass of fragments. They simply rolled from the declivity, and stopped when they had exhausted the momentum imparted to them by their weight. In. the case of the debacle of Bagnes, above Martigny, in a valley leading to the St. Bernard, the circumstances were very different. A glacier, advancing beyond its usual limits and rising against the opposite mountain-slope, dammed up the waters of the torrent and caused a lake to be formed. The obstruction gave way in the course of time, and the waters of the lake rushed out, carrying along with them huge boulders and a mass of loose materials of all sorts, and scattering them over the plain below. Such an accumulation of debris differs from the pebbles and loose fragments found in river-beds. The comparatively short 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 controversy among geologists respecting the nature and origin of the sheet of loose materials scattered over a great part of the globe turns upon it. The debris of which the drift consists are thrown together pell-mell, without any arrangement according to size or weight, larger and smaller fragments being mixed so indiscriminately that the heaviest materials may be on the very summit of the mass, and the lightest at the bottom in immediate contact with the underlying rock, or the larger pieces may stand at any level in the mass of finer ones. Impalpable powder coarse sand, rounded, polished, and scratched fragments of every size, are mixed together in a homogeneous paste, in which the larger materials are imbedded, to use a homely but expressive comparison, like raisins and currants in a pudding. The adhesive paste holding all these fragments together is, no doubt, the result of the friction to which the whole was subjected under the glacier, and which has worked some of the softer materials into a kind of cement. The mode of aggregation of water-worn materials is very different. Examine the shingle along our beaches; we find it so distributed as to show that the fading tide-wave has carried the lighter materials farther than the heavier ones, and the successive deposits exhibit an imperfect cross-stratification resulting from changes in the height of the tide and the direction of the wind. Moreover, in any materials collected under water we find the heavier t ones at the bottom, the lighter on the top. It is true that large angular boulders may occasionally be found resting upon beach-shingle, but their presence in such a connection is easily explained. They may have been dropped there by floating icebergs, or have fallen from crumbling drift-cliffs. I should add, in speaking of drift-materials, that, while we find the large angular boulders resting above them, we occasionally find boulders of unusual size mingled with them; but, when this is the case, such massive fragments are more or less rounded, polished, and marked in the same way as the smaller pebbles, or as the surfaces over which the glacier has passed. This is important to remember, because, when we examine the drift in countries where the ice, during the glacier-period, overtopped nearly all the mountains, so that few fragments could fall from them upon its surface, we find 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 drift-ponds, of our river-beds and estuaries, as well as the river-terraces standing far above the present water level. And now, if it be asked how much of this evidence for the former existence of glaciers is to be found in Great Britain, I answer, that there is not a valley in Switzerland where all these traces are found in greater perfection than in the valleys of the Scotch Highlands, or of the mountains of Ireland and Wales, or of the lake-region in England. Not a link is wanting to the chain. Polished surfaces, traversed by striae, grooves, and furrows, with a sheet of drift resting immediately upon them, extend throughout the realm,-the roches moutonnees raise their rounded backs from the ground there as in Switzerland, transverse moraines bar their valleys and lateral ones border them, and the boulders from the hillsides are scattered over the plains as thickly as between the Alps and the Jura, and are here and there perched upon the summits of isolated hills. This being the case, let us examine a little more closely the local phenomena connected with the ancient extension of glaciers in this region, and especially the parallel roads of Glen Roy. Among the Grampian Hills, a little to the northeast of Ben Nevis, lies the valley of Glen Roy, a winding valley trending in a northeasterly direction, and some ten miles in length. Across the mouth of this valley, at right angles with it, runs the valley of Glen Spean, trending from east to west, Glen Roy thus opening directly at its southern extremity into Glen Spean. Around the walls of the Glen Roy' valley run three terraces, one above the other, at different heights, like so many roads artificially cut in the sides of the valley, and indeed they go by the name of the "parallel roads." -These three terraces, though in a less perfect state of preservation, are repeated for a short distance at exactly the same levels on the southern wall of the valley of Glen Spean, just opposite the opening of the Glen Roy valley; that is, they make the whole circuit of Glen Roy, stop abruptly, on both sides, at its southern extremity, and reappear again on the opposite wall of Glen Spean.

Figure 1. (also see note 1.)

I should add, however, that all three do not come to this sudden 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 the centre free into which Glen Roy opens, while, by the time the water had sunk to the level of the lowest terrace, one of these barriers, that to the east, must have been removed, for the lowest terrace, as I have said, is continuous throughout the eastern part of Glen Spean. 1. Prepossessed as I was with the idea of glacial agency in times anterior to ours, these phenomena appeared to me under a new aspect. I found the bottom of Glen Spean so worn by glacial action as to leave no doubt in my mind that it must have been the bed of a great glacier, and Dr. Buckland fully concurred with me in this impression. Indeed, the face of the country throughout that region presents not only the glacier-marks in great perfection, but other evidences of the ancient presence of glaciers. There are moraines at the lower end of Glen Spean, remodelled, it is true, by the action of currents, but still retaining enough of their ancient character to be easily recognized; and some of the finest examples of the roches moutonnees I have seen in Scotland are to be found at the entrance of the valley of Loch Treig, a lateral valley opening into Glen Spean on its southern side, and, as we shall see hereafter, intimately connected with the history of the parallel roads of Glen Roy. These roches moutonnees may very fairly be compared with those of the Grimsel, and exhibit all the characteristic features of the Alpine ones. One of them, lying on the western side of the valley where it opens into Glen Spean, is crossed by a trap-dike. The general surface of the hill, consisting of rather soft mica, has been slightly worn down by atmospheric agencies, so that the dike stands out some three quarters of an inch above it. On the dike, however, the glacier-marks extend for its whole length in great perfection, while they have entirely disappeared from the surrounding surfaces, so as to leave the dike thus standing out in full relief. This is an instructive case, showing how little disintegration has gone on since the drift-period. All the currents that have swept over it, all the rains that have beaten upon it, have not worn away one inch from the original surface of the hill. I have observed many other roches moutonnees in Scotland, especially about the neighborhood of Loch A we, Loch Fyne, and Loch Etive. In fact, they may be found in almost all the glens of Scotland, in the lake-region of 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 mountains into Glen Spean had begun to retreat, and to form local limited glaciers, two of those lateral glaciers, one coming down from Ben Nevis on the southwest, the other from Loch

Treig on the southeast, extended farther than the others and stretched across Glen Spean. These two glaciers for a long time formed barriers across the western and eastern extension of this valley, damming back the waters which filled Glen Roy and the central part of Glen Spean. Evidently the glacier descending from Loch Treig was the first to yield, for, by the time the Glen Roy lake had sunk to the level of the lowest terrace, the entrance to the eastern extension of the valley must have been free, otherwise the water could not have spread throughout that basin as we find it did; but it would seem that by the time the western barrier, or the glacier from Ben Nevis, was removed, the sheet of water was too far reduced to have left permanent marks of its outflow into the Great Glen, except by disturbing and remodelling the large moraines of the older Glen Spean glacier. There are faint indications of other terraces in Glen Roy, even at a higher level than the uppermost parallel road, owing their origin probably to the short duration of a higher level of the glacier-lake, when the great general glacier had not yet been lowered to a more permanent level determined by a limited circumscription within the walls of the valleys. There are other terraces in neighboring valleys at still different levels, Glen Gloy, for instance, where the one horizontal road was no doubt formed in consequence of the damming of the valley by a glacier from Loch Arkeig. Mr. Darwin has seen another in Glen Kinfillin, which I would explain by the presence of a glacier in the Great Glen, the marks of which are particularly distinct about the eastern end of Glen Garry. The evidence of the ancient presence of glaciers is no less striking in other parts of the Scotch Highlands. Between the south-eastern range of the Grampian Hills, in For-farshire and Perthshire, and the opposite ridge of Sidlaw Hills, stretches the broad valley of Strathmore. At the time when Glen Spean received the masses of ice from the slopes of the western Grampian range, the glaciers descended from the valleys on the southern slope of the southeastern range and from those on the northern slope of 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, dropping 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 phenomena existed over the whole region. Among the localities of Scotland where the indications of glacial action are most marked is the region about Stirling. Near Stirling Castle the polished surfaces of the rocks with their distinct grooves and scratches show us the path followed by the ice as it moved down in a northeasterly direction toward the Frith of Forth from the mountains on the north-west. To the west of Edinburgh, also, there is a broad glacier track, showing that here also the ice was ploughing its way eastward to find an outlet on the shore. The western slope of the great Scotch range is no less remarkable for its glacier-traces. The heads of Loch Long, Loch Fyne, Loch Awe, and Loch Leven everywhere

show upon their margins the, most distinct glacial polish and furrows, while from the trend of these marks and the distribution of the moraines, especially about Ben Cruachan, it is obvious that in this part of the country the glaciers moved westward and southward. About Aberdeen, on the contrary, they moved eastward, while in the vicinity of Elgin they advanced toward the north. It thus appears that the whole range of the Grampians formed a great centre for the distribution of glaciers, and that a colossal ice-field spread itself over the whole country, extending in every direction toward the lower lands and the sea-shore, As the glaciers, which now descend through all the valleys of the Alps, along their northern as well as their southern slopes, and in their eastern as well as their western prolongation, though limited, in our days, within the valley-walls, nevertheless once covered the plain of Switzerland and that of Northern Italy, so did the ice-fields of the Grampians during the greatest extension of the Scotch glaciers spread over the whole country. They also were, in course of time, reduced to local glaciers, circumscribed within the higher valleys of the more mountainous parts of the country, until they totally disappeared, as those of Switzerland would also have done, had it not been for the greater elevation of that country above the level of the sea. Scotland nowhere rises above the present level of perpetual snow, while in Switzerland the whole Alpine range has an altitude favorable to the preservation of glaciers. In the range of the Jura, however, which had at one time its local glaciers also, but which nowhere now rises above 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 tracks of ancient glaciers might easily fancy himself crossing the ancient moraines at the foot of the northern slope of the range of Mont Blanc, through which the Arve has cut its channel, the valley of Chamouni standing in the same relation to Mont Blanc as the valley of Loch Nilly does to Ben Calcagh. I have dwelt thus at length on the glaciers of Great Britain because they have been the subject of my personal investigations. But the Scotch Highlands and the mountains of Wales and Ireland are but a few of the many centres of glacial distribution in Europe. From the Scandinavian Alps glaciers descended also to the shores of the Northern Ocean and the Baltic Sea. There is not a fiord of the Norway shore that does not bear upon its sides the tracks of the great masses of ice which once forced their way through it, and thus found an outlet into the sea, as in Scotland. Indeed, under the water, as far as it is possible to follow them through the transparent medium, I have noticed in Great Britain and in the United States the same traces of glacial action as higher up, so that these ancient glaciers must have extended not only to the sea-shore, but into the ocean, as they do now in Greenland. Nor is this all. Scandinavian

boulders, scattered upon English soil and over the plains of Northern Germany, tell us that not only the Baltic Sea, but the German Ocean also, was bridged across by ice on which these masses of rock were transported. In short, over the whole of Northern Europe, from the Arctic Ocean to the northern borders of its southern promontories, we find all the usual indications of glacial action, showing that a continuous sheet of ice once spread over nearly the whole continent, while from all the mountain-ranges descended those more limited glacial tracks terminating frequently in trans- verse moraines across the valleys, showing, that, as the general ice-sheet broke up and contracted into local glaciers, every cluster or chain of hills became a centre of glacial dispersion, such as the Alps are now, such as the Jura, the Highlands of Scotland, the mountains of Wales and Ireland, the Alps of Scandinavia, the Hartz, the Black Forest, the Vosges, ,and many others have been in ancient times.

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 of the upper roads. The outlet for the water at the period during which the second terrace was formed, not known when I visited Glen Roy, has been discovered by Mr. Milne-Holme, and also observed by Professor Jamieson. During the formation of the upper terrace the waters escaped through the western-most tributary of the river Spean, in the direction of the northeast corner of the woodcut, and during that of the lowest terrace, at the eastern end of Loch Laggan, also through the valley of the Spean. The state of preservation of the parallel roads is such as to prove that no disturbance of any importance can have taken place in the country since they were formed. Far from believing, therefore, that these remarkable shelves are ancient sea-beaches, I am prepared to maintain that, had the area occupied by them been sub- merged only for a few days, under an ocean rising and falling for several feet with every tide, no vestige would have been left of their former existence.

ICE-PERIOD IN AMERICA.

IN the autumn of 1846, six years after my visit to Great Britain in search of glaciers, I sailed for America. When the steamer stopped at Halifax, eager to set foot on the new continent so full of promise for me, I sprang on shore and started at a brisk pace for the heights above the landing. On the first undisturbed ground, after leaving the town, I was met by the familiar signs, the polished I surfaces, the furrows and scratches, the line-engraving of the glacier, so well known in the Old World; and I became convinced of

what I had already anticipated as the logical sequence of my previous investigations, that here also this great agent had been at work, although it was only after a long residence in America, and repeated investigations of the glacial phenomena in various parts of the country, that I fully understood the universality of its action. A detailed description of these appearances could hardly 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 south, with occasional slight inclinations to the east or west, according to the minor inequalities of the surface. There is, however, no decided modification of their general trend in consequence of the range of hills intersecting them at right angles for nearly the whole width of the continent between latitudes forty-six and fifty; indeed, the Canadian, or, as they are sometimes called, the Laurentian Hills, did not form a more powerful barrier to the onward progress of the immense fields of ice covering the continent than did the small hummocks, or roches moutonnees, in the Swiss valleys to the advance of the Alpine glaciers. In fact, these low hills may be considered as a succession of roches moutonnees trending in a continuous ridge from east to west, over which the masses of northern ice have moved unimpeded to the latitude of the Ohio. Owing to the absence of high mountain- ranges over this vast expanse of land, the glacial phenomena of America are not grouped about special centres of dispersion, radiating from them as in Europe. During the greatest extension of the ice-fields, there were but few prominent peaks rising above them, and dropping here and there huge boulders on their surface, to be transported to great distances without losing their rough angular character. When the temperature under which these vast frozen masses had been formed rose again, the wasting ice must have yielded first on its southern boundary, gradually and uniformly retreating to the Arctic regions, without breaking up into distinct glacial regions, separated from one another, each with its local distribution of erratic boulders and glacier-marks radiating from circumscribed areas on higher levels as they occur everywhere in Europe. It is true that there are a few localities within the Alleghany range, on the Green and White Mountains, and in parts of Maine, where it is evident that local glaciers have had a temporary existence; but even throughout this eastern coast-range the elevation of the mountains is so slight, and their trend so uniform in. a northeasterly and southwesterly direction through twenty degrees of latitude, that the localization of the phenomena is less marked than in Norway, Great Britain, or Switzerland. In short, the ice of the great glacial period in America moved over the continent as one continuous sheet, overriding nearly all the 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 on the prairies of Illinois or Iowa. One may follow these boulders to the fortieth degree of latitude, beyond which they become more and more rare, while the finer drift alone extends farther south. It is not only, however, by tracking the boulders back to their origin in the North that we ascertain the starting-point of the whole mass; we have another kind of evidence to J this effect, already alluded to in the description of the roches moutonnees. Wherever the natural surface of any hill, having a steep southern slope, is exposed, the marks are always found to be very distinct on the northern side and entirely wanting on the southern one, showing that, as in the case of many of the roches moutonnees in Switzerland, the mass moved up the northern slope, forcing its way against it, grinding and furrowing the northern face of the hill as it moved over it, but bridging the opposite side in its descent without coming into contact with it. This is true, not only of hills, but of much slighter obstacles which presented themselves in the path of the ice. Even pebbles imbedded in masses of pudding-stone, but rising sometimes above the level of the general surface, often have their northern side polished and scratched, while the southern one remains untouched. Moraines are not wanting to complete the chain of evidence respecting the ancient existence of glaciers in this country, although we cannot expect to find them here so frequently as in Europe, where the many local glaciers in circumscribed valleys afforded special facilities for the building up of these lateral and transverse walls. Over the broad expanse of the United States, on the contrary, with such slight variations of level, the disappearance of the ice at its breaking-up would naturally be more complete and continuous than in a country intersected by frequent mountain-chains, where the ice would linger in the higher valleys long after it had disappeared from the plains below. Yet it is evident that here also in certain localities the boundary line of the ice underwent oscillations, pausing here and there long enough to collect mounds of the same character as those spanning the valleys of Switzerland and Great Britain. We have several of these mounds in our immediate vicinity. The Waverley Oaks, so well known to all lovers of fine trees in our community, stand on an ancient 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 the characteristic composition of glacier-drift, and nowhere that of an aqueous stratified deposit, except when afterwards remodelled by the action of water. But of this stratified drift I shall have occasion to speak more in detail hereafter. There is, however, one circumstance, of frequent occurrence, along our New England shores, requiring special explanation, because it is generally misunderstood. Along our sea-shore, and even within the harbor of Boston, at the base of the harbor-islands, as well as the outlet of our larger Atlantic streams, numbers of boulders are found of considerable size; and this fact is often adduced as showing the power of water to transport massive fragments of rock to great distances, the mineralogical character of these boulders being frequently such as to show that they cannot have originated in the neighborhood of their present resting-places. But a careful examination of the surrounding country, and a comparison of the nature and level of the drift on the mainland with those of the same deposits on the harbor-islands, suggest a different explanation of these phenomena. The sheet of drift was once more continuous and extensive than it is now, and the localities 1n which we find these crops of boulders are spots where the tide has eaten into the drift, wearing away the finer materials, or the paste in which the larger fragments were imbedded, and allowing them to fall to the bottom, or where the same result has been produced by the action of rivers cutting their way through the drift, and thus finding an outlet to the sea. In short, instead of showing the power of currents to carry along heavy fragments, these stranded boulders prove, on the contrary, the inability of water to produce any such effect, since it is evident that the tides washing against the shore, or the rivers rushing down to the sea, were equally incapable of bearing off the weightier materials, and allowed them to drop to the bottom, while they readily swept away the lighter ones. Such localities compare with the surrounding drift much as the bottom of a gravel-pit which has been partially worked compares with its banks. Look into any gravel- pit, a portion of which has already been carted away. At its bottom a number of larger stones and boulders are usually lying, too heavy for the cart, and therefore left upon the spot. Fragments of the same size and character, and 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 same phenomena may be produced over level, open I countries. I believe that circumstances similar to those determining the more rapid advance of the glaciers from higher to lower levels at that point where the alternate thawing and freezing, the infiltration of water and consequent expansion of the ice under frost, are greatest, would also determine the motion of a large body of ice from north to south, since it would be along its southern limits that these conditions would prevail; while the great reservoir of snow at the north would correspond to the upper troughs of the present glaciers, from which their lower ranges are constantly fed. The change of snow into ice is owing to alternation of temperature, to partial melting and subsequent freezing, constantly renewed,- and also to the sinking of the mass upon itself in consequence of its own weight, the lower portions being thus forced out by the pressure of the superincumbent ice. Upon an inclined plane the movement consequent upon these changes will of course be downward; but what would be the result, if a field of snow many thousand feet thick, corresponding, except in its greater bulk, to the accumulations by which the present glaciers are caused, were stretched over an extensive level surface? The moisture from the upper superficial layers would permeate the larger mass as it now does the smaller one, trickling down into its lower portions, while the pressure from above would render the bottom hard and compact, changing it gradually into ice. If this should take place under climatic conditions which would keep the whole as a mass in a frozen state, the pressure from above would force out the lower ice in every direction beyond its original circumscription, thus enlarging the area covered by it, while the whole would subside in its bulk. Let us for a moment assume that such an accumulation of snow takes place around the northern and southern poles, stretching thence over the northern and southern hemispheres to latitude forty, and that this field of snow acquires a thickness of from twelve to fifteen thousand feet. Such a mass would subside upon itself in consequence of its own weight; it would be transformed into ice with a greater or less rapidity and completeness, according to the latitude determining the surrounding climatic Influences and the amount of moisture 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, Sweden, Scotland, England, and Ireland were covered by sheets of Ice many thousand feet in height, the ice-fields of Greenland must have shared in the same climatic influences, and have been much thicker and far more extensive than they are at present? Notwithstanding the absence of lofty mountain-chains in America, we are not wholly without the means of measuring the thickness of the ice-sheet, by comparing it, as in Europe, with some of our highest elevations. The slopes of the Alleghany range, wherever they have been examined, are glacier-worn to the very top, with the exception of a few points; but these points are sufficient to give us data for the comparison. Mount Washington, for instance, is over six thousand feet high, and the rough, unpolished surface of its summit, covered with loose fragments, just below the level of which glacier-marks come to an end, tells us that it lifted its head alone above the desolate waste of ice and snow. In this region, then, the thickness of the sheet cannot have been much less than six thousand feet, and this is in keeping with the same kind of evidence in other parts of the country; for, wherever the mountains are much below six thousand feet, the ice seems to have passed directly over them, while the few peaks rising to that height are left untouched. And while we can thus sink our plummet from the summit to the base of Mount Washington and measure the thickness of the mass of ice, we have a no less accurate indication of its extension in the undulating line marking the southern termination of the drift. I have shown that the moraines mark the oscillations of the glaciers in Europe. Where such accumulations of loose materials took place at its terminus, there we know the glacier must have held its ground long enough to allow time for the collection of these debris. In the same way we may trace the southern border of our ancient ice-sheet on this continent by the limit of the boulders; beyond that line it evidently did not advance as a solid mass, since it ceased to transport the heavier materials. But as soon as the outskirts of the ice began to yield and to flow off as water, the lighter portions of the drift were swept onward; and hence we find a sheet of finer drift-deposit, sand and gravel more or less distinctly stratified, carried to greater or less distances, and fading into the Southern States, where it mingles 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 rounded masses in one as in the other. The facts, however, are as I have stated them, and the difference may be due partly to the broken character of the ground over which the drift must have passed in Europe, subjecting it to a more violent process of friction and grinding than in America, and partly to the use that has been made of the drift-boulders during so many centuries for building purposes in the Old World, the drift-boulders being naturally taken first, because they are more easily reached, while the angular ones are frequently perched on almost inaccessible spots, Indeed, the stone fences in both countries tell us the use to which many of the rounded boulders have been put, and the ground in many parts of the United States has already been cleared to a great extent of its rocky fragments for this and like purposes, In the course of time they will, no doubt, disappear from the surface of this country, as they have done from that of Europe.

GLACIAL PHENOMENA IN MAINE

THREE or four years ago I began a series of papers in the "Atlantic Monthly," which, though they appeared as separate geological sketches, had, nevertheless, a certain sequence. These contributions have been unavoidably interrupted for more than two years; and, in taking up the thread again, my readers will excuse me if, by a rapid review of the subject then under discussion, I recall to them the point at which we parted. There were two sets of facts which first awakened the attention of geologists to the ancient extension of glaciers, though at first no investigator connected them with the agency of ice. The first was the presence of boulders in Central Europe and England, which had their birth-place far to the north of their actual position; the second was the presence of similar detached boulders scattered over the plain of Switzerland, and on the slopes of the Jura, which, on the contrary, had travelled from the south northward, 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, and coming into sharp contact with the rocks beneath; the accumulation of loose materials pushed along by the advancing ice, or carried on its edges, and forming ridges or walls at its terminus and on its sides. The study of these combined results of glacial action now became part of the subject, and were sought for by geologists wherever the erratic phenomena were investigated. Out of these comparisons has gradually grown a belief that, as the Alpine glaciers were formerly more extensive, so did the northern ice-fields, now confined to the Arctic

regions, once stretch farther south. I suppose there are few geologists now who would not readily give their assent to the glacial theory, expressed in this general form. But while the wider distribution of glacial phenomena from mountainous centres in ancient times is now generally admitted, the theory in its more universal application, involving, that is, the existence of an ice-sheet many thousands of feet in thickness moving across whole continents, over open, level plains as well as along enclosed valleys, still meets with many opponents, the staunchest of whom stand high as geological authorities. If not openly said, it is whispered, that, after all, this great ice-period is a mere fancy, worthy at best of a place among the tales of the Arabian Nights; that no moraines have ever been noticed in North America; and that what has been ascribed to the agency of terrestrial glaciers, upon this continent, is simply the work of icebergs stranding against a coast which has subsequently been raised, so that the boulders first deposited by the floating ice along the shores now lie inland at a great distance from the sea. According to this suggestion all the erratic phenomena in North America, the extensive sheets of drift, the continuous and prominent ridges of drift materials, the larger scattered boulders, the scratched, polished, and grooved surfaces, are the work of floating ice, poured forth, then as now, from the Arctic regions. If this be so, we should expect to find all these so-called traces of glacial action running from the coast inward. Let us see now how this agrees with the facts. I will not recapitulate the substance of my last article on this subject, "The Ice-Period in America." It gave a general summary of the glacial phenomena on this continent, as compared with those of Europe, stating at 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 change of color, which is as constant as any other botanical character (each kind of tree having its special tints peculiar to itself, and not reproduced by other kinds), may not be amiss. Indeed, not only does every species have its appointed range of color, but each individual tree has its history told more or less distinctly in the ripening of the foliage. A weaker or a younger limb may have put on its autumn garb, and be almost ready to drop its leaves, while the rest of the tree is untouched. A single scarlet maple red oak often gives us the most beautiful arrangement of tints, from the green of mid. summer, through every shade of orange and red; in the same way one leaf may riper unequally, its green surface being barred spotted with crimson or gold for days before the whole leaf turns. These differences give ample opportunity for studying the ripening process. In attempting to determine the cause of these changes, it ought not to be forgotten that they occur locally, and also make their appearance on particular trees much earlier than

upon others; so early, indeed, as to show clearly the fallacy of the prevalent idea that they are caused by frost. The temperature remains ten or fifteen degrees above the freezing-point for a month and more after a good many of our trees have assumed their bright autumnal hues. The process is, no doubt, akin to that of ripening in fruits; especially .in such fleshy fruits as turn from green to yellow, purple, or red, like apples, peaches, plums, cherries, and others. The change in color coincides with changes in the constitutive chemical elements of the plant; and this comparison between the ripening of foliage and fruit seems the more natural, when we remember that fruits are but a modification of leaves, assuming higher functions and special adaptations in the flower, so as to produce what we call a fruit. The ripening process by which the leaves take on their final colors is as constant and special as in the fruits. The cherries do not assume their various shades of red, deepening sometimes into black, or the plums their purples, or the peaches their velvety-rose tints or the apples their greens, russets, browns, and reds, with more unvarying accuracy than the different kinds of maples and oaks, or the beeches, birches, and ashes, take on their characteristic tints. The inequality of the 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 pebbles, while moraines are built chiefly of angular fragments of rocks. Neither can they have been accumulated by currents of water; for they occur in positions where any flood passing over the country, far from producing such an arrangement, must have swept them away, or at least have scattered them and destroyed their ridge-like character. They are, indeed, identical with the bottom glacial drift, that is, with the materials collected beneath the present glaciers, and ground to a homogeneous paste by their pressure and onward movement. I would call such accumulations ground moraines, that is, moraines formed completely under the glacier, and resting immediately upon the rock or soil beneath. Of course, masses of drift below a great sheet of ice, moving steadily in the same direction over uneven, rocky surfaces, cannot preserve the same thickness throughout. Here and there the incumbent weight will press more heavily in one direction than in another, thus crowding the loose materials together, rolling them into ridges following mainly the direction of the movement. Occasionally such uneven pressure may drive these materials up from either side, along the summit of a rocky ledge, or heap them at any height upon its slope. We have seen that the horsebacks, though uneven and winding, usually run from north to south; but occasionally also they trend from east to west. This is the case where a morainic accumulation of loose materials may have been pushed forward, along

the margin, in front of an extensive sheet of ice moving southward, and then left unchanged by the subsequent retreat northward of the whole mass. I conceive that such horsebacks, running east and west, may be compared to terminal moraines, which, as is well known, owe their origin to oscillations of the front end of a glacier, pushing forward a mass of loose materials, thus throwing it up into a transverse ridge, and then melting away to some point farther back. I have already shown, in previous articles, how such walls are constructed, often forming concentric ridges one within another, each of which marks a retreating step of the glacier. Sometimes the summit of the horsebacks is so broad and even that the country people consider them as natural roads, and build their highways along them. They are indeed occasionally so sym- metrical that they have been taken for artificial Indian 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 previously formed. I therefore infer that the local phenomena were the latest in time, and consequent upon the shrinking of the larger continuous ice-sheet. It is' my belief that the ice-period set in, as our winters now do,- only upon a gigantic scale,- by snow-falls, and that it faded as do winters, leaving local patches of ice wherever the temperature was favorable to their preservation. I may say, without exaggeration, that glacial phenomena extend over the whole length and breadth of the State of Maine, wherever : there is no obvious cause for their disappearance. One word of explanation, that this assertion of their omnipresence may not seem overdrawn to those who follow me over the same ground, expecting, perhaps, to find the glacial writing at every step along the road-side, and to see the polished surfaces as shining and slippery as a metallic plate or a marble slab. In the first place, all kinds of rock do not admit the same degree of polish. Coarse and friable sandstone cannot be polished under any circumstances. Only the finer granitic rocks retain the striae and the polished surfaces very distinctly, in this region; and even upon these they are frequently hidden by the accumulation of soil, or occasionally obliterated by decay, where the rock is not hard enough to resist the atmospheric influences. The loose materials themselves, which have served as emery to grind down, polish, and groove the surface of the soil, may eventually become a screen to cover it from observation. The skill of the geologist consists in tracing these Marks from spot to spot over surfaces where they were once continuous. When I say that I followed the glacial marks, compass in hand, from north to south, over a line a hundred miles in length, I do not mean that I never lost sight of them for that distance; but simply that one set of lines, which always ran due north and south, unless deflected as we shall see by some local cause usually explicable, on the spot, might be traced at intervals over all the rocky surfaces. If they disappeared under a stream on its northern shore, they reappeared on the southern side; if hidden for a time by some mass of vegetation, they were found again farther on; and thus- allowing for natural and inevitable interruptions -it may be correctly said that they are continuous over the whole country. The glaciated surfaces -to express in one word the combined 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 of Bangor, and especially near Pushaw Lake, the roches moutonnees are very extensive, and, from their character, particularly instructive. These rolling hills are formed by thin upturned clay-slate beds, standing edgewise, in a vertical position, and striking east-northeast. Scratches, grooves, and furrows of every dimension, sometimes very distinct, sometimes fainter, but always rectilinear and always running due north, traverse the edges of these beds at right angles with the surfaces of stratification and the trend of the beds. It is evident that here there can be no confounding of the glacial marks with structural lines, or cracks in the strata, -for these would not run at right angles with the structure of the rock itself; or with furrows made by water, -for these would have followed the strata instead of crossing them; or with any displacement of the beds moving upon one another, -a suggestion which has sometimes been made to explain the appearance of these marks upon horizontal surfaces. Nor is there any trace of the angular ledges which must have resulted from the tilting of these stratified rocks. The whole region is levelled and smoothed down to an undulating plain. While investigating the facts in this locality, I could not but recall the criticism of the "greatest geologist of the age ". 2. upon the glacial theory, then in its infancy; and the ridicule thrown upon the idea that the polished and scratched rocks of the valley of Hasli had been fashioned by ice. He considered these appearances as the natural effects of the shrinking of melted masses under the process of cooling, which might produce some displacement or movement of successive layers one upon another, leading to marks of different kinds belonging to the structure of the rock itself, and not due to any external action. Had the strata in this instance been vertical . in their position, like those of which the roches moutonnees on Pushaw Lake consist, instead of slanting but slightly, like those of the valley of Hasli, such an interpretation could not have been admitted for a moment, and the doctrine of a former greater extension of glaciers would perhaps have been recognized twenty-five years- earlier by scientific men. From Bangor eastward to Eastport, I have made but a hasty survey, -not in the present journey, which included only the country between the Katahdin Iron Works and 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 likely to have remained longer upon the higher ground, and when the lower tracks were inundated by the melting of the general sheet of ice, the water, as it rose, may have floated off the remaining bergs, and drifted them across the normal primary scratches bearing due north. On our return from the Katahdin Iron Works our road lay through Brownville, Orneville, Bradford, Hudson, and then along the shore of Pushaw Lake, to Bangor. Through- out this whole tract scratched and

polished surfaces and roches moutonnees are frequent. But the most instructive localities of all, in reference to glacial phenomena, are to be f found near the slate quarries of Brownville. Here again, as in the roches moutonnees at .Pushaw Lake, the marks run at right angles with the trend and dip of the beds. To explain fully the significance of the facts in this region, I must say something of its general formation. Pleasant River runs through a wide, open valley, the direction of which is very nearly from north to south. The finely laminated clay beds in which the slate quarries are excavated are lifted to an angle of seventy degrees and more, that is, standing almost vertically; and their trend is across the valley east to west, at right angles with it. More favorable circumstances for the study of glacial erosion could hardly be found. On comparing the marks and polished surfaces lich pass at right angles over the edges of these upturned slate beds in the bottom of the valley as well as upon its sides, they are found have exactly the same direction due north as the valley itself. Evidently, then, the agent which produced them must have been instrumental in shaping this trough, as it moved down the valley, before it could follow its path unimpeded by any inequalities of surface. ad it been a fluid mass, it would have fitted self to the lay of the land: it would have followed the vertical edges of the strata, working its way in between them, instead of cutting them all to one evenly rounded surface, as it has done. Indeed, it would seem as if this lace were meant to facilitate the task of the investigator. It presents the data for an immediate comparison between the action of water and that of ice, the limit of the former being distinctly visible in the narrow furrow at the bottom of the valley in which the river has cut its bed. This furrow is sunk somewhat below the general undulating 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 ex- tent over which the same set of phenomena may be traced forms an important part of the inquiry, I may indicate a few other points at which similar appearances occur. On the summit of the hill half-way between Brownville and Milo, near the Sebec River, the scratches and furrows are distinctly seen trending due north and south. They recur, after crossing the ferry, on the brow of another hill farther to the south. Between Orneville and North Bradford there are extensive flats, on which the rocks, wherever they are not decomposed, exhibit even and polished surfaces traversed by rectilinear grooves and furrows trending mainly from north to south, though here and there diverging to the west, and even forming occasionally an angle of from twenty to twenty-five ; degrees with the main set of lines. Farther south, as the land begins to rise again, all the marks point once more uniformly northward. To the north and south of the town of Hudson,

and especially near the post-office, the scratches are very distinct, bearing due north across slaty rocks, which trend east-northeast. The views from the high lands over all this region are very beautiful. O'Lammon, the Peaked Mountains, and the Union River Mountains limit the horizon in the east; Dix's Mountain rises in the distance on the west; while the Katahdin Mountains are still visible far to the north. On returning to Bangor, I proceeded at once, according to my original intention, to Mount Desert; but before giving an account of the glacial phenomena on that island, I must say a few words of the physical features of the country between Bangor and the sea. This region is intersected by three distinct ranges of hills, without counting the low range between Brewer and Holden. The first divides the valley of the Penobscot from that of Union River, passing through the townships of Clifton, Holden, and Dedham; the second separates the valley of the Union River from the Coast Range; the third is the Coast Range itself, of which Mount Desert and the elevated islands on either side of it form a part; for all these islands, so broken and picturesque in their outlines, must be looked upon as the higher summits of a partly submerged mountainous ridge. These chains do not run exactly parallel with the coast, their trend being more to the north than that of the shore itself; so that the ridges extending 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 north, pushed up and over the face presented to it, while the southern face was comparatively protected, the rigid mass no doubt often ill bridging the opposite declivity without even v-n touching it. I suppose these facts, which perhaps seem insignificant in themselves, must be far less expressive to the general observer than to one who has seen this whole set of phenomena in active operation. To me they have been for many years so familiar in the Alpine valleys, and their aspect in those regions is so identical with the facts above described, that, paradoxical as the statement may seem, the presence of the ice is now an unimportant element to me in the study of glacial phenomena. It is no more essential to the investigator who has once seen its connection with the facts, than is the flesh which once clothed it to the anatomist who studies the skeleton of a fossil animal. In the face of these facts it seems preposterous to assume that the loose materials and boulders scattered over this interval should have been stranded by icebergs driven inward from the sea-shore by currents or tidal waves. The whole movement, whatever its cause, was un- questionably in the opposite direction. The testimony of the loose materials and erratic boulders is the same all over the United States. They are always of northern birth. I have never seen a single fragment of rock from any more southern locality resting upon glaciated surfaces

to the north of them, though I have searched for them from the Atlantic coast to Iowa. The picturesque island of Mount Desert lies on the southern shore of Maine, in Hancock County, and is separated from the mainland by a narrow arm of the sea. Much higher in the centre than on the margin, its mountains seem, as one draws near, to rise abruptly from the sea. It is cleft through the middle by a deep fiord, known as Somes's Sound, dividing the southern half of the island into two unequal portions; and its shores are indented by countless bays and coves, which add greatly to its beauty. We entered the island on the northwestern side, from Trenton, and proceeded at once to Bar Harbor, on the eastern side. This is a favorite resort in summer on account of its broken, varied shore, and of the neighborhood of Green Mountain, with its magnificent view from the summit and its exquisite lake, sunk in a cup-like 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 inequalities will make little impression upon the onward movement of the whole mass; but in proportion as the ice wanes, it adapts itself to the depressions and knolls of the surface, in consequence of which the glacial marks lose the uniformity of their trend. The morning following my arrival at Bar Harbor I spent in examining the glacial phenomena in its immediate neighborhood. At Bar Harbor itself, the marks-bear north and north-northwest. A mile farther south they are all in a north-northwesterly direction. The cove of the Spouting-Horn, however, a deep recess in the rock, where the surf acts with wonderful force, -is engraved on both sides with lines running due north. On the same side of the island, considerably to the south of Bar Harbor, there is a striking sea-wall composed of coarse materials, thrown up in a line along the shore, formed, no doubt, by some unusually severe storm, coinciding with high-water. It resembles the well-known sea-wall of Chelsea Beach. Behind this wall stretches an extensive marsh, formerly a part of the sea. Somewhat beyond it, on the shore, are two very distinct polished and grooved surfaces, with the lines running due north. On the afternoon of the same day, I ascended Green Mountain. Along the lower part of the road the marks run northwest, then north-northwest, converging more and more toward their normal course, until, after passing the first summit, and thence upward, they lose entirely the slanting direction impressed upon them by the deflection of the ice about French-man's Bay, and run due north again. All the way up the last slope of the mountain, wherever the rock is exposed, may be see well-engraved flat surfaces of rose-colored protogine, on which the scratches and grooves sometimes run for twenty feet without any perceptible interruption. On the very summit is a quartz dike, cut to the same level with the general outline of the knoll, on

which the marks are very distinct. I arrived on the extreme point- where the southern descent is so abrupt that the mountain seems to plunge into the ocean; -just at sunset. The sea as far as the eye could reach was still glowing with color; amethyst clouds floated over the numerous Islands to the southwest; while on the other side in the gathering shadows lay the little lake midway on the mountain slope, and, below, the many inlets, coves, and islands 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, being of a softer quality than the granitic rock which it intersects, it has been cut to a little lower level, and the vertical walls of the fissure are polished, scratched, and grooved in the same way. I met here with one of those incidents showing the character of the working-class in America which always strikes a European with astonishment. There was a blacksmith's shop near this dike, and being extremely anxious to obtain a specimen from it on account of the clearness of its glacial characters, I requested the head workman, who had been watching my observations with a good deal of interest, to break me off a piece. It was not an easy task, for there were no angles, the dike being sunk below the surrounding surface and perfectly smooth. After a time, and not without some hard work, a wedge was driven in, and with the help of a crow-bar two or three very satisfactory specimens were pried out. I naturally wished to pay the man for his labor; but he refused to take anything, saying that he saw I was a geologist travelling for the sake of investigation. He added, that he subscribed for one or two papers and magazines: perhaps he should meet with some of the published results of my journey one of these days, and that would be the best reward for the little help he had given. Seeing his interest in the object of my researches, I explained to him the significance of this dike, showed him the direction of the marks pointing straight to the north, and evidently entirely independent of tidal action, since they ran at right angles with it. As I bade him good by, he said, "Henceforth this dike shall be my compass; I shall know when the wind blows due north." The locality was, indeed, especially interesting from several points of view. It is one of the few instances I have seen in which a dike, being composed of a softer paste than the adjoining rock, has yielded more readily to the ice-plough, and is cut to a lower level, thus forming a broad, flat a furrow, the upright walls of which are scored as deeply as the horizontal surface of the dike. Another most important fact is, that the tide daily flows across these marks. Evidently, then, they have not been made by water, since water has no power to erase them, or to obscure them by other lines of the same kind. A mile and a half to the south of Bass Harbor there is a ledge facing north, on which the glacial 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, upon which these moraines rest, consists of fine sand and loam with scratched pebbles. Seven or eight miles west the of West Ellsworth the hills, consisting of clay about slates on edge, trending from east to west, are there abraded, and upon the polished surfaces of their levelled edges rest two other longitudinal moraines, with angular boulders of Dedham granite, running from north to south, and resting upon an extensive ground moraine containing many smaller rounded and striated boulders. Ten miles west of Ellsworth there is still another longitudinal moraine; but the largest of all these parallel moraines is about three miles farther west, that is, about thirteen miles west of Ellsworth. Half a mile south of Bucksport the clay slates are nearly vertical, and their upturned edges are evenly polished and scratched. These surfaces are partially covered with the mud of the Penobscot River. Similar facts may be traced all the way between Bucksport and Bangor. Everywhere the scratches point due north. The coast range east and west of Somes's Sound is divided into a series of hills by transverse valleys, in most of which there are small lakes formed by transverse moraines at their southern extremity. Beginning east, and not counting the less prominent peaks, we have, first, Newport Mountain; next, Kebo and Green Mountains; then, Jordan Mountain, Bobbey Mountain, Hadlock or Pond Mountain, and Westcot Mountain, all to the east of Somes's Sound; then follow Dog Mountain, Defile Mountain, Beach Hill, and West Mountain, all on the west side of Somes's Sound. Denning's Pond, which I have examined more in detail, lies between Dog Mountain and Defile Mountain. The road along the lake follows the eastern or left lateral moraine of the glacier, which once filled its basin; and the lake itself is hemmed in by a crescent-shaped terminal moraine at its southern extremity. The lakes, eleven in number, intervening between the other mountains, are likewise bordered by moraines. We have thus satisfactory evidence that at an early period of the retreat of the great ice-field covering this continent, when it no longer moved over the highest summits of the land, local glaciers were left in the gorges facing the sea. We have thus traced the glaciated surfaces over the whole width of the State of Maine, 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 the drift phenomena along our Atlantic coast, showing also that at that period the ice-fields were not bounded by our present shore line, but extend-ed considerably beyond it, over surfaces now occupied by the ocean. At a later time, during the shrinking and gradual disappearance of the ice-sheet, the ice no doubt, retreated within the shore islands. The aspect of the coast of New England must then have been very similar to that of Greenland in its colder portions. Mount Desert itself must have been a miniature Spitzbergen, and colossal icebergs floated off from Somes's Sound into the Atlantic Ocean, as they do nowadays from Magdelena Bay.

1. Those who wish to follow the localities indicated in this article should consult H. F. Walling's map of the State of Maine, published by J. Chace, Jr., Portland.

2. Leopold von Buch.