Traces of the Great Ice Age in Derbyshire.

By GEORGE FLETCHER, F.G.S.

ANY reference to the subject of the Glacial Epoch in circles other than Geological, fail, we fear, to convey any definite impression. Indeed it may be doubted if people in general regard the ascertained facts respecting the Great Ice Age as more than "speculations of so-called men of science." Yet the evidence for the view—that at a period very recent (geologically speaking) the whole of northern Europe and America was buried under a huge and almost continuous ice-sheet—is overwhelming; indeed, it may be regarded as a fact as well ascertained as that of the Roman occupation of Britain. A study of the widespread deposits classed as "Drift" has taught us not only that during this period intensely arctic conditions prevailed in northern Europe, but that alternations of arctic and temperate conditions took place, the directions in which the ice flowed, and, approximately, to what limits. To quote the words of Professor James Geikie, "it is hardly too much to say that we are as well acquainted with the distribution of glacier-ice in Europe during the Ice Age as we are with that of *existing* snow-fields and glaciers."

To present the facts briefly:—Scattered over the surface of the British Islands, as far south as a line extending from the Bristol Channel to the mouth of the Thames, and occupying an area of some thousands of square miles, is a deposit known to geologists as *till* or *boulder-clay*. It consists of *unstratified* material—mainly clay, sand, and gravel—containing boulders of all sizes, these being sometimes of the same kind of rock as that in the vicinity, sometimes of rocks found *in situ* only at great distances. The suggestions made from time to time that such deposits are evidence of a deluge, or that they have been deposited by water, cannot for one moment be entertained by those who have studied them. Water possesses a wonderful capacity for sorting out the material it transports, and depositing it in layers (depending upon the character of the sediment and the velocity of the water) in such a manner that it is impossible to confuse it with the unstratified morainic matter which owes its position and arrangement, or lack of arrangement, to ice. Besides this, the boulder-clay is frequently found resting on rock surfaces which are polished and grooved in a manner similar to those which are now to be seen below existing glaciers, and in other cases it rests upon strata which have been enormously disturbed and contorted as by the passage of a glacier.

Thick and widespread deposits, similar to our boulder-clay, occur upon the undulating low grounds of southern Sweden, Denmark, Holland, Switzerland, northern Germany, Poland, and Russia. In Switzerland this material is known as "*Moraine profonde*" or "*Grundmoräne*," and as "*Geschiebelehm*" or "*Geschiebemergel*" in Germany. Often the boulders contained in it are striated and polished in a manner impossible to be produced by any known natural agent save ice, and in many cases the clay is crumpled and exhibits a sort of lamination as though subjected to intense pressure.

Geologists recognise at least two of these boulder-clays, both in these islands and on the continent of Europe, these being separated in places by beds of terrestrial, freshwater, or marine origin. In England, the lower boulder-clay has been traced as far south as the valley of the Thames, while the upper one does not extend south of the Midlands. These *interglacial beds* (as the beds of aqueous origin separating the clays have been called) indicate a retreat of the ice-sheet, and an amelioration of climatic conditions until the country was clothed with a flora similar to that existing at the present day; while animals such as the wild ox, the great Irish deer, the horse, elephant and rhinoceros, roamed over the now fertile ground. Professor James Geikie recognizes no fewer than four of the interglacial periods, each one characterized by a retreat of the glaciers, and a return to temperate conditions.* These alternations were accompanied by oscillations of the sea level.

But—and especially since this Society is Archæological rather than Geological—it will not be out of place if we digress slightly in order to describe very briefly the phenomena accompanying the passage of a glacier over its rocky bed. The problems we are discussing can only be attacked in the light of our knowledge of the phenomena of glacial action taking place at the present day.

We may first of all place on one side the idea that glaciers have scooped out the valleys down which they flow. That glaciers do possess considerable power of eroding even hard rock there can be no doubt, but that they have produced the valleys down which they flow, or have flowed, there is no evidence to prove; those were almost invariably produced in the first place by the action of running water, but may have been deepened by glacial action. Considerable light is thrown on the glacial phenomena of our own country by a study of what is taking place at the present time in a glacier district such as that of the Alps. In many cases the Swiss glaciers (*e.g.*, the Rhone) have receded greatly in recent years, and one can readily observe the action of the ice on the rocky bed over which it has flowed. In the first place it rounds and polishes the rock, and also produces a number of grooves and striæ, which are more or less parallel to the direction of motion of the ice. Where large bosses of rock lie in the path of the glacier, the side upon which the glacier impinges is worn down until it presents an inclined plane, the opposite side being as a rule more craggy—a phenomenon known as "crag and tail." It is not difficult to see how all this comes about. The detrital material perpetually falling from the cliffs, and rolling down the slopes (and which, in a river valley would fall into and be carried away

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* "Fragments of Earth Lore," p. 321.

by the stream), is received by the surface of the glacier, forming lines of *débris* known as moraines. A vast quantity of this *débris* finds its way down the numerous crevasses with which the surface of the glacier is intersected, and, held by the ice as by a vice, these angular fragments play the part of cutting tools upon the bed of the glacier. Nay, they are more effective than if held by a vice, for the yielding character of the ice retards their breaking up. These effects may be well seen in many of the Swiss valleys, notably in the Haslithal between Meiringen and the Unteraar Glacier. A portion of the path along this valley passes over bosses of rock of considerable extent which have been polished as smooth as glass, and, though the angle of slope is not considerable, it has been found necessary to cut steps in the rock. This rounding and polishing may be observed high upon the precipitous sides of the valley, proving that at one time the valley was full of ice, which probably overrode all but the highest peaks. It may be seen on a level with the Grimsel Pass.

But the previous extension of a glacier is manifested by another fact. The path of the river of ice is bounded by two lines of *débris*—the lateral moraines—and, where it melts, all the material brought down is deposited, forming a terminal moraine. Where a glacier is receding, a number of terminal moraines along the valley mark the stages of its shrinking. Many of the blocks are grooved and striated after the manner of the bed of the valley, and in a manner quite different to the smoothing produced in a stream-worn boulder or pebble. Many boulders however, in fact the great majority, are not marked at all — it must not be forgotten that many of them have remained on the upper surface of the glacier, or embedded in the ice, to the end of their journey, and others are of a material which fails to retain the markings for long periods. Sometimes the glacier in its shrinking will leave enormous blocks perched in the most remarkable manner on the sides of the valley (as may be seen to perfection in our own country, together with the other phenomena here mentioned—in the Vale of Llanberis). It will be seen that rocks may thus be transported from the very source of the ice stream to its termination, and although this distance is not considerable in the case of the now shrunken Swiss glaciers, it would be considerable at the time of their maximum extension.

An examination of the Swiss valleys shows that the glaciers now occupying them are but the ghosts of their former selves. Taking, for example, the Rhone Valley, we find ice-markings on the Schneestock (near the source of the glacier) at a height of 11,500 feet above sea level, or 1,500 feet above the present level of the glacier. At Fiesch, about twenty miles below, the ice was about a mile in thickness; while fifty miles lower, where the glacier was deflected sharply to the north, it was scarcely less thick. On reaching the wide part of the valley, just above the Lake of Geneva, the glacier spread out as a wide and nearly level sheet of ice transporting Alpine boulders to the flanks of the Juras, landing them at a height of 3,000 feet above the level of the lake. Here one branch spreading southwards was joined by a tributary from Mont Blanc at the foot of the lake, and a north-easterly branch was joined in the vicinity of Berne by the ice-stream which descended from the northern flanks of the Bernese Oberland through the valley of the Aar. These united streams filled the whole valley with ice as far down as Soleure. Near this place is a block of granite, weighing about 4,100 tons, brought hither from the Valais, a distance of some 115 miles.

South of the Alps, from the flanks of Mont Blanc and Monte Rosa, enormous glaciers descended into the Val d'Aosta, and spread out over the plains of Lombardy, leaving huge moraines, some of which are 1,500 feet in height.

Turning to our own islands we find abundant traces of this cold period. Scotland was completely enveloped in a sheet of ice, which extended to the west of the Hebrides, and it has been shown how the characteristic rounded forms of the Scotch mountains are due to this. The ice-sheet moved out from the high lands in a westerly and southerly direction, a movement to the east being checked, in the period of greatest cold, by an enormous glacier which came from Scandinavia, filling up the North Sea and deflecting the ice from the eastern slopes of

Britain into a westerly direction, and scattering rock fragments from the eastern counties over the midlands. In the early portion of the glacial period the mountains of Britain formed centres from which glaciers radiated, these at last becoming confluent, and debouching upon the coast. It will be seen that, from its physical character, the Irish Sea would form an interesting region. In the earlier part of the period, the ends of the glaciers broke off, forming icebergs; but later, the Irish Sea was completely filled with ice. An ice-sheet moved southwards from Galloway, becoming confluent with one from the mountains of the Lake District and one from Ireland. Glaciers, too, descended from the mountains of Wales, and the northern part of the Pennine Chain. Anglesea and the Isle of Man were completely overridden by the ice.

Turning to Derbyshire, we find the traces of this cold period of great importance, though less abundant than in the counties to the north. Within the county the evidence is almost confined to deposits of boulder-clay and erratics. Of the glacial striæ, so common in Scotland, Cumbria and Wales, we have none. It is true it has been suggested that the boss of rock called the "Bloody Stone" (on the foot-road between Cromford and Bonsall), is a glaciated rock. Sir Andrew Ramsey, who visited this stone, declined to accept it as a glaciated rock, although he said that in a well-glaciated country it would pass muster as such.* The writer has visited and examined this stone several times, and is satisfied that the grooves and striæ are not of glacial origin. The rock is, presumably, more exposed than formerly. However this may be, the striæ may, in places, be seen to dip *into* the rock, and doubtless, if the rock were cleaved, would be found inside. This structure, which closely simulates glacial markings, is not uncommon, and similarly marked boulders may be found on the footpath between Ambergate and Crich.

But we need not be surprised at the absence of glacial markings on rocks *in situ*. It is not near the terminations

* "Geological Survey Memoir for North Derbyshire," p. 92.

of glaciers that we expect to find them. There has been much misapprehension through gauging glacial action from the phenomena to be observed at the terminations of glaciers: here the erosive action is at a minimum. It is high up among the mountain valleys where the glaciers were thickest that we may expect to find the action most strongly marked, and this is exactly where we do find the polishing and grooving already described. But though glacial striæ are absent, we have abundant patches of drift, containing in many places ice-scratched boulders. It is interesting to note that in North Derbyshire these deposits are confined to the valley of the Wye, or to that part of the valley of the Derwent which lies below the junction of the two rivers. Above Rowsley, the Derwent valley is free from drift. The explanation of this would seem to be that the drift came from the west, through a gap in the Pennine Chain. The glaciers from the Lake District—prevented from going into the Irish Sea by the enormous mass of ice which filled it—were deflected eastwards, and a portion at least of the ice was driven up the valley of the Mersey, up the Goyt and over the low ridge along which runs the London and North-Western Railway (here not more than 1,100 feet above sea-level), and so into the Wye valley.

A depression of from 1,100 to 1,200 feet would convert this pass into a strait, while it would leave the greater part of the adjoining table-land above water. From phenomena presented by certain shell-bearing gravels near Macclesfield, on Moel Tryfaen, and at Gloppa, near Oswestry, it was held that at some time during the Glacial Epoch this part of the country was submerged to a depth of at least 1,200 feet, and that the drift deposits of the Wye valley were carried thither by floating ice. It cannot, however, be admitted that the evidence for such a submergence is satisfactory. It has been successfully analysed and disposed of by Mr. Percy F. Kendall.* Professor James Geikie, who maintained the "great submergence" view, has

* *Vide* "Man and the Glacial Period," G. F. Wright, p. 167.

been led from a re-examination of the evidence to discard it. That some amount of submergence took place is doubtless true, but it cannot have been nearly so extensive as to convert the ridge between the Goyt and Wye into a strait.

Glacial deposits occur as high up the Wye Valley as Monsal Dale. Thus on the lower slopes of Fin Cop, and in the walls near Ashford, may be found numerous boulders of granite, slate, millstone grit, Yoredale rock, quartzite, toadstone, and limestone. These are unquestionably glacial, although I have seen no boulders which can with certainty be said to be ice-scratched. A similar collection of ice-carried boulders may be found on the lower slopes of Highfields, some of them undoubtedly glaciated. None are to be found on or near the summit. Near the railway bridge, to the south of Monsal Dale station, the cutting shows a deposit of boulder-clay, containing rounded limestone boulders. On the hills, to the west of Bakewell, are to be found deposits of boulder-clay, containing beautifully glaciated boulders of granite, limestone, etc. ; while lower down the valley on the hills behind Haddon Hall are to be found patches of boulder-clay, containing glaciated boulders of granite, limestone, etc. A good exposure is to be seen in the cutting near the north end of Haddon Tunnel, containing numerous boulders. In laying out the grounds of the Whitworth Institute at Darley Dale, similar deposits were met with, containing glaciated boulders of many rocks foreign to the district. Among others, was a portion of a silicified tree trunk, which is now, I believe, to be seen in the Museum of the Institute. I was informed by Mr. J. H. Dawson that during the excavations an extensive, though thin, bed of peat was cut through. From the contour of the district it seems not improbable that a lake at one time occupied this portion of the valley, the only outlet to which is the gorge in the limestone escarpment at Matlock Bridge. This layer of peat supports this view, and the matter is well worth careful investigation at the hands of geologists resident in the county.

Other deposits of boulder-clay occur on Riber Hill, on the southern extremity of the Crich inlier of limestone, and still further south between Alderwasley and Belper. A number of patches of drift occur on the eastern flank of the Pennine Chain, but it is not proposed to enumerate them here. In and near Derby itself are several interesting sections of boulder-clay. One near the top of Argyle Street, on Burton Road, overlies Keuper clays. This contains many quartzites and coal-measure pebbles, and Mr. R. M. Deeley found in it a fragment or fragments of chalk, thus proving it to belong to the Great Chalky Boulder-clay. Another interesting deposit occurs in the upper part of Littleover Lane, where it is well exposed on either side of the road. There are here numerous pebbles of coal-measure ironstone, showing, on fracture, an interesting concentric structure produced by weathering. In the clay-pit near the Firs Estate Board School, the Keuper strata are brought into a nearly vertical position by a fault, and the upper ends exhibit a recurving, which has probably been produced by the passage of ice over the surface. A sketch of this will be found in my paper, "On an Exposure in the Keuper Clays and Marls, Derby," which appeared in the *Journal* (January, 1891).

Coming to the basin of the Trent, the glacial deposits have been observed and correlated in an extremely careful manner by my friend, Mr. R. M. Deeley, F.G.S.* He classifies them as follows :—

Newer Pleistocene Epoch.

Later Pennine Boulder-clay. Interglacial River-gravel.

Middle Pleistocene Epoch.

Chalky Gravel. Great Chalky Boulder-clay.
Melton Sand.

Older Pleistocene Epoch.

Middle Pennine Boulder-clay. Quartzose sand.
Early Pennine Boulder-clay.

The deposits of the Older Pleistocene Epoch consist of two boulder-clays separated from each other by false-bedded gravel,

* "Quarterly Journal, Geological Society, 1886," p. 438.

sand, or brick-earth. The boulders contained within these clays are derived from the Derbyshire hills lying to the north, and would seem to be the *débris* brought down by local glaciers at the commencement of the Glacial Epoch. The Quartzose Sand indicates submergence and a temporary relaxation of the arctic conditions. A section of the Older Pleistocene Boulder-clay occurs on Waterloo Hill, near Burton-on-Trent. It contains erratics, "probably of Cumbrian origin." Interesting exposures also occur at Spondon, at Chaddesden, and Sheldon Wharf. Spondon itself is built on it, and it is exposed in several other places. It contains Carboniferous boulders, and rests on a surface of contorted Keuper marl. One of the erratics weighs at least six tons, and many exhibit fine glacial polishing and striæ. Finely glaciated Carboniferous boulders also occur in the deposits at Chaddesden and Sheldon Wharf.

The deposits of the Middle Pleistocene Epoch are of particular interest, and indicate a remarkable change in the physical conditions. Widely distributed over the area occupied by the Trent basin are deposits known as the Great Chalky Boulder-clay, and these deposits indicate the passage of an ice-sheet from the east. The evidence is this: the deposits contain numerous boulders and fossils which must have been derived from rocks which lie far to the east. Thus we find on Chellaston hill a deposit of Boulder-clay overlying the Keuper strata, which here is being worked for gypsum. This deposit contains well-glaciated boulders which have been derived from Cretaceous rocks. Chalk and chalk flints are to be found, together with Gryphæa and other Liassic fossils. But there are no hills to the east capable of giving rise to glaciers. From whence then did the ice come? An exhaustive study of these deposits and of the phenomena on the coast of Norfolk (notably around Cromer) has led geologists to the conclusion that during this period intense cold prevailed, and that an enormous ice-sheet, fed from the Scandinavian mountains, moved across and filled the shallow North Sea, and, joining and brushing aside the ice from north-east Britain, brought fragments of Scandinavian rocks to our shores.

These fragments are to be found in abundance at Cromer, and while it is only fair to say that certain geologists explain their presence there in an altogether different manner, the phenomena support the view presented above. Pennine rocks occur in the Great Chalky Boulder-clay, but it seems probable that these were derived from the Older Pleistocene deposits over which the ice passed.

The deposits of the Newer Pleistocene Epoch indicate the first signs of a return to temperate conditions. "During this stage," says Mr. Deeley, "the rivers cut down their valleys through the older Boulder-clays and sands to within about twenty feet of their present depths, and left their gravels stranded as terraces at various heights above their present courses." Resting upon these interglacial gravels, or the older rocks, is a Boulder-clay, which indicates from its contents a period of cold, when the Scandinavian ice had disappeared, and glaciers from the Pennine Chain once more deposited their moraine matter over the area. There is evidence to show that during this stage glaciers from the Scotch and Cambrian Mountains invaded the western portion of the area.

It will be seen that, although many of the facts are involved, the subject is one of deep interest. That the problem is difficult—that the deposits have been disturbed again and again is no reason why careful study should not be given to them. Mr. Deeley's paper, quoted above, shows what can be done by careful and persistent work, but much remains to be done. It has only been possible here to give the briefest outline of the facts, and the inferences to be drawn from them. It is desirable that observations should be multiplied. If they support the views held, well; if they do not, still well; for men of science ever hold facts to be superior to theories and so-called "laws of nature," and, while they regard a well-established doctrine as a law, ever strive to increase our knowledge of *facts*, and when this fails to harmonise with their doctrines, however cherished these may be, they are readily relinquished, for the end and aim of all science is a search for truth.