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DO GLACIERS EXCAVATE?*

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The publication of the late Sir A. Ramsay's paper on the Glacial Origin of certain Lakes in Switzerland,† full thirty years since, marks an epoch in the study of an important branch of physical geology. It dissipated sundry old-world fancies which still lingered, like the mountain mists, over the Alpine lakes, and propounded a hypothesis, which from its own plausibility and its author's scientific position and literary skill, attracted general attention. It was, however, opposed by Sir R. Murchison and Sir C. Lyell, and failed to win the allegiance of those members of the English Alpine Club, who cared for mountain physiography not less than for mountain climbing. In the ten years which followed the publication of this paper, four of the most experienced among these persons had expressed their dissent. The results of my own study of the question were given in a group of papers published between the years 1871 and 1877 inclusive Of these I shall avail myself this evening, though not without making full use of the more precise information which is now accessible, and of the opportunity for a somewhat different method of treatment. I adopt this course because, so far as I am aware, no advocate of Sir A. Ramsay's hypothesis has ever attempted to meet my objections by precise and definite statements, or has really added, except in one respect, to the arguments which the author originally advanced. New instances of the erosive action of glaciers are not unfrequently cited, but when regarded with a sceptical eye, they are only valid in the event of the original hypothesis being correct, that is to say, they depend upon instead of confirming it.

So since no one, so far as I know, has attempted the laborious task of following my footsteps in the Alps, and combating the difficulties which I have raised, by detailed discussion instead of vague generalities, I shall adhere very nearly to the old lines of attack, taking most of my

* Paper read at the Meeting of the Royal Geographical Society, March 27th, 1893.

† *Quart. Jour. Geol. Soc.*, vol. xviii., p. 185.

instances from the Alps, though other glaciated regions are not unknown to me, because that mountain chain is sure to be familiar to my audience, and is the one which I know the best.

It may be well to call attention at the outset to the fact that lakes—as all admit—may be formed in various ways. After the removal of subterranean masses of soluble salts, the surface of the ground may subside, and the local lowering of the bed of a stream may cause its waters to overflow and form a mere. This often happens in Cheshire and Worcestershire, owing to the extensive pumping of brine. Such lakes, however, are usually small, and, so far as I know, are always shallow. Again, a stream may be blocked either by a berg-fall, or by the terminal moraine of a glacier, or even by the drift which a tributary has swept down. The first of these produced the Lago d'Alleghe: the second the Mattmark See: by the third the level of many Alpine lakes, whatever be their origin, has been raised. Of the lakes, however, which actually occupy rock-basins, not a few are contained in old craters; doubtless, most of these are comparatively small; still some are not; for instance, the Lago de Bolsena, the area of which is only exceeded by that of the largest Alpine lakes. As regards these, the level of their waters, at least in several instances, is raised by masses of drift, brought down from other drainage areas by important tributaries, which has obstructed the course of the main river.* This, however, is a detail. I admit that most, if not all the great Alpine lakes, as well as the tiny tarns high up in the mountain fastnesses, occupy true rock basins, which in the case of the former, as well as in that of the latter, are attributed by the school of Ramsay to the erosive action of glaciers.

The paper, already mentioned, began with a discussion of certain earlier hypotheses, in the course of which it was proved, conclusively as I think, that the rock-basins of the Alpine lakes could not have been produced by any kind of local subsidence, or by fissures in the Earth's crust or by the erosive action of the rivers themselves. It was pointed out that they were abundant in regions which had been formerly occupied by glaciers, and it was urged that ice could erode and scoop. So, as no other hypothesis remained as a competitor, its advocates claimed a verdict in its favour.

Two weak points in this argument at once suggest themselves to careful and somewhat sceptical readers of Sir A. Ramsay's paper. The first one, why the lakes are so few and occur so low down in the valleys, is indeed noticed, but is met only by two or three vague generalities of little argumentative value. The second, and more grave one, is that a mode

* Thus the first outcrop of solid rock in the bed of the Rhone to the east of Geneva is about 34 feet below the level of that lake, and in the bed of the Rhine, so far as I know, about 25 feet below the level of Constance. It must be remembered that a lake once formed regulates the velocity of the principal stream, while the tributary can be greatly swollen. That is the case with the Rhone and the Arve below Geneva.

of forming a series of lake basins which brings them into close connection with processes of mountain-making, has been entirely overlooked. Subsequent attempts to strengthen Sir A. Ramsay's argument have been directed rather to supplying the deficiencies in the former case, than to dealing destructively with the latter difficulty, and later defenders of his hypothesis have apparently deemed silence on this topic more prudent than speech.

The discussion then as to the erosive power of glaciers may be subdivided into three propositions. These are the following:

(1) Lakes are abundant in glaciated regions;

(2) Glaciers are potent excavating agents;

(3) No agent but ice is competent to produce a lake basin.

The first may be briefly dismissed, for I do not dispute its truth. Lakes occupying true rock basins, so far as I know, are commoner in glaciated regions than in any other. At first sight this may seem like surrendering the key of the position. But the concession does not amount to very much; for the tarns of Cumberland, Wales, and the Highlands merge almost insensibly into such lakelets as Windermere and Derwentwater, Bala and Llanberis, Katrine and Lomond, and these again into Zug and Orta, Thun and Brienz, Zurich and Lucerne, Como and Geneva, in a word, into all the Alpine lakes. From these, however, we are led, step by step, to the great lakes of North America, and to those which feed the Nile, the Congo and the Zambesi in Africa. But no one, so far as I am aware, regards these lakes as the results of glacial erosion, or attributes to this either the Dead Sea or Lake Van, either the Aral or the Caspian. But such inland basins seem closely related to those of the Sea of Marmora and the Euxine, and these are hardly separable from the basins of the Mediterranean and of the outer oceans. Obviously then, if some rock-basins have been excavated by ice, dimples also exist on the Earth's face, which are due to other causes, and the concession still leaves individual cases open to discussion.

For the present then let us pass on. As to the second proposition, that glaciers are potent excavating agents, it may be well to remark at the outset that *abrasion* and *excavation* are not identical terms, and that it is not enough to prove the existence of the former in order to establish the latter. How a glacier works must be ascertained by studying the contours of its bed; these can be most readily examined in districts from which the ice has disappeared so recently (geologically speaking) that its foot-marks are still fresh. For this purpose, the higher valleys in the Alps are preferable to the mountain regions of our own island, not only because all the features are on a grander scale, but also because there is no important difference of opinion as to the extent of the glaciers and no complications are introduced into the problem by the possibility of a submergence.

But before examining the effects of ice in the Alps an objection

which has been sometimes advanced must be discussed. When an enthusiastic glacialist is pressed hard by evidence gathered from the Alps, he retorts, "These glaciers are poor, shrivelled affairs. No inferences can be safely drawn from them as to the conditions prevalent in a region enveloped in ice-sheets like those of Greenland." The objection, so far as it applies to the existing glaciers, is not without some justice. The phenomena of the Gross Aletsch Glacier will differ from those of the Jakobshavn Glacier as the phenomena of the Thames differ from those of the Amazon; but it will be after all a difference in degree rather than in kind. The objection, however, becomes less and less applicable as we proceed to examine Alpine valleys some distance away from the existing glaciers. When ice occupied every glen in the Alps; when the confluent sheets welled up against the flanks of the Jura several hundred feet above the level of the present lakes of Neuchatel and Bienne, then the condition of Switzerland was fairly comparable with that of Greenland at the present day. Hence the valleys of the Alps should exhibit the contours of a region from which an ice-sheet has vanished; in any case they must bear the marks of ice-streams which, according to the hypothesis in question, were competent to dig out the Alpine and Sub-alpine lakes. Unless it can be shown that the contours of a valley, down which the course of a glacier can be tracked, differ markedly in its several parts, the Alps furnish us with examples of the action of large ice-streams no less than of small glaciers. But the difference, if any, is never more than one of degree. My experience of the Alps is extensive and of long standing, and I make this statement confidently and without reservation.

Rocks worn by glaciers should testify to the action of a scooping tool, and any valley materially deepened by such a substance as ice (a more or less plastic solid) should exhibit a section bearing some resemblance to the letter U. Let us compare the contours of a region such as Sinai, where glaciers, if ever present, must have been always unimportant features, with those of the Alps. Between the peaks of the one and the aiguilles, or ridges, high above the ice-fields in the other, there is no marked difference—nay, I will go so far as to say that the differences in outline presented by mountain ridges out of the reach of glaciers, whatever may be the cause, depend much more upon the character of the rock than upon altitude above sea-level or the temperature of the region. Frost no doubt is more destructive than heat, but the dominant outlines are alike in climates warm or cold. Place before a geologist a series of photographs of Sinai, the Alps, the Caucasus, the Himalayas, the Lofoten Islands, or New Zealand, and if a little snow be introduced into some, and vegetation carefully concealed in all, he will be unable to determine the locality if he is not aided by actual knowledge of the views. To speak only of gneisses and harder crystalline schists: jagged, splintered, and toothed ridges stand out against the sky, sharp-edged

buttresses, grooved by fissures, furrowed by ravines, broken by precipices, descend towards the valleys. Wherever the ice has not left its mark, there, whether the ranges be high or low, whether the crags overshadow tropical ferns or Alpine pines, the features which are sculptured by meteoric influences other than glaciers are substantially the same.

What contours then are exhibited in those parts of the valleys which have been once overflowed by glaciers? The Alps are well adapted for answering this question. This is the sum of their evidence: toothed prominences have been broken or rubbed away, the rough places have been made smooth, the rugged hill has been reduced to rounded slopes

ROCKY HEADLAND WORN BY ANCIENT GLACIERS OF THE AAR AT THE GRIMSEL HOSPICE, SWITZERLAND.

of rock "like the backs of plunging dolphins." But the crag remains a crag, the buttress a buttress, and the hill a hill; the valley also does not alter its leading outlines, the V-like section so characteristic of ordinary fluviatile erosion still remains; all that the ice has done has been to act like a gigantic rasp; it has modified not revolutionised, it has moulded, not regenerated. No sooner do we come to study in detail the effects of the ancient glaciers in the upper valleys of the Alps than we are struck by their apparent inefficiency as erosive agents. Here, where the ice has lingered longest, just beneath the actual glacier, we see that a cliff

continues to exist. Again and again in a valley we may find that on the lee side of prominences crags still remain, sometimes in sufficient frequency to be marked features in the scenery. Let us take as an example a single valley—the Haslithal. The long level delta of the Lake of Brienz extends to a little above Meiringen, there the valley is barred by a craggy ridge, which is cleft by the Aarschlucht. This chasm has been sawn by the subglacial torrent, while the ice itself has moulded every rock on the barrier into billowy undulations. From its crest we look down upon a level meadow, which extends to the junction of the Gadmenthal with the Haslithal. This grassy basin might well be claimed as an instance of glacial erosion—by which indeed it possibly may have been deepened; but if we attribute to this agency the removal of all the rock between the summit level of the barrier and the present meadow-floor, how are we to explain the existence of the steep rocky slope down which the road to Imhof descends in zigzags. The slopes, in the teeth of an advancing glacier, are always comparatively gentle, and very unlike those which are presented by this rocky rib. Again, after the comparatively uncharacteristic slopes which continue for some distance above Guttannen have been left behind, the region of hard crystalline rocks is entered which extends not only to the Grimsel pass but also into the heart of the great Oberland peaks. What contours does this possess? Everywhere, no doubt, ice-worn rocks meet the eye; curving slopes extending far above the valley floor, spurs and ridges, which are now one vast group of *roches moutonnées;* but hardly ever the faintest approach to a trough-like section; instead of this the normal V-like outline characteristic of the action of heat and cold, of rain and snow. Perhaps no district in the Alps exhibits the traces of ice-action on a grander scale, yet these have been only superimposed upon and modify the features of fluviatile erosion. Yet the contours of ice-action and in some cases the very striæ can be traced almost down to the surface of the torrents. But the Haslithal is not at all an exceptional case. I have examined almost every important valley which leads up into one of the greater groups of crystalline peaks in the Alps, with the same result—namely, that the major features, whether in crag, rock, slope, or ridge, are those of the ordinary processes of meteoric and fluviatile erosion, the minor only being due to glacial action. Hence it follows that, when the ice first emerged from the fastnesses of the central peaks, it descended valleys corresponding in their main outlines with those which still exist, say nearly identical in depth and breadth; but at that time every crag was rough, every ridge was sharp or serrate. The ice took possession of the region. It rasped and rubbed, and, when it finally disappeared, the rock surfaces exposed were worn and defaced, like the sculpture of some bas-relief which has been trodden underfoot till only the main outlines of its design can be distinguished. The Val Bregaglia, the Val Mastalone, Val Anzasca, the Valley of the Dranse

and many others have afforded me the clearest proofs that the ice has occupied without materially deepening, excavating, or modifying the glens. Crags which as it advanced must have risen up like peel-towers from the floor of the valley have been buried deep below the frozen mass, and have emerged, worn, rounded, scored, but only so far changed as to have become humps.

The same is true of the limestone regions; but here the valleys as a rule are rather more troughlike in outline, and the results of ice action are more often blurred or removed by subsequent disintegration, so that these districts are less suited for examination.

But surely there are tarns in the Alps? Yes; though if we restrict ourselves to those which unquestionably occupy rock basins, they are not very numerous. Probably they would become relatively more abundant if the glaciers wholly disappeared from the Alps. But these rock-basins commonly occur, as in the more mountainous districts of our own islands, either in corries, that is, at the foot of precipices or steep rock slopes, or else at the back of low ridges of rock by which the valley is almost barred. In these two situations a semi-solid substance like glacier-ice might put forth considerable erosive power—in the one case owing to the sudden change in the inclination of the bed, in the other from a similar cause which acted, so to say, in the contrary direction; for here the ice is forced uphill by the pressure of the masses advancing from behind.

Now, in 1893, after nine more visits to the Alps—not to mention other mountain regions—during which these problems have never been absent from my mind, I repeat the statement made in 1874, that the Alpine "valleys appear to be much older than the Ice age, and to have been but little modified during the period of maximum extension of the glaciers."

I pass on to another question. Does an examination of existing glaciers suggest that as a rule they have much erosive power? An answer to the enquiry may be sought both on the ground from which a glacier has recently retreated, and on that where it is beginning to encroach. But, as bearing on this point, I will for once quote what I have not seen. The Muir Glacier in Alaska is surely big enough to do a little erosion on its own account. It is 25 to 30 miles long. It is now, however, smaller than formerly, and in retreating has exposed a mass of gravel over which, according to Dr. Wright, it has once flowed. This does not indeed lie in the path of the main stream, but still some erosion might be expected. The stems of dead trees are still upright, rooted in the soil in which they formerly grew. The ice then has passed over this gravel without disturbing it, and the glacier can be seen in other places still resting on a similar gravel.* The glaciers of Greenland, according to Mr. Whymper, leave uncovered in their retreat

* Wright, 'The Ice Age in North America,' chap. iii.

level surfaces, without any sign of basins, and inequalities in the hardness of the rock masses produce little or no effect upon the surfaces worn by the ice.*

In the Alps about the year 1860 the glaciers began to dwindle. By 1870 considerable tracts of bare rock or *débris* were exposed, which a dozen years before had been buried under the ice. On none of these have I seen any basin-like hollow or sign of excavation as distinguished from abrasion. The Unter Grindelwald Glacier in the last stage of its descent passes over three or four rocky terraces. The angles of these are not very seriously worn away, nor are hollows excavated at the base of the steps. The bed of the Argentière Glacier (I made my way some little distance under the ice) was rather unequal, and was less uniformly abraded than I had expected. "There were no signs whatever of the glacier being able to break off or root up blocks of the subjacent schistose rock: it seemed simply to wear away prominences." This also is true of other glaciers.

But prior to 1860, and again in 1891, I saw glaciers which were advancing. What did these accomplish? They ploughed up the turf of a meadow for a foot or two in depth; they pushed moraine-stuff in front of them, showing some tendency to override it, and nothing more. But further testimony may be obtained in respect to this enquiry by examining ground from which glaciers have recently retreated. In 1875, at the foot both of the Glacier des Bois and of the Argentière Glacier, was a stony plain. Both these proved to have been recently uncovered by the ice; in other words, the glacier had not been able to plough up a boulder-bed even at a place where, owing to the change of level, some erosive action not unreasonably might have been expected. But, further, on both these plains big blocks of protogine were lying.† These were striated on sides and top, thus showing that the ice had actually flowed over them, as if it were a stream of mud. Here, however, we might be reminded of the insignificance of the Alpine glaciers. Permit me then to point out that these localities must have been buried beneath ice when a glacier covered the area of the Lake of Geneva, and must have continued to be buried for centuries and centuries after the ice had melted away from every lake-basin in Switzerland or Italy. But it may be urged that in the glacial epoch this district was covered by *névé*, and that *névé* does not excavate. Speaking for myself, I think its erosive power is small; but, if so, there will be a schism in the ranks of glacial erosionists, for then glaciers cannot have excavated cirques, and to admit this would entail unpleasant consequences; so I

* 'Scrambles in the Alps,' chap. vi.

† One in front of the Glacier des Bois was 12 by 8 by 4 yards; the largest before the Argentière Glacier was 12 by 7 by 5 yards. I think it very probable that these larger blocks at any rate were dropped at a late period in the history of the glacier, and are only temporarily overflowed by ice.

content myself by observing that *névé* would cease to occupy a district barely 4000 feet above the sea some time before the glaciers could be called insignificant. So far then as the evidence goes which I can collect from the Alps, and, I may add, from all that I have seen in Britain, the Pyrenees, Norway and Canada, the lakes which are due to glacial erosion (*i.e.* removing all dams of moraine or drift) are rather local, small, and shallow.

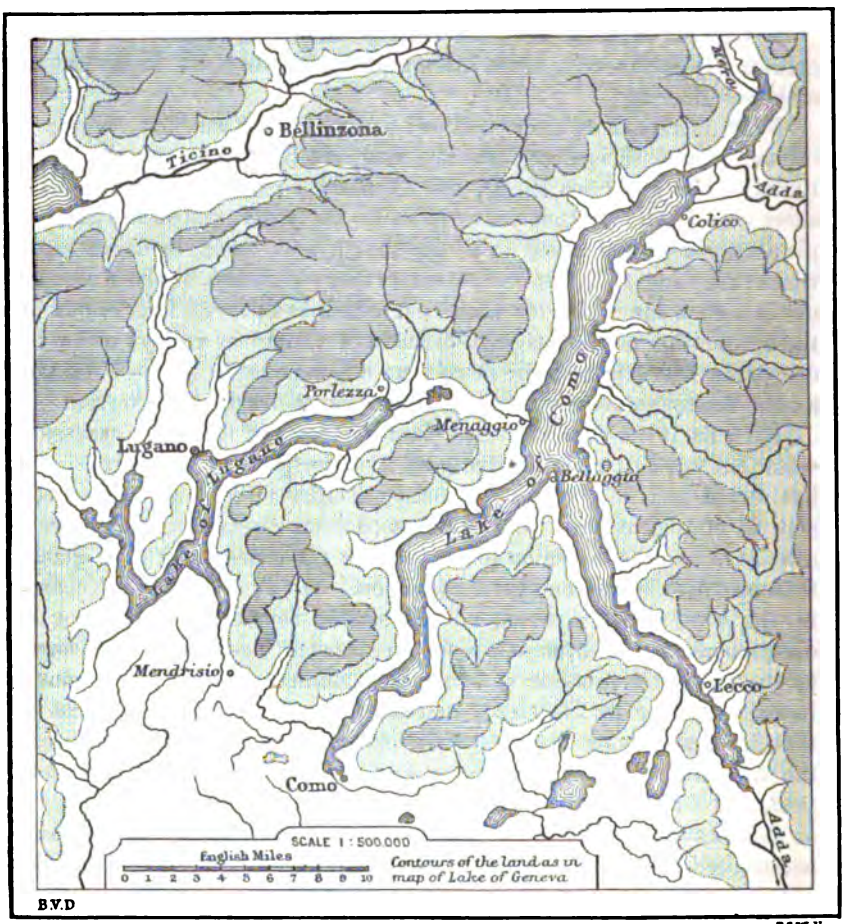
I pass on now to consider certain difficulties presented by the greater Alpine lakes when we attempt to attribute them to the erosive action of glaciers.

First, in regard to their position: some of them, such as Constance, Geneva, Como, Maggiore, &c., are comparatively near to the lower limits of the great ice sheets, and so would be covered for a relatively short time. All of them are many miles from the ends of the existing glaciers, yet we are asked to admit that a rock basin, in depth sometimes exceeding 1000 feet and generally more than 500, has been scooped out in a time much shorter than that which has proved insufficient for the obliteration of the original features of the upper valleys or for the deepening of their beds by more than a few yards at most—indeed, as a rule, the ice seems never to have been able to overtake the torrent.

Perhaps it may be answered that a stream of ice like a stream of water has not the same erosive force in every part of its course. Probably that is true; but we may fairly decline to take account of this general statement until we are informed what there is in the physiography of each lake region to account for the quickening of a glacier from an inert to an energetic condition. We find no marked change in the level of the ground, no remarkable confluence of valleys, no conspicuous straits through which the crowded ice-streams were forced by the relentless pressure of the masses behind. Surely Como cannot be accounted for by the slight descent from Chiavenna, or Geneva by that from the rocky barrier of St. Maurice, or Brienz by that from the Aarschlucht, while Constance, Zurich, and Wallenstadt, Maggiore, Orta, and Garda, are hopeless puzzles? Moreover, what are we to say of the Achensee, that deep lake, so strangely nestling among comparatively low limestone peaks; or of Zug, half sheltered by the block of the Rigi; or of Lugano, with its radiating arms enclosed on almost every side by mountains comparatively low?

Let us turn to another group of facts. The general outline of certain of the larger Alpine lakes, such as Constance, Zurich, Geneva, and Garda, at first sight is not unfavourable to the idea that they have been excavated by a glacier, but serious difficulties are presented on closer examination. The water from a considerable extent of the south side of the central range in Tyrol passes away down the valley of the Adige; during the glacial epoch the ice must have followed the same path. Yet no lake records the fact, and if one ever existed it must

have been small and shallow. The Lake of Garda lies, no doubt, in the path of a glacier, but this drained an area comparatively restricted, occupied by mountains far from lofty. The crags and headlands in the middle part of the lake are curiously unlike, in their general outlines, what might be expected as the ruins left in the track of a gigantic scoop which has dug out a basin, in one place full 900 feet



LAKES OF LUGANO AND COMO.

deep. Geneva also does not lie in the path of the thickest part of the ancient glacier, but as it curves round towards the south it follows a line along which the scooping force must have been comparatively slight. As will be presently seen this initial difficulty is strengthened by a closer study of the form of its bed. Again, how are the radiating arms of Lugano and Lucerne to be explained? Supposing the orographic features of these districts in each case to be first outlined and the

valleys excavated down to the present water level, what is there in the structure of either to explain the scooping out of lateral valleys? If the recurved hook and lateral bays of Lugano are the memorials of as many ice streams, it may be fairly asked why almost every transverse tributary valley in the Alps is not also provided with a lake? In the case of Lucerne how was the Küssnacht arm of the lake produced? Did a glacier plunge headlong down the little slope made famous by the legend of the "hollow way," or did the ice stream either from the Brünig Pass or from the Engelberger Thal crawl across the back of the glacier of the Reuss Thal, like one snake over another, and then compensate itself for this feat by excavation? Perhaps such an intertwining of ice streams would not be too great a trial for the faith of some glacialists, but speaking for myself, I should like to be supplied with a few corroborative facts before removing it from the imaginative poetry to the sober prose of science.

But the Lake of Como is even more perplexing, if regarded as an instance of glacial erosion. Its subaqueous contours present serious difficulties; but for the moment only those which meet the eye shall be noticed. The lake in form roughly resembles the letter Y, its base pointing to the mountains. The water flows out of the eastern, or Lecco, arm; the western, or Como, arm is closed by a line of sandstone hills (molasse), which rise a few hundred feet above the level of the water. The original lake basin extended nearly up to Chiavenna; its present length, measured to Como, is about 31 miles, and to Lecco about 24 miles. The deepest part of the lake is 1341 feet—642 feet below sea-level. Chiavenna is only about 350 feet above the lake, and the valleys tributary to the Maira do not descend from very high mountains, since those draining the principal peaks of the Bernina group enter the Val Telline; and the junction of that huge tributary produces no appreciable effect in widening the main valley. Thus we are justified in asking how it was that the ice suddenly acquired this erosive force, after having been previously such an inefficient excavator. Again, if it be assumed that the valley was carved out by ordinary agencies nearly to the present lake-level—for without this assumption I cannot account for the existence of the promontory of Bellagio, and the severance of the ancient glacier into two forks—let us proceed to examine the western, or Como, ice-stream. It passed over the site of the town; it climbed the slopes beyond, for their beds of conglomerate are smoothed and striated; it crossed the sandstone ridge, leaving blocks of granite from near the Forno and Albigna glaciers poised on its crest, and piling up moraines on the lowland some distance away to the south. How, then, has this projecting barrier of comparatively soft sandstone escaped from being planed flat by the ice which was so potent an agent as to dig out the long basin to the north? So little has it suffered, that its crest is a ridge, unusually narrow and sharp, often only a few feet, hardly ever a

few yards, across, with steep slopes on either side. The lower end of the Lake of Orta, from the northern part of which water is discharged to the Lago Maggiore, affords a similar and no less puzzling problem. Not less perplexing are the subaqueous contours of the Lake of Como. The arm ending at that town is deeper than the upper lake, its bed for a considerable distance being about 1300 feet below the surface; while the basin north of Bellaggio, with a maximum of 1116 feet, is less than 1000 feet deep as a rule. But nearly opposite to Bellaggio, just below the point of division of the ancient glacier, and where we should suppose its erosive force to be still very great, the bed of the lake rises to within 438 feet of the surface. The basin of the Lecco arm, however, is shallower than that of the upper lake.

The subaqueous contours of the Lake of Geneva, recently described in Professor Forel's monograph,* do not lend themselves very readily to any theory of glacial excavation. As a physical feature it is later than the middle of the miocene period. Its slopes, and almost certainly its bed, are covered with glacial *débris;* its waters once stood at a higher level.† It consists of a wide deep upper basin and a narrower and shallower lower one. In the former, at the base of the cone of *débris* deposited by the Rhone, the lake-floor is a broad, nearly level, plain, about 300 m. (984 feet) deep. The contours of its sides are evidently closely related to those of the slopes which rise from its margin. The fall is rapid, almost precipitous, beneath both Chillon and St. Gingolph. West of Vevey it is about 1 in 4, changing gradually to 1 in 10 opposite to Ouchy. The rise at the western end of the basin is gradual, and the depth at the barrier of Promenthoux is only 75 m. (246 feet). The other basin—the Petit Lac—between this place and Geneva, is a narrow, shallow trough, the bottom of which rises very slowly from a depth of about 70 m. (230 feet) to 50 m. (164 feet), thence gradually mounting to the efflux of the Rhone; but the continuity of the floor is slightly interrupted by five small shallow hollows,‡ roughly linear in arrangement. No alteration in the level of the lake-bed corresponds with the change from the comparatively hard limestone about the upper end of the larger basin to the comparatively soft sandstone of its lower end. The shallowing up to the barrier of Promenthoux and the Petit Lac itself do not seem related to the ancient glacier, for, so far as we know, its line of maximum thickness, which might be expected to indicate its greatest erosive force, pointed towards Neuchatel. If this glacier were competent to excavate the lake, surely it should either have worked steadily along the line of the Rhone to Geneva, and thus made a lake changing gradually in outline and depth, or have kept on more nearly along the axis of the upper lake.

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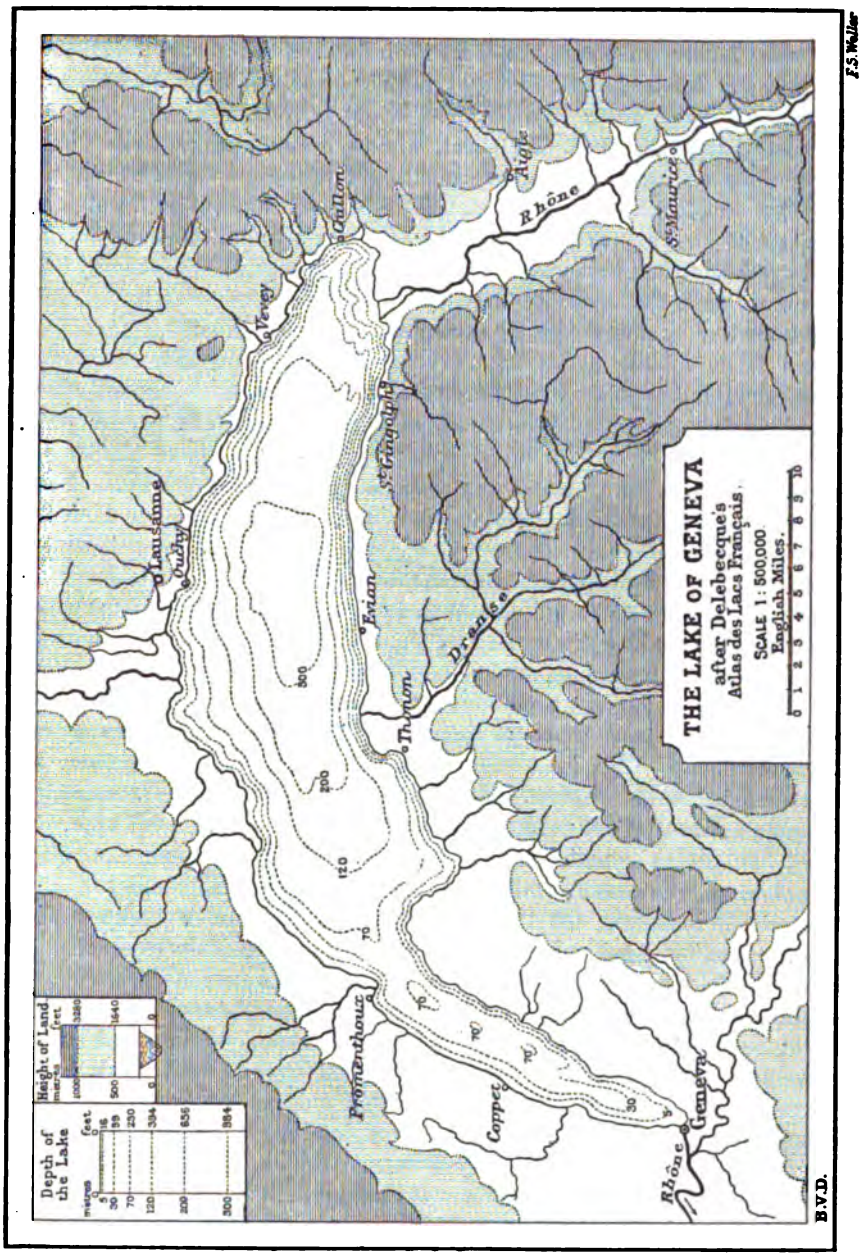
* Le Léman 'Monographie Limnologique' (tome premier).

† Not less than 100 feet, and possibly higher.

‡ These sink from 15 to 20 feet below the general level.


THE LAKE OF GENEVA
after Delebecque's
Atlas des Lacs Français.
Scale 1: 500,000
English Miles.
0 1 2 3 4 5 6 7 8 9 10
Depth of the Lake
Height of Land
Lausanne
Ouchy
Vevey
Villeneuve
Evian
St Gingolph
Thonon
Rhône
Ripaz
St Maurice
Promenthoux
Coppet
Rhône
Geneva
B.V.D.
F.S. Weller

An atlas of about twelve French lakes, including that of Geneva, has been recently published by M. Delebecque, of Thonon. In one of these a submerged river channel can be traced across a rather wide part of the lake. In most the depth diminishes wherever the shores approach. In the Lac de Bourget the slopes of the Mont du Chat are prolonged under water to a depth of about 300 feet—*i.e.* nearly to the lowest part of the bed. In short, almost every one of these lakes presents some anomaly hard to reconcile with a theory of glacial erosion.

One fact to which Professor J. Geikie has called attention,* seems at first sight strongly to support Sir A. Ramsay's hypothesis, and is the only real addition, in my opinion, which has been made to the original reasons. It is that many of the Scotch lochs are true rock basins, and that similar basins frequently occur outside their mouths. This also often holds of the fjords in Norway, New Zealand, and elsewhere. Professor Geikie points out that several of these basins occur just when the ice might be expected to obtain an increased scooping power. His map at first sight appears very convincing; but a study of the larger charts reveals many anomalies. Loch Linnhe, for example, from below the entry of Loch Leven, maintains a general depth of from 34 to 50 fathoms; then, below Loch Corrie, a channel may be traced which varies in depth from 50 to 60 fathoms, after which, in the Lynn of Morven, we find it deepen to 70 fathoms, then to 90 fathoms; and at last a little north-east of the line joining Barony Point with Lismore Point, it expands into a basin with a maximum depth of 110 fathoms. But outside, in the Sound of Mull (to the north-west) the depths become very irregular, varying from about 35 to 70 fathoms. Barony Point appears to be connected with Mull by a submerged isthmus, generally less than 20 fathoms below the surface. But here, if the glacier were stopped by impinging on Mull, it ought in splitting to be pushing hard upon its bed. In all this region the irregularities of the ice-bed are very perplexing, whatever hypothesis be adopted; but I will restrict myself to a single instance. Off the west coast of Scarba, under the lee of the "Islands of the Sea," and where the opening towards Colonsay makes it improbable that the ice can have forced into a narrower space, an elongated basin occurs in which the soundings—outside about 60 fathoms—deepen to 100, and at one place to 137 fathoms. The sea-bed about Arran presents similar difficulties. In short, here, at Loch Etive, Loch Lomond, and in other places, all goes well only so long as we restrict ourselves to generalities and abstain from details.

The Sogne Fjord in Norway is a remarkable basin. As its arms unite, its bed sinks to 511 fathoms at the mouth of the Aurlands Fjord; then descends gradually down to 567 fathoms, after which for a long way the soundings vary from 637 to 660 fathoms; but on reaching the outer

* 'The Great Ice Age,' p. 519.

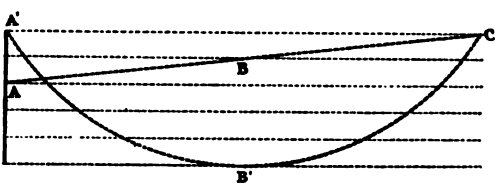
islands the sea-bed rises till it comes within the 100-fathom line. There is nothing, however, in the contour of the fjord to account for the marked increase of depth, while the opening at the islands seems insufficient to explain the shallowing; for the ice stream, according to the modern school of geologists, swept out far away to sea at the time of maximum glaciation.

The Vest Fjord also offers a number of difficulties, of which I must mention one only—namely, that a channel about 200 fathoms deep lies near the Norway coast to which the sea-bed descends very gradually from the Lofoten Islands. But the latter, as their outlines show, cannot have given birth to glaciers comparable with those of the mainland. Hence the scooping effect produced by the struggle between the opposing ice streams should have been manifested on the western, not on the eastern side of the fjord.

From these and other instances I infer that these singular basins, as a rule, have not been excavated by glaciers. Unequal subsidence frequently appears to occur. The movements near a coast-line often seem to be far from uniform. It must be remarked also that moraines are often left by retreating glaciers, and if these are on a scale at all similar to those of the old Alpine glaciers, very considerable inequalities would be produced. To such a cause the curious irregularities in the bed of the St. George's Channel seem—in part, at least—to be far more probably due. At any rate, I have never been able to connect them with any theory of glacial excavation. In short, the evidence of lochs, fjords, and the neighbouring sea-bed, does not appear to me sufficiently convincing to outweigh the arguments in the contrary direction.

The evidence which has been summarised above seems to lead to the conclusion that the excavatory power of glaciers has been much exaggerated. The European glaciers generally have not been very potent agents of erosion or even of abrasion, probably because the glacial epoch was comparatively of short duration. But I may be fairly expected to offer an hypothesis as a substitute for that which I discard. This was done full twenty years since, during which time advocates of the other have been almost unanimous in "letting it severely alone," but since then the evidence in its favour has been strengthened. Strange to say, this hypothesis was overlooked by Sir A. Ramsay when he claimed a victory for his own one, not so much for its positive merits as on the ground of its being the only one that held the field. Yet the hypothesis has always appeared to me one of the most simple and natural. It is this. The lakes above and below water present, as we have seen, the contours of ordinary valleys. Suppose them to have been eroded by the ordinary agencies, among which ice would sometimes play a subordinate part, and their beds to have been subsequently affected by differential movements. If the lateral pressures by which

a mountain chain has been formed have begun again to act after an epoch of comparative rest, during which the folded masses have been carved into peaks and valleys, it is more probable that alternating zones parallel with the axis of the chain would be affected by uplifting and down-sinking movements than that the massif would rise or sink uniformly as a whole. Probably, if such differential movements were comparatively slight, they would be more marked towards the outer part of the chain nearest to the region on which incoherent materials had more recently been deposited. Suppose then the outermost zone to rise and the next within it to sink, that part of the river valley would at once be converted into a lake. As a simple illustration take two points A and C in a valley 20 miles apart, and B half-way between them, and suppose the fall to be 10 feet a mile; B is 100 feet above A, C the same height above B. Suppose C to remain fixed, B to sink 400 feet, A to rise 200 feet, *i.e.*, to the level of C. A basin is now formed 20 miles long, which at its middle point under B is 500 feet deep. But it might be urged that evidence of such a flexure should be afforded by the rocks themselves. Suppose they had originally been horizontal—

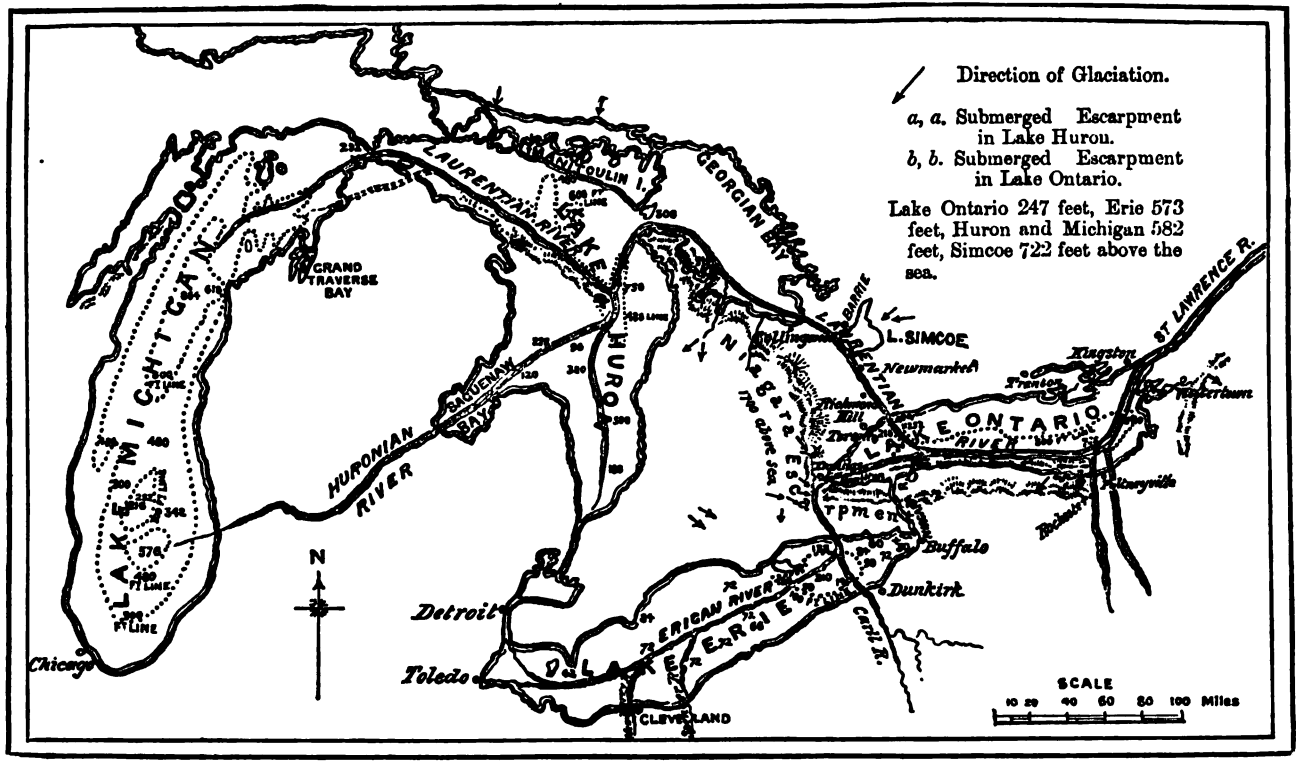


The intervals between the horizontal lines represent 100 feet.

they would now, between A and B, dip from the former to the latter at an angle measured by 500 feet in 10 miles, not quite 1 in 100, *i.e.*, less than one degree.

Such a case, however, is exceptionally favourable; as a rule the strata were considerably flexured, and folded long before the lake basin was formed, so that the detection of so trifling a disturbance is an impossibility. It is obvious that the effects of such a depression in a valley which was fairly regular in form would be to make the broadest and deepest part correspond. At the same time the contours of valleys are so variable, and depend so much on the nature of the rocks through which they are cut, that deviations from this rule are to be expected.

But we may be fairly challenged to cite any instance of lakes which have been produced by differential movements of the Earth's crust. Extreme glacialists formerly cast longing eyes at the great lake-basins of North America. They lie within the territory once occupied by an ice-sheet; they are true basins of considerable depth. Of late years their beds have been studied, and a convenient summary of the results



THE ANCIENT LAURENTIAN VALLEY NOW OBSTRUCTED AND FORMING TH GREAT LAKES. (*From the Qy. Journ. Geol. Soc.*, 1890.)

is given by Professor J. W. Spencer.* I must content myself with the veriest outline. Lake Michigan is divided into two basins—the northern, 864 feet deep, the southern, 576 feet—by a broad plateau, about 450 feet below the surface. An old river channel, now choked by glacial drift, connects the latter basin with Saguenay Bay, in Lake Huron; the other one was united with that lake as at present, but also by a buried channel. Huron formerly did not drain, as it now does, into Lake Erie, but its slopes converge opposite to the opening between the southern end of Manitoulin Island and the mainland, and the valley thus formed can be traced through Georgian Bay to its southern end, whence another choked-up valley leads into Lake Ontario, west of Toronto. Erie, thus separated wholly from Huron, drained, also by a buried valley, into Ontario. In Huron and Ontario submerged escarpments have been detected. The contours, then, of this lake system, if it could be cleaned from the glacial *débris*, would resemble those of a system of river valleys. The lower part of the St. Lawrence has been proved to be a submerged river channel, and indicates a change of level amounting to some 1800 feet. At the present time Michigan is 582 feet above sea-level, and a portion of its bed more than 250 feet below it. The deepest part of Ontario is as much as 500 feet below this. But differential movements have continued since the lakes were formed, for the "Iroquois" raised-beach is full 600 feet higher at the north-eastern part than it is at the western end of the lake.

To conclude, glaciers, when the paths which they have traversed are carefully studied, appear to have acted, as a rule, as agents of abrasion rather than of erosion. Even in the former capacity they have generally failed to obliterate the more marked pre-existent features due to ordinary fluviatile and subaerial sculpture. In the latter capacity they seem to have been impotent, except under very special circumstances; thus, while we may venture to ascribe to glaciers certain shallow tarns and rock basins in situations exceptionally favourable, we cannot assign to their agency either the greater Alpine lakes or any other important lakes in regions which were overflowed by the ice only during the period when it attained to an abnormal development.

The question which I have ventured to bring before you this evening has been discussed hitherto by the geologist rather than by the geographer. In reality it belongs to the wide neutral zone which lies between the two provinces of scientific investigation. In my treatment of it I may have seemed to some geologists to be almost abandoning their claims, by practically denying that glaciers are direct erosive

* *Quart. Jour. Geol. Soc.*, 1890, p. 523. Lake Superior, which certainly does not help the glacial erosion hypothesis, is not included. The depth of Michigan is 864 feet, of Huron 750 feet, of Erie 210 feet, of Ontario 738 feet. I am indebted to the kindness of Prof. Spencer and of the Council of the Geological Society for the use of the map illustrating the Paper just mentioned.

agents of the first magnitude. But however we may differ on this question, we should all agree—and this no less concerns the geographer —that glaciers have a most marked, even if it be a somewhat superficial, influence on scenery, and that by acting as storehouses of water and feeders of rivers they indirectly play a most important part in the work of earth-sculpture.

Before the reading of the paper the President said: To-night we make an excursion, I will not call it an incursion, into the territory of our neighbours the Geological Society. I think it is very desirable that we should make these excursions from time to time, if only for the purpose of showing that we claim to concern ourselves with everything that belongs to the theatre in which man lives and works. The eminent geologist whom we welcome to-night is known to all of you by name, and to some of you personally. I am sure that you will all listen with the greatest attention to what he has got to say, and I am not the less sure that when he has concluded his observations some members, to whose opinions also we attach great importance, will attack his views.

After the reading of the paper the following discussion ensued:—

Dr. BLANFORD: I am sorry the task of replying to Professor Bonney has not fallen into the hands of some one better qualified, for although I am prepared to defend the views of the late Sir Andrew Ramsay, of whom I was a pupil, I am at the same time not willing to go to the extent he did, and I do not attempt to suggest that the great lakes of America are due to glacial action. With regard to the moderate sized lakes of the Alps, such as Como or Geneva, the question is a very difficult one indeed, and if I were to attempt to go into it I should take as long to put the other side as Professor Bonney has done in laying before us his admirable summary of the arguments of the anti-glacialists. The chief points I should like to urge upon you are first, that I think Professor Bonney rather underrates the effect of erosion by ice. Not the ice but the stones imbedded in it scrape away the rocks upon which they impinge, just as the emery or diamond dust on the wheel of a lapidary grind down a gem. I cannot admit that the shape of a valley eroded by a glacier is the same as that caused by ordinary fresh water action. In Europe we are likely to forget that the big valleys among our mountains are glacial valleys, but if you go into countries where no glaciers ever acted and come upon the typical V-shaped valleys you see the difference immediately. In the Himalayas there are U-shaped valleys at higher and V-shaped at lower elevations, the higher ranges are the same in appearance as in the Alps, but the different form of the lower valleys strikes you at once. The evidence of erosion in glaciers does not depend upon what a glacier in its most effete stage can do, but the proof that glaciers do erode is to be found first of all in the very simple fact that the water issuing from beneath a glacier is always thick with mud. If ice has no effect in eroding what is the origin of the boulder clay? High up upon the sides of numerous peaks in countries affected by glaciers you find curious little tarns; there is one on the north side of Cadr Idris, one or two on Snowden; one of the most interesting I have seen is on the east slope of Snæhette in Norway; in this case there is a little glacier coming down from the peak ending in a lake about ½ mile long. An extremely good instance of a rock-basin formed by erosion is Easedale Tarn above Grasmere. Professor Bonney agrees that such tarns must have been excavated by ice action, but then comes the question where is the line to be drawn. As Professor Bonney has pointed out you may begin with tarns and go on by almost imperceptible

gradations to the biggest lakes in the world. This was the argument maintained by Sir Andrew Ramsay, the only difference being that Professor Bonney begins by showing that the larger rock basins cannot be glacial, while Sir A. Ramsay commenced with the little tarns and showed the gradual passage from them to larger lakes. That the smaller tarns are due to glacial erosion is easy of demonstration, but the difficulties become great when we come to lakes like Como, because it is not easy to understand how glaciers can work down to that great depth and rise up again, and excavate a deep basin while moving over so long a space. On the other hand it is a curious and extraordinary fact, as Sir Andrew Ramsay pointed out, that in the area where ice has had effect lakes abound, but where no ice has affected the surface lakes are few in number. At the base of the Himalayas no lakes are found. The Himalayas are probably more recent than the Alps, as the beds of sandstone, conglomerate, etc., found disturbed at the foot of the Himalayas are more recent than those found in the Alps, so that if lakes are due to disturbance and tilting only, they ought to be at least as numerous in the lower Himalayas. Then we come to a most difficult question, that of fjords. You find them in Norway, on the west coast of Scotland and in America; one of the most typical being that of the Saguenay running into the St. Lawrence; it is excessively deep and terminates in a comparatively shallow sea. Why should fjords of this peculiar character be found so often in high latitudes where we know ice played a part, and why are they wanting in the tropics? In the tropics are found valleys depressed much below the sea-level. At the mouth of the Persian Gulf on the western side are numerous inlets formed by depression, well surveyed, because the telegraph cable was at one time carried across, but having by no means the characters of fjords. This then is the crux that remains to be solved, where we know that ice sheets and glaciers have existed we have lakes in large numbers, and the peculiar phenomena of fjords, but they are not to be found in places where so far as we know ice has not been. I do not mean to say positively that the larger rock-basins have been excavated by ice, but at the same time if no other theory save that of tilting is put forward, how does it come to pass that tilting has only taken place where ice has been. I must say that so far Sir Andrew Ramsay's theory holds its place.

Mr. Douglas Freshfield, President of the Alpine Club: Some years ago when, as editor of the *Alpine Journal*, I had the privilege of being in correspondence with Mr. John Ruskin, he concluded one of his letters to me with the following characteristic sentence: "I hope that some day the members of the Alpine Club may desire to gather together their knowledge of glaciers and make a wholesome end of all glacier theories by due acknowledgment of James Forbes's conclusive ascertainment of glacier facts. They owe this duty to science, and should, it seems to me, take honourable pride in fulfilling it." I do not think the Alpine Club can be accused of having failed in doing its part in the work Mr. Ruskin proposed for it; in bringing, that is to say, recent geological theories into close contact with geographical facts. Mr. Whymper, as we all know, in his book on the Alps, entered largely into the question of glacier action, and since that time four Presidents of the Club—our late respected and beloved Fellow and Councillor, Mr. John Ball, Mr. William Mathews, Mr. Bonney (whom you have heard to-night), and last and least myself, have done our best to show that the geological theory of glacial excavation is inconsistent with the topographical facts as we and others have seen them, and that it is supported mainly by appearances which I may fairly call superficial. It would be preposterous in me to imagine that anyone here remembers, or that more than a few have read, a paper which I printed in December, 1888, in our Society's *Proceedings* upon "The Conservative Action of Glaciers." I cannot now recapitulate the facts I gave there; I can only refer to them. Among other things I pointed out how Sir Andrew

Ramsay himself had admitted the incapacity of glaciers in excavation. He writes for instance: "One great fact which the striations teach is this, that the broad and thick ice-sheet, urged on from the north, buried the whole of the region described; and, further, that the glacier moulding itself to the shape of the country (after the manner of all glaciers) was pressed right onward with so much force that the long northern slopes of the east and west valleys offered, comparatively, no more impediment to its onward march than an occasional transverse bar of rock hinders the onward flow of a river." It is physically certain, I believe, that ice must do most work in abrasion where its weight and velocity, its pressure and friction, are greatest. What we claim to show is that among the existing glaciers of the Alps you cannot find one which, where its weight and velocity are greatest, has done more than smooth and polish resisting protuberances and carry on loose material—not one which has done any serious excavation. Many of those present must have visited the end of the Mer de Glace, the Bossons Glacier, the Brenva Glacier, where they descend into the valleys. The ice has retreated of late, and let us see what it has done under its bed. These glaciers have left no lake-basins in their retreat; they have rather raised than excavated the ground. There is a steady upward slope from the village of Chamonix to the end of the Glacier des Bois. Turn to extinct glaciers. The old glacier of the Valley of Aosta could not widen the gorge of Bard; it left undisturbed on the plain near Ivrea gravels deposited before its visit. The old glacier of the Rhône had to mould itself to the narrow limits of the gorge of St. Maurice; where it was met by a great tributary from the Valley of the Arve, it dug no basin. The depths of the Lake of Geneva do not correspond to any sudden increase in the ice's volume or velocity. Look, again, across the Atlantic. The enormous Alaskan glaciers do not uproot tree-trunks; the Greenland glaciers break against the Nunataks; they do not remove them. Even the mighty ice-sheet that once spread across the North American continent had no power of destruction. I challenge our opponents to meet the facts set out in the Reports of the United States Surveyors I quoted five years ago. If then we find no modern glaciers digging lake-basins, how can we believe that the hollows on the earth's surface were made, or in any great part made, by glaciers? Dr. Blanford's argument from the frequency of tarns in mountain regions may be retorted upon himself. Some parts of the Alps are thickly set with tarns; true, but other parts, once equally glaciated, are not. The tarns occur in particular geological formations. In the chain of the Caucasus, 700 miles long, there are no lakes, there is hardly a tarn. What have the Caucasian glaciers been about, if it be glaciers that make lake-basins? Lake-basins, we admit, sometimes (not always, by any means) exist near and on glaciated ranges. Yes; and there will be found sufficient reasons for the fact. Where on the surface of our globe there are heights, there must be hollows; where there are central ridges, there will be furrows also, and parallel elevations. Then there must be basins; and until torrents, acting as saws, have tapped them, or, acting as mud-carts, have choked them, these basins will hold water. Another class of lakes will be formed by moraines acting as dams. There are many of these in New Zealand. The history of the hypothesis I am combating is not an uncommon one. There is a great deal of human nature in it. Geologists, like the simple children of the Syrian desert who attribute anything great to Alexander, have been apt to account for any strange phenomena by an heroic cause. At one time it was an universal deluge, or many partial deluges. Even De Saussure belonged to this school: he thought erratic blocks had been distributed by some mighty flood. Then there was the theory of volcanic, or igneous action: of catastrophes. Lastly, the true origin of erratic blocks was discovered, and the scratches and rubbing of the ice recognised. These superficial appearances were found over vast

areas. Ice became the new toy for science; and one of the ways in which science shows its eternal youth is in its passion for new toys! I will briefly point out, in conclusion, some of the effects glaciers have produced on contemporary landscape, and their geographical importance. Professor Heim of Zurich, whose important work is very insufficiently known in this country,* has laid down the law that "glaciation is equivalent to a relative cessation in valley formation." The cloak of ice protects the soil from the alternations of heat and cold; from floods and earth-slips and mud-avalanches. Water is at work under the ice, but under strict limitations. The torrent that has made its plunge in some *moulin* carves secretly and silently a deep, narrow cleft. Consequently, the traveller after passing the moraine-heaps which mark the most recent considerable extension of the glacier, finds the valley more U- in place of V-shaped, and at the same time shallower. Any rocky barrier across it shows convex surfaces smoothed and scratched by the glacier on the side opposed to its advance, and is slit through by the gash cut for itself by the once sub-glacial stream. Such are the features of the well-known Kirchet, near Meyringen. Of course it follows that some of the solid matter found in glacial streams is due to their own erosion, and not merely to the pounding together as they move along of the blocks to which the ice is serving as carrier. The bottom of a lately glacier-covered valley is flat because the ice has protected its bed from sub-aerial denudation; as well as from the inroads of earthslips and the fan deposits of side-streams. I saw once in the Caucasus an enormous mountain-fall carted clean away and carried ten miles by one of the glaciers of Ushba. The glacier was acting not as a spade but as a sledge. I could easily go on talking about the ways and varieties of the glaciers I have known; but I must not detain the meeting longer, lest the question before us should be changed from "Do Glaciers Excavate?" into "Do Glaciers Bore?"

Sir Henry Howorth: I think it is a little hard upon my friend Professor Bonney that I should be called upon to speak on his side, as he is himself fond of fighting. This week I am publishing a big book, in which I propose to do my best to speak plainly about the views of the ultrà glacialists, and to-night I must limit myself to one or two points. The first point is, that they have no right to appeal to ice until they prove the potency of ice to do the work. Now the mathematicians have shown that ice, under the pressure required to excavate a lake after travelling over a flat plain, would be crushed long before it reached the lake. It is thus shown that such excavation is a mathematical impossibility, as you have to import into ice an entirely new force before you can make it excavate. It is not a question to be treated on theoretic grounds, as it is often treated. You must ground your argument on some solid base before you are justified in proceeding at all. The arguments put forward by Sir Andrew Ramsay and Professor Tyndall on this subject, urging that all lakes and valleys are excavated by ice are mutually destructive, as one insists that the ice gradually loses its force, and the other declares that it must keep its force. Both these men wrote, long before it was proved that Forbes was right (to the very letter) in maintaining that ice, instead of being a rigid mass, or nearly so, travelling over slopes and great level plains, is, in fact, a viscous mass moving as water moves, and that when it ceases to get the impetus from the slopes behind, it ceases to move and work at all. Experiments published in the 'Philosophical Transactions of the Royal Society' proved that Forbes's grand generalisation was perfectly true, and proved also, it seems to me, that ice is an impossible agent to appeal to as an excavator. We are told to-night that these lakes only occur in regions which have been occupied formerly by

* Heim, 'Handbuch der Gletscherkunde.' See Review by Mr. F. F. Tuckett in *Alpine Journal*, vol. xii.

glaciers. The fjords have also been appealed to. Dana, as far back as 1849, was the first to appeal to ice as the excavator of fjords. Now these fjords exist in many places where, so far as we know, no ice or glacier ever existed at all. Falsan has shown that all along the southern shores of France, in Dalmatia, and on the shores of Asia Minor, fjords exist. Now the Austrian geologists who tramped in search of evidence of ice action all over European Turkey, could not find a trace of an old glacier. There is the remarkable fact also pointed out by Mr. Freshfield, that in Greenland, where the study has been carried on notably by one remarkable Englishman who lived there twenty years, and whose papers have been overlooked, and also by Peterssen, who both show that on the spot nothing like excavation by these enormous glaciers with their rapid motion can be found. My friend Dr. Blanford says if you do not appeal to glaciers, what about the boulder clay? I say boulder clay has not been formed by glaciers at all. I have been where glaciers are working hard, and, like a good many other people, have absolutely failed to find boulder clay being formed. Boulder clay necessitates an appeal to something more than glacial action, and certainly we find nothing in the moraines of glaciers in the least resembling boulder clay. There seem to me to be other facts and arguments which preclude absolutely this appeal to ice. Ice is exactly like the sand paper used by the sculptor after his assistant has chipped out the statue. What comes out of the bottom of a glacier, as was said by Mr. Freshfield, in the shape of the so-called glacier milk is largely the result of the rubbing down of the masses that have fallen down the crevasses from the backs of the glacier. A glacier can no more take blocks of stone out of its own bed than a man with his hands tied behind him can pull teeth out of his own head: and the products of erosion we see everywhere are caused by the rubbing of the stones that fall down the crevasses and chafe against the rocky bed. Thus we find that glaciers do not excavate, but only polish. Being a disciple of Professor Bonney, who has done so much to illustrate this question, I could not resist your invitation to say a few words.

Mr. W. M. Conway: Reference has been made to the Karakoram Mountains, and the Himalayas have been described as later than the great range of mountains behind them. I have recently visited a portion of that range, and seen the largest glaciers in that district, notably the Hispar, which is the largest of all. It has, in quite recent times, retreated 25 miles, and is now only 40 miles long. In the first place it has not left a U-shaped valley, but a remarkably V-shaped valley, and there is no trace of the valley having been gouged out; and in the second place, nowhere in the neighbourhood does there remain any lake whatever. This afternoon I saw two men looking in a print-shop window, arguing as to how an engraver had produced a certain effect with the burin; as a matter of fact the thing was a mezzotint. Their discussion reminded me of the arguments regarding lake basins. I think, if the geologists arguing about this matter made themselves familiar with glaciers by contact with many, it would ultimately occur to them that they had never seen one engaged in excavating. I, and many others, have been under glaciers, both in their upper, middle, and lower courses, and have never seen one excavating. They slope and slide in the smoothest possible manner, and here and there do a little scratching. It was looking at the print, and not being familiar with the process, that brought this theory into prominence.

Professor Bonney: My friend, Sir Henry Howorth, Mr. Freshfield, and Mr. Conway have left me very little to say, but I will just touch upon one or two points very briefly. With regard to the St. Lawrence, I may point out that the basin of the Saguenay is formed by a submerged moranic boundary between the valley of the Saguenay and the main valley of the St. Lawrence. With regard to the absence of lakes from the Himalayas, and presence in the Alps, if basins were made by glaciers

the two results would be simultaneous; so the question of relative age will not come in. With regard to tarns in rock basins, these only occur under most favourable circumstances, where ice may have been expected to have had great erosive power. Now, the argument of my earlier papers was, that if glaciers do excavate, they should make tarns at intervals down the valley. Dr. Blanford forgot that mud from glaciers does not prove erosion, but only abrasion, a distinction which I have drawn; and I quite agree with Mr. Freshfield, a large quantity of mud comes from tributary streams, not from the glacier. Several of the Alpine lakes, in fact, the most important, occur at the ends of the courses of glaciers, where, according to most people, they would be quite impotent to excavate, in fact, where they approach their deathbeds. It would seem that glaciers are like some people, who idle away the best part of their life, and try to have a desperate expenditure of good deeds before they leave it. Another point, on which I do not agree with my friend, is that of Alpine valleys. These, as a rule, are not U-shaped, but V-shaped, only being U-shaped in a few very exceptional cases. I have followed up, I should think, half the valleys in the Alps. The upper Haslithal Valley is throughout V-shaped, yet it is ice-worn almost down to the level of the torrent. My argument amounts to this, that if we accept the hypothesis put forward by Professor Ramsay, we are landed in a crowd of practical difficulties.

The PRESIDENT: You will, I think, agree with me in the opinion that Professor Bonney's views have been well smitten and well defended, and will direct me in your name to return your very best thanks alike to him and everyone else who has taken part in the discussion.

PYTHEAS, THE DISCOVERER OF BRITAIN.

By CLEMENTS R. MARKHAM, C.B., F.R.S.

THE discovery of the British Isles in the third century before Christ, by a Greek scientific explorer, was the last link in a chain of events which commenced with the establishment of the Ionian colonies in Asia Minor. We may trace these events as they succeed each other, with ever growing interest, for we shall find that their motive was always a noble thirst for geographical discovery and exploration. The original impulse came from those Ionian colonies in Asia Minor, whose people were gifted with all the Grecian genius for scientific research, for imaginative speculation, and for maritime enterprise. They are said to have established themselves on this coast in about 1060 B.C., to have formed themselves into twelve autonomous cities, to have advanced in civilisation, and to have extended their influence in various directions, during a long period of peace and prosperity, extending over several centuries. Their coast reached for about 80 miles from Phocæa on the north, to Miletus on the south, bordering on Caria; and the Ionian territory included the islands of Chios and Samos. Deeply indented by bays, it is formed into numerous harbours, and the dozen cities were clustered round their shores. First on the north, between the Cumæan and Hermæan Gulfs, was Phocæa, a colony from Ionian Phocis. Then came