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ORDINARY GENERAL MEETING.*

CAPTAIN G. P. HEATH, R.N., IN THE CHAIR.

The Minutes of the last Meeting were read and confirmed.

The following paper was read by the author :—

NOTES ON THE THICKNESS OF THE LUCERNE GLACIER OF THE POST-PLIOCENE PERIOD. By Professor EDWARD HULL, M.A., LL.D., F.R.S. (Secretary).

THE valley of the Lake of Lucerne, or as it is better known, the Vierwaldstätter See (Lake of the Four-forest cantons) is unsurpassed in Switzerland for the beauty and grandeur of its scenery. Its lofty banks, clothed with forest, give place to mural cliffs of limestone too steep for trees to grow on, but diversified by terraces of richest green verdure; while the waters of the lake itself present a sparkling surface of bluish-green tint reflecting the azure of the cloudless sky. Following the direction of the upper lake into the valley of the Reuss, you behold the landscape bounded by lofty mountain peaks and ridges, rising higher and higher till culminating in the far distance amongst the snowy summits of the Bernese Oberland. Here the pure white cone of Finsteraarhorn pierces the sky to a height of 14,026 feet above the level of the sea; farther on extend the more massive group of St. Gotthard heights. It is hard to conceive that such a scene of verdure and beauty as that which we survey immediately around us from the terraces of the Burgenstock or the Seelisberg Hotels was once enveloped in snow and ice; that an immense glacier occupied the lake lying so placidly at a depth of about 1,500 feet beneath our feet, and not only filled the channel to the level of its surface, but reached

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* Monday, May 9th, 1904.

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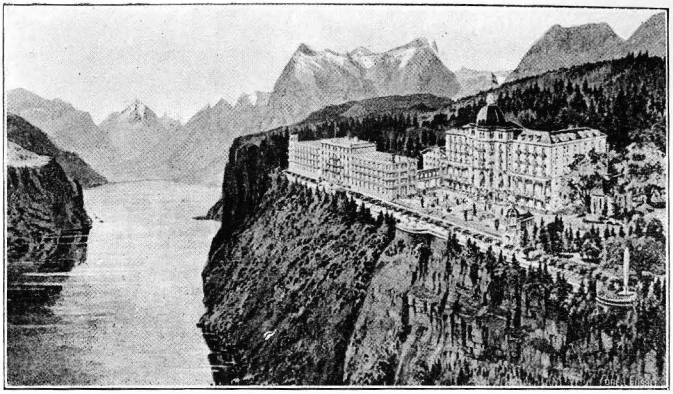

FIG. 1.—LAKE OF LUCERNE.

Section through moraine at Bellevue above Treib.

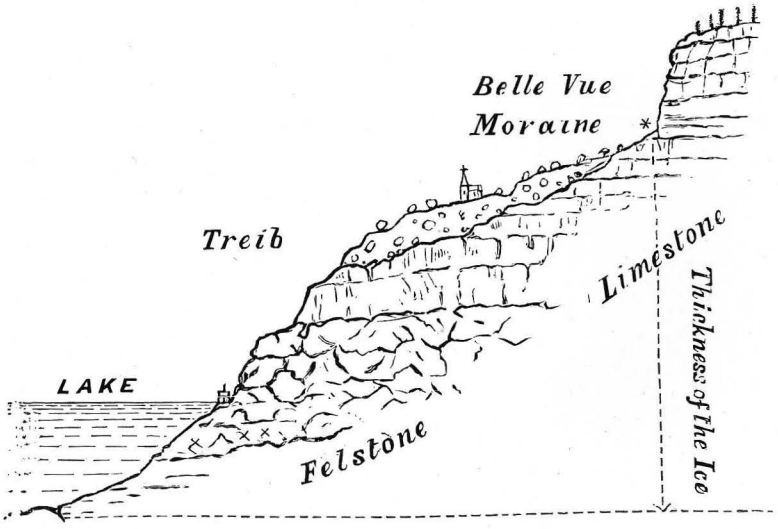

FIG. 2.—GEOLOGICAL SECTION ACROSS LAKE LUCERNE.

* Indicates the upper limit of the glacier ice.

to the height at which we stand, and that all the lofty heights and terraces above and around were enveloped in a perennial mantle of snow. In a word, to reproduce to the mind the present scene as it was during the Glacial epoch, we must ascend the higher valleys of the Bernese Oberland seen in the distance, and stand on the cliffs overlooking the Mer de Glace under the slopes of Mount Blanc, at a height of 10,000 feet above the level of the sea. Such is the transformation scene indicated by the phenomena visible at intervals as we wander along the dense forests or open glades around, at a level of only about 2,780 to 2,800 feet above the sea.

There is, of course, nothing new in what has been stated above. The late Sir Andrew Ramsay in his memorable essay entitled "The Glacial Origin of Lakes," recognised that the valley of the Lake of Lucerne was once the channel of a "great glacier," and shows that the lake itself lies in a "rock basin," being deeper in the central part than at the outlet; and he overthrows the view—at that time held by some Swiss geologists—but, I presume, now generally discarded, that the lake occupies the space left by "a gaping fissure."* The fact that the present glaciers of the Alps once descended so low as to fill the valleys of the great lakes, rising high on their banks, has been recognised since the days of De Saussure, Charpentier,† and others. Their former extension is testified to by the occurrence of boulders of gneiss, granite and protogene derived from the central core of the Alps, lying scattered over the sides of the valleys formed of the more recent formations of Cretaceous and Tertiary strata, for the most part composed of fossiliferous limestone and shale; while the surfaces of the rocks themselves are often polished and worn by glacial grooves and striations at long distances from the nearest limits of the existing glaciers. This being so, it occurred to me, while endeavouring to realise on the spot, during the late summer, the physical change that has taken place, to endeavour to measure with some approach to accuracy the actual depth to which the glacier of the Lucerne valley attained during its period of maximum evolution.

Fortunately the data for the solution of this problem are not wanting, and I hope to make it clear how they are to be applied.

Upper limit of Glacier action how determined.—The height

* *Quart. Journ. Geol. Soc.*, vol. xviii, p. 196. Ramsay makes the depth of the lake 853 feet, which would be probably near the centre opposite Vitznau.

† *Essai sur les Glaciers.*

to which a vanished glacier once extended is determined by the phenomena presented by the sides of the valley which it once occupied. These phenomena are chiefly of two kinds:—either the surfaces of the rocks of which the valley is formed are glaciated, or moraine matter with erratic boulders is found resting on them. Should the sides of the valley be sufficiently lofty as to have surmounted the glacier, the rocks rising above the glaciated limit will be fresh and sharp, presenting no evidence of ice-erosion; nor will they be covered by morainic matter or erratic blocks. The subjoined section will illustrate these statements, and it is one taken at the spot where I propose to measure the thickness of the former ice in the valley of the Lake of Lucerne. (Fig. 2.)

The section on the wall, and that also given in the paper, will illustrate this more clearly. The Seelisberg Hotel stands on a promontory jutting out into the valley of the Lake of Lucerne at the point marked Treib.* The section Fig. 2 is taken about half a mile from where the Belvue Hotel stands; and where the church is built upon a large moraine formed of gravel and boulders, some of which boulders are of enormous size; and at its upper limit, which is presumed to be also the limit of the former ice, the limestone rock rises in a lofty cliff, which was uncovered by the ice; in fact, there was no glacier higher than that limit, as far as my knowledge extends. Those brownish patches illustrate the moraine which rests upon the limestone; and below this you descend by a winding road down to that point at Treib which is just where the lake makes its sharp bend. The lower part of the section is a mass of bedded felstone, as far as I was able to make out, and contemporaneous with the formation.

Above the point of Treib where the "Lake of the Four-forest cantons" makes a sudden bend to the east, there occurs the moraine above referred to, on which stands the Belvue Hotel, amidst forest trees and gardens. In the background is a rampart of lofty vertical cliffs of bluish limestone. The surface of the moraine, although much modified by art from its original rugged and broken outline, is formed of rubble, clay and gravel, and is largely covered by forest trees. But from time to time we meet huge blocks and boulders of granite, gneiss and schists strewn in groups or separate; some of these weighing probably from 40 to 50 tons. None of these huge blocks belong to the district: they have their source in the far off

* The hotel directly overlooks that branch known as the Bay of Uri.

mountains of the Bernese Oberland and adjoining heights. Similar erratic blocks are to be observed near the Seelisberg (Sonnenberg) Hotel, resting directly on the surface of the native limestone and amongst the forest trees overlooking the lake. The height to which these erratic blocks extend above the surface of the lake is about 1,400 feet, which may be taken as the limit to which the edge of the former glacier extended.

That these transported blocks had their origin in the Bernese Oberland, the St. Gotthard and the Finsteraarhorn, at a distance of 20 or 30 miles from the head of the lake, there can be no doubt. The valley of the Reuss, which is continuous with that in which the upper lake lies, points towards these distant snow-clad masses; and we know from the observations of geologists that they are formed of granite and varieties of gneiss and schists, similar to those of which the boulders themselves are formed.* From Dr. Baltzer's section, the Finsteraarhorn is shown to be a mass of solid granite called "black granite," while the St. Gotthard mass consists of gneiss and varieties of schist. Such is the composition of the boulders lying on the slopes of the Seelisberg at a distance, as I have stated, of some 20 to 30 miles from their source. Similar blocks occur on the adjoining ridge of Bergenstock; and by an opening in the moraine matter on the south side of the ridge above Stanz I was able to observe the direction of the glacial striæ, indicating clearly that the ice had passed right over the ridge into (what is now) the lake of Lucerne on the other side.

It may be observed that the promontory above Trieb at Seelisberg very naturally became the site of a moraine during the period when the valley was the channel of a great glacier. Here (as above observed) the glacier coming down from the interior mountains along the Valley of the Reuss into the upper arm of the present lake called the Urner See, would be forced to change its course to a direction at right angles, owing to the barrier presented by the ridge of the "two mysterious Mythen" as they are called by Lord Avebury† by which the ice was diverted westward. The ridge of Seelisberg formed the inside of the elbow, and the movement of the ice would be here retarded, with the result that the moraine matter with its blocks of granite would be deposited at this spot.

* See Von Dechen's *Geologische Karte von Deutschland*; also *Livret-guide Géologique de Le Jura et les Alpes* (1894), Sheet 9, by Dr. A. Baltzer.

† *The Scenery of Switzerland*, by Sir John Lubbock (Lord Avebury), p. 283.

Thus the thickness of the great ice river which filled the valley of the Urner See was about 2,157 feet, being the height of the limit of the erratic blocks above the surface of the lake (namely, 1,500 feet) added to the depth of the lake itself (about 657 feet) at the bend of the valley at Brunnen.

Lord Avebury states that the glacier of the Reuss extended to Aarau and down the valley of the Aar to Coblenz. On the east it filled the lakes of Egeri and Zug, extending along the Albis to the Uetliberg and to Schlieren on the Limmat, following the valley down to Coblenz.* Measured from the St. Gotthard, this would be a distance of seventy-five English miles in a straight line; but measured along its numerous windings it would be probably at least eighty. This length, however, is far exceeded by the old glacier of the Rhone and the Rhine, which almost enclosed the glaciers of the Aar, the Reuss and the Limmat, and had their origin in the same great central mass of the Bernese Oberland.

DISCUSSION.

The CHAIRMAN.—We are much obliged to Professor Hull for the paper he has read, and although it is short, I have no doubt there are gentlemen here who can supplement it by some remarks on its contents. (The Chairman then called on Professor Logan Lobley.)

Professor LOGAN LOBLEY.—Mr. Hudleston, who is a much greater authority on glacial phenomena than I am, is here, and I should like you to have his remarks first.

Mr. W. H. HUDLESTON, F.R.S.—I cannot say that I am much of an authority on glacial phenomena. It is certainly not my special subject.

I have listened with great pleasure to Professor Hull's paper, which if short is, at any rate, very effective, and gives one a most excellent idea of the interesting phenomena that surround Lake Lucerne. I was so interested when I received this short paper that I ventured to jot down one or two notes which, with your permission, I will read in preference to making a regular speech. I made the

* *The Scenery of Switzerland*, by Sir John Lubbock (Lord Avebury), p. 130.

notes in reference to certain passages which appear in the paper, and they are as follows :—

1. The "*Valley*" of the Lake of Lucerne, which valley? This lake results from a combination of old preglacial valleys, both longitudinal and transverse, the Bay of Uri forming part of the transverse system.

2. "*Beauty and grandeur of its scenery.*"—One realizes at once that the great limestone masses of the Alps cut up into far finer figures than do the gneisses of the Italian side, as evinced, for instance, in the Lago Maggiore; hence the wonderful scenery of this lake which culminates in the bay of Uri. The head of the Lake of Geneva presents similar features, due in a measure to similar geological causes. But nothing in the Alps, nothing perhaps in the world, can vie with the Bay of Uri. It derives historical interest also as the birthplace of Switzerland. The Lower Cretaceous limestones are the chief formations, drawn out along two great folds involving portions of the Lower and Middle Tertiaries.

3. "*It is hard to conceive.*"—With geologists there is no difficulty; everybody nowadays realizes that there was such a thing as a Pleistocene Glacial period, and that a mountain chain like the Alps must have experienced its severity to the utmost. The whole of Switzerland is full of proofs, and the sight of the transported boulders of granite from the central massifs is one of the charms of a Swiss trip. Doubtless there was a *Mer de Glace* moving down the Valley of the Reuss and its continuation, the Bay of Uri, and there must have been a fine turn round the corner above Treib, where the Belle Vue moraine is situated.

4. *The* "*Glacial Origin of Lakes.*"—On this point there may be some room for divergent opinion. Of course the idea of a gaping fissure due to tectonic causes, in the case of the very complex Lake of Lucerne, is quite out of the question. As I said before, the Bay of Uri forms part of one of the most striking transverse valleys of erosion in the whole Alps. It was at one time a gorge of one of those rivers which are almost as old as the mountains themselves, and which kept deepening their channels *pari passu* with the axial elevation of the chain. Hence the Bay of Uri has been in the course of its history a cañon, a *Mer de Glace*, and now a submerged river valley, forming part of the most complex lake system in the Alps.

5. *Measurement of the thickness of the glacier at its maximum.*—The Belle Vue moraine, as I understand, is situated at the corner above Treib, and must represent, one would say, the remains of the left hand lateral moraine of the old glacier as it made this sharp turn to the westward. This may possibly represent an excessive upper datum line, since the extra pressure of the ice at this point might tend to lift the left lateral moraine somewhat above the mean level of the glacier; otherwise there can be no doubt as to the thickness of the ice at this point being fully 2,000 feet.

6. *The general limit of the erratic blocks.*—This being about 1,400 feet above the lake, if we add the depth of the lake, the sum fairly well represents the thickness of the glacier. As to the nature of the boulders, one would naturally expect to find the granitoid gneiss of St. Gothard which is in a direct line, but any granite coming from the Finsteraarhorn itself must have made a long détour by way of the Furka pass and the Urseren thal across the Aar valley in the first instance.

7. *The barrier of "the two mysterious Mythen."*—It is an open question whether the glacier did or did not follow a route previously indicated in pre-glacial times. There can be very little doubt that the original valley of the Reuss passed northwards by way of Brunnen, Schwyz and the Ægeri sea. The mysterious Mythens form a mountain mass which prevented both river and glacier from extending to the eastward, but it is doubtful if this mountain mass had any other effect on the old Reuss drainage. The origin of the middle part of the Lake of Lucerne is obviously very difficult to explain, hence the precise cause of the deflection of the Reuss drainage to the westward instead of to the northward is not quite clear. But I suggest that the transverse valley of the Reuss found its way into a valley which was partly longitudinal (geotectonic) and partly transverse, and which now constitutes the middle section of the Lake of Lucerne.

As regards the two "mysterious Mythen" themselves, they are represented by Schmidt as a mass of Jurassic rock resting on the usual Eocene of the district. Since there are no Jurassic rocks in the immediate neighbourhood, their appearance in this attitude seems to have astonished even the Swiss geologists themselves, accustomed as they are to the most unexpected inversions.

8. *Retardation of the ice on the angle formed by the Seelisberg.*—This subject has been already considered under No. 5.

9. *Extension of the Reuss glacier.*—We are told that this glacier extended as far as Coblenz on the Rhine, and we may well believe that it was there simply merged in the mass of the Rhine glacier, which appears to have been bounded on the north by the granite hills of the Black Forest. It is only by tracing its moraines that the individuality of a glacier could be shown in the midst of the huge sea of ice, which must have, more or less, filled the central valley of Switzerland during the period of maximum glaciation.

I think those are the principal points that I wish to make, and it has given me great pleasure to have been able to make them.

Mr. MARTIN ROUSE.—Did you say that the Jurassic rested on the Eocene ?

Mr. HUDLESTON.—Yes, that is so in the case of the Mythen.

The SECRETARY.—And there is isolation ?

Mr. HUDLESTON.—Yes.

The CHAIRMAN.—What is the meaning of the term "Mythen" ?

Mr. HUDLESTON.—I cannot say.

The CHAIRMAN.—There is something mythical about it, perhaps.

Professor LOGAN LOBLEY, F.G.S.—I have listened with much interest to Professor Hull's paper which, though short, as Mr. Hudleston says, is very effective. I have also listened with very great interest to the notes containing the valuable and interesting remarks by Mr. Hudleston, who knows the district exceedingly well. He has dealt with the local features so adequately that I think it would be unnecessary for me to say anything further about them. The great features which we see displayed by that map have been explained as it is only possible they can be explained. The series of longitudinal valleys and transverse valleys are very marked in the Swiss area. If you looked down on that model of Switzerland, which existed some little time ago in the Museum of Practical Geology, but which I regret to say is not there now, you could see those longitudinal valleys and transverse valleys with very great distinctness.

One point Mr. Hudleston referred to which is very well illustrated in this country, not far from where we are, and that is the cutting open of the river gorges *pari passu* with the raising of

the land. That is shown by the gorges on the south side of the great Weald Valley, where you have rivers flowing from the Weald northwards to the Thames and southward into the English Channel. These rivers have been flowing in that direction from the time they originally flowed, when their source was higher than the Chalk. They have continually flowed down and eroded the Chalk until at the present time the river valleys are deep gorges, transversely crossing the chalk, and have been eroded, as I have said, at the same time that the land was being raised and at the same time as the surface was being lowered by denudation.

But a larger consideration is suggested by Professor Hull's paper, and that is the cause of this great mass of ice being in this valley at the Post-pliocene period. It seems to me that we cannot dissociate this from those great features of the glacial period we know of in the European area. We have had glacial conditions in this country extending southwards to the Thames, and we have glacial conditions in various parts of Europe extending over a very much larger area. Those conditions were evidenced in a paper brought before the Institute by Professor Hull some time ago on the glacial conditions on an extensive scale occurring in the south of Europe.* It seems to me that all these glacial phenomena must be due to some one great cause. What is that one great cause? The origin of glacial phenomena has been attributed to astronomical changes; but it seems to me they may be more probably accounted for by geographical changes, such as by elevations of large areas. If there were a general elevation of the northern portion of Europe, continued for a sufficient length of time and of sufficient dimensions, we might get a repetition of the glacial conditions of which we have such abundant records as having occurred in the past. If the whole of Switzerland were higher, by 2,000 feet, or even 1,000 feet than at present we should have glacial phenomena, which we have in different parts of Switzerland, extending over a much greater area than the glacial phenomena described by Professor Hull to-day. It seems to me to be unnecessary to bring in these astronomical causes to account for the glacial epoch. We can recognise the enormous thickness of the ice in the Valley of Lucerne at a distance of nearly

* "Another Possible Cause of the Glacial Epoch," *Trans. Vict. Inst.*, vol. xxxi.

twenty miles from where we have at the present time actual glacial conditions, and the *Mer de Glace* and other portions of Switzerland which have enormous thicknesses of ice; so that comparatively little elevation would give an enormous extension of ice into the adjoining lower regions such as those of the Lucerne Valley.

The SECRETARY,—in reply to a question by Mr. Rouse—said that the Finsteraarhorn is known to be composed of what is called "black granite." I suppose it is blue granite, with black mica.

Mr. HUDLESTON.—I cannot say.

The SECRETARY.—But I cannot say that I examined the boulders very carefully, nor am I sufficiently acquainted with the granite of the Finsteraarhorn; but I think in some portions it is very likely there is some of this granite amongst the boulders. As I understand from Mr. Hudleston's map, there is a continuous valley and Finsteraarhorn would be somewhere *here* [*pointing*].

I think, giving glaciers due credit for the wonderful things they perform in the way of transporting blocks, I do not think there is anything insuperable in the idea that the granite comes from these heights, as there is a continuous channel.

Mr. HUDLESTON.—Oh yes.

The SECRETARY.—I am exceedingly gratified that Mr. Hudleston has been able to be here this evening. He is one of our Vice-Presidents and a most valued member. It is not often that we have the pleasure of seeing him, which is partly due to the fact that he is unable to be in London during most of the period of our session in winter. I am very glad that he has been so good as to put his observations on paper, because they will supplement my own short paper very considerably, and they touch on points that I have not noticed.

With regard to the glacial origin of lakes to which Mr. Hudleston referred, I simply referred to it as a chronological question; and as Mr. Hudleston did not express his individual dissent to the theory of my late friend and chief, Sir Andrew Ramsay, I do not think it necessary to defend Sir Andrew Ramsay's theory. I think myself, from the phenomena of the lakes in Switzerland and the fact that they are really excavated or eroded out of the solid formations, though sometimes helped to rise above the level by means of moraines thrown across their outlet, there is very strong evidence that glaciers had a great deal to do with the deepening of the central

parts of the lakes, and that view finds great support, I might almost say confirmation, by the soundings along the fiords of Norway. Nearly all the great Norwegian fiords are deeper in the central parts than at their outlets by a very considerable amount of depth, sometimes 1,000 or 2,000 feet, and if these fiords, like the valleys in the Alps we have been discussing, were originally river valleys, and they were also unquestionably filled by glacial ice, it is very hard to resist the evidence they give that they owe part of their depth (the deeper parts) to the erosion of former glaciers which we know to have existed.

The rocks rising above the surface of the Lake of Lucerne have undergone the most extraordinary modifications in their structure by means of the forces to which they have been subjected, as shown by the wonderful flexuring and contortions one sees on looking across this part of Lucerne Lake. The whole of the southern side of the lake, which rises to about 2,000 feet above the surface, here presents the most wonderful flexures, foldings and inversions of the strata of limestone.

Mr. HUDLESTON.—Oh yes, foldings like gneiss itself.

The SECRETARY.—Yes, I have often wished I could take a picture of them, had I been an artist, to place before the Institute, but I admit they are valleys of erosion, and that combination of the longitudinal with the cross valleys has no doubt determined the main features.

I do not know that I can quite agree with Mr. Hudleston, though no doubt he has good reason for supposing, that the glacier originally went out in *this* direction [*pointing*].

Mr. HUDLESTON.—Even straighter than that. Well, I cannot say that any glacier went *that* way, but a pre-glacial river went that way [*referring to the diagram*].

The SECRETARY.—That is a very interesting point.

Then with regard to Professor Logan Lobley's view of the cause of the glacial period, I think he is quite aware that I am altogether with him in that view, that the elevation of the whole of Central Europe (western and northern) has been the great preliminary cause of the cold of the glacial epoch; but we need not discuss that now.

I am much obliged for the way you have received my paper.