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- [B.M. = British Museum. All the figures are of the natural size.]

IV.—ON THE DISTRICT OF THE ANCIENT GLACIERS OF THE ISAR AND OF THE LINTH.

By Prof. ALBERT HEIM, of Zurich, and Prof. ALBRECHT PENCK, of Vienna.¹

IN order to interchange our views, and arrive at a common understanding on the question of the connection of glaciers with the formation of lakes, we undertook a joint excursion in Upper Bavaria, in the district of the Ammer Lake, Wuerm Lake, Staffel Lake, and Rieg Lake, and later, in the month of September, we visited together the shores of the Lake of Zurich, partly accompanied by Dr. K. I. V. Steenstrup, of Copenhagen, Dr. A. Wettstein and Dr. E. Brueckner, of Hamburg. We have drawn up a short protocol, both on the facts observed and of our views respecting them, which we here propose to communicate.

¹ Translated from the authors' MSS., by Dr. G. J. Hinde, F.G.S.

I.—*The Division of the Quaternary Formation in the District of the Highland Lakes of Bavaria.*

Throughout the lake district of Upper Bavaria, the basement bed is everywhere formed by the "Flinz" (Upper Miocene Clay, Marl, and Clayey Sandstone), on which rest the Quaternary beds, which are briefly characterized below.

(a.) A layer of Conglomerate (Nagelfluh) from 20 to 30 mètres in thickness, having a nearly even surface, and rising with remarkable uniformity in a gentle slope towards the S. and S.W. It consists of pebbles of limestone and dolomite, and contains very few erratics of Archæan rocks. The material is fairly evenly rounded, and united by a calcareous cement. Hollow boulders and decayed pebbles are abundant in it.

(b.) A deposit of gravel which may readily be distinguished from the Conglomerate (a) or "Deckenschotter," by the greater irregularity in the size of the pebbles, and the far greater abundance of pebbles of Archæan rocks. It is seldom cemented into a conglomerate, it contains no hollow boulders, but there are in it rolled fragments of the diluvial Nagelfluh mentioned above (a). This gravel deposit is the Lower "Glacialschotter" of Penck (*Die Vergletscherung*, etc., p. 142). It is also of great uniformity and is widely distributed. Its general dip from south towards the north is less than that of the diluvial Nagelfluh (a), so that in the lake district to the south it is deposited lower on the slopes of the valleys (which consist of Miocene Flinz) than the Nagelfluh (near Weilheim 100 m.), whilst towards the north, near Munich, it overlies the Nagelfluh.

Here, in the Isar Valley above Grosshesselohé, an intermediate, independent deposit of gravel (intermediate Schotter, Penck, *Die Vergletscherung*, p. 290) is interposed between the Nagelfluh and the Lower Glacialschotter, which has not yet been noticed in the lake district.

(c.) An irregular covering of genuine morainic material, swelling up in places into hilly ridges, extends in the lake district, in a very discordant manner, as well over the elevations occupied by the Nagelfluh, as over the Miocene Flinz, and the slopes of the diluvial gravels (b), up to the foot of the hills. Only in the district of the outer moraines (near Fürstenfeld-Bruck, etc.), are the diluvial gravels (b) and the slopes of Flinz free from this morainic covering.

The moraines show nearly the same admixture of pebbles as the gravels (b). They contain scratched boulders, together with angular fragments of the same kinds of rock. All these scratched and angular fragments are usually small, they very seldom reach a diameter of half a mètre, generally they vary from the size of a nut to that of one's fist. This type which is characteristic of the ground-moraine is particularly represented also by the longitudinal ridges. Therefore the latter may be recognized as the ground-moraine scooped out at the margin of the ancient glacier.

In the district embraced in our excursion, no moraines are present at the base of the Nagelfluh or below the glacial gravels (b). Below these latter, however, beyond the excursion district, near

Toelz, Laufen on the Salzach, and at Stefansbrücke near Innsbruck, Penck has discovered moraines; but at the base of the Nagelfluh, Tertiary strata exclusively have been met with.

Where we met with recently exposed surfaces, showing the deposition of the moraine on the diluvial Nagelfluh (at Tutzing, Berg, Starnberg), the surface of this latter was smoothed and polished as distinctly as if it had been a homogeneous rock, and striated in the same direction as the course of the valley. The individual pebbles in the Nagelfluh were also evenly cut through in section.

Also when the contact surface of the moraine and the glacial gravels (*b*) was exposed, there was nearly always a sharply-marked, often discordant, boundary between the two deposits, without disturbance in the underlying gravel; and occasionally the projecting boulders in the gravel were striated in the direction of the valley, though no connected striated surface had been formed on them.

North of the Starnberg Lake, we noticed a moraine irregularly interpenetrated with beds of gravel and sand; which we recognize as a deposit formed near the terminal end of a glacier (Penck, *Vergletscherung*, etc. p. 132, figs. 4, 5).

II.—*The Quaternary Deposits in the District of the Lake of Zurich.*

In the valley of the Lake of Zurich, as in the lake district of Upper Bavaria, Upper Miocene strata form the foundation on which the Quaternary deposits rest, and these latter are also divided into gravels (Schotter) and moraines.

In contrast, however, to the exceptional regularity with which the gravel deposits in the Bavarian lake district succeed each other under the moraines, those at the lower end of the Lake of Zurich show, on the one hand, an extremely slight connected development, and on the other, they present such great differences in regard to the respective elevations at which they are deposited, that it seems almost impossible definitely to mark out their limits, or to parallel the deposits of different localities.

(*a.*) There is indeed found occasionally, on certain particular elevations between the valleys, a deposit of Nagelfluh, resembling petrographically the Bavarian diluvial Nagelfluh (Uetliberg 870 m., Baden 470—490 m., Sihlsprung near Hirzel [outside the bounds of our united excursion] 580—640 m.); but this is so limited in its distribution, and the places in which it appears are so far apart, that, with our present knowledge, it cannot be considered as the remains of a general covering. Besides, moraines occur under the cavernous Nagelfluh of the Uetliberg, whilst they have never been met with below the Bavarian diluvial Nagelfluh, and on the other hand moraines do not any longer appear above this Nagelfluh as they do in that of Bavaria. The cavernous Nagelfluh of Sihlsprung near Hirzel rests, according to Heim, on ground-moraines, and is covered by immense upper moraine deposits.

(*b.*) A somewhat different formation of loose gravels (Schotter) and Nagelfluh, either with or without decayed pebbles, is present, though in very few localities, on the slopes of the valley of the Lake

of Zurich (Waedensweil, Utnach). We find similar gravels and Nagelfluh far wider distributed at the north-east border of the Glatt Valley, where they lie between the ground-moraine and the upper-moraine. Near Dürnten and Wetzikon, lignites are deposited between the gravel and the ground-moraine. These deposits of rolled materials also, which we here place under (*b*), are isolated to such an extent, and deposited at such different heights, that they cannot be regarded, at least so far as the valley of the Lake of Zurich is concerned, as the remains of an extended connected valley deposit.

(*c*.) The Nagelfluh of the Au peninsula, on the Lake of Zurich, is distinguished by its "delta structure" from the above-mentioned deposits of rolled materials in the neighbourhood of the Lake, and it has no equivalent in our Bavarian excursion-district. It calls to mind the ancient Kander delta, on the Lake of Thun, and according to Penck (*Vergletscherung*, etc., p. 343), the Nagelfluh of Biber in the Inn valley, and that of the Mönchsberg of Salzburg. Its relation to the moraines is not exposed. From the mode of its occurrence it very probably belongs to the base of the upper moraine.

(*d*.) Of all the Quaternary deposits, the moraines of the Lake of Zurich play the most important part. There is an astonishing contrast between them and the typical Bavarian moraines. The morainic hills are shown by the prevalence of large, angular, erratic blocks and sand, and the diminished quantity of clayey material, to belong mostly to the upper-moraines; such are altogether absent in the Bavarian lake district. The pure ground-moraines form in Switzerland an irregular, but not very thick layer, overlaid by the upper-moraines, or by the gravelly deposits above mentioned. Only the terminal moraines, and not the longitudinal moraines, have obtained a great part of their materials from the ground-moraines.

III.—*The Relation of the Upper Bavarian Lakes to the Quaternary Deposits.*

The Ammer Lake and Wuerm Lake occur in wide valleys, which form deep bay-shaped indentations in the southern margin of the same deposit of Nagelfluh. In the valleys especially, which have been excavated in the deposit of Nagelfluh, and also in the surrounding district of the above-named lakes, the gravels (*I. b*) are developed, and, indeed, they can be seen with constant characters, in the lower part of both lakes, in the upper part of Ammer Lake, and on the east margin of Wuerm Lake. The Lakes of Staffel and Rieg are situated to the south of the Nagelfluh district, where they extend themselves in a basin in the ancient Molasse, which is partly filled with the gravels *I. b*. (Schotter). They are bounded above and below by ridges of the dislocated Molasse, whilst between both only horizontal beds of the gravels (*I. b*) are raised above the surface.

The moraines form a surface layer, alike on the tops of the hills between the lakes, as on their slopes down to the margins of the lakes, thus, as a rule, covering discordantly the outcrops of Nagelfluh, Miocene Flinz and gravel (*I. b*); so that these various deposits are only exposed in lateral gullies or in steep cliffs.

Ammer Lake and Wuerm Lake are limited above and below by recent deposits. Their valley basins are bounded below by moraine walls, which the outflow from the lake cuts through, forming extremely narrow valleys. In the sections laid bare, the gravel (*b*) is shown under the moraine, and in the Wuerm Valley the Flinz is also exposed. Lower down the valley, beyond the moraine walls bounding the lake-basins, the gravel (*I. b*) forms extended terraces, partly interrupting the covering of the Nagelfluh and the outer moraine.

IV.—*The Relation of the Lake of Zurich to the Quaternary Deposits.*

Wuerm Lake and Ammer Lake, both in their relation to the Quaternary deposits, and also to the Molasse valley to which they belong, show very different phenomena to those of the Lake of Zurich and of the other large lakes of the Alpine borderland of Switzerland. The valleys in the Molasse in these latter are much deeper. A deposit like the gravel (Schotter) (*I. b*) in Bavaria, which both above and below the lakes exhibits the same uniform slope, is altogether unknown in the Lake of Zurich, in which the only gravels found are those mentioned under (*II. b*). On the declivities of the valley of the Lake of Zurich, the Molasse rock is itself carved into distinct erosion terraces, independent of the stratification, and these are often only sparsely covered with glacial *débris*, and not seldom altogether bare, whilst a similar condition of things is not observable on the borders of Wuerm Lake and Ammer Lake on account of the slight elevation of the outcrop of the Flinz and of the valley slopes, and of the soft character of the material. In Switzerland, for the most part, the valleys below the lake basins remain widely open, and show more especially the characters of main lines of ancient valleys. Hardly anywhere is the outlet of a lake through a narrow gully. The Molasse in the district of the Lake of Zurich is plainly not horizontal, but it forms a shallow trough between the Alps and Jura: the depression in this has affected the ancient erosion-terraces in unequal proportions.

The Quaternary deposits rest on the dislocated Molasse terraces of the declivities of the valley, so that the lateral moraines, with their somewhat steeper inclinations in the direction of the valleys, cut the margins of the Molasse terraces at an oblique angle.

On the other hand, Rieg Lake and Staffel Lake in some measure call to mind certain of the smaller lakes of the Alpine borderland, as, for example, Greifen Lake and Pfaeffikon Lake in the Glatt district.

V.—*The Question of the Origin of the Lake-Basins.*

In our excursion in Upper Bavaria, Heim had the opportunity of ascertaining the facts respecting this district published by Penck in his "Vergletscherung der deutschen Alpen."¹ On the other

¹ A review of this work is in the GEOLOGICAL MAGAZINE for 1883, Decade II. Vol. X. p. 177.

hand, Penck was able to confirm the facts which had been published by A. Wettstein in his work, "Geologie von Zürich und Umgebung." We are completely agreed respecting the facts observed, and differences can only arise on the conclusions to be drawn from the facts. The great differences in the Quaternary deposits of Bavaria and of Switzerland deserve special prominence. They teach that the greatest prudence is necessary, in regard to generalizations based on conclusions drawn from a limited area.

The grounds which Penck brings forward in favour of the Glacial origin of the Bavarian highland lakes are:—(1) the coincidence of the position of the lakes with the glacial deposits; (2) the characters of the lake valleys are such as are produced by erosion; and (3) the age of the lakes.

Their character as products of erosion is made clear from the fact that they are valley-shaped gaps in a continuous uniform series of undisturbed stratified gravels, whilst their diluvial age is proved by the fact that these stratified gravels end with the deposit of the diluvial Nagelfluh (I. a). On the other hand, both above and below the lakes, as well as round their margins, the horizontally stratified gravels (Schotter) (I. b) are shown, in which the lake-basins appear to form excavations. As these gravels (I. b) are, on the one hand, covered by moraines, and on the other, contain a notable number of pebbles of Archæan rocks, which could only have been transported by glaciers from the central region of the Alps over the passes of the limestone Alps, they must therefore have been formed immediately before the advance of the glacier into the lake district. As, however, the lake-basins are excavated in these gravels, they are necessarily more recent; they could thus not have yet been in existence at the commencement of the last glaciation of this district to which the gravels correspond. On the other hand, the deposition of the moraines on the slopes of the lake-basins shows that these latter were formed at the time of the retreat of the glacier. Their origin must therefore have taken place at the time of the glaciation itself.

Of these three grounds brought forward by Penck, the first one is established. As regards the second, it might be said that the gaps in the south margin of the covering of Nagelfluh might have been produced in it originally; that glacial-tongues, which covered the areas of the lake-basins, produced the Nagelfluh, as a fluvio-glacial deposit, whilst they protected the lake-basins against the accumulation of gravels. Against this, is,

(a.) The high degree of uniformity in the petrographical characters and the stratigraphical deposition of the Nagelfluh (I. a).

(β.) The absence of any morainic material below the Nagelfluh, as also the non-existence of genuine glacial materials, such as striated boulders, etc., within it.

A further possible mode of formation of the lakes might consist in a relatively small change of level in the lake district, by which the original slope of the Nagelfluh was diminished, whilst the valleys cut in it became reversed, and converted into lake-basins. This is

the more conceivable, since the southern part of the covering of Nagelfluh has a somewhat steeper dip than the more northern part; this, however, may readily be regarded as its original structure.

A positive proof of such changes cannot be found in the oldest deposits of the district of the Bavarian highland lakes, which thus contrast with those of the Lake of Zurich, because connected erosion-terraces are wanting, and more especially because the position of the strata of the Miocene Flinz cannot be accurately determined. But though the possibility of such an origin of the lakes through local changes of level cannot be proved to be inconceivable, it is so, nevertheless, if it leaves the coincidence of the extension of the glacier with the formation of the lakes, and the absence of lakes beyond the margin of the glacier, to be explained as the result of pure chance.

As regards the third ground for the glacial origin of the Bavarian highland lakes, *the age of the lake-basins*, it may be remarked that the gravels (I. *b*) are deposited on the slopes of Nagelfluh and Flinz. As the gravels were formed before the advance of the glacier, the valley which they cover, as well as the gaps in the covering of Nagelfluh, must also have been in existence *before* the glacier, as, moreover, Penck has already noticed (*Vergletscherung*, p. 357). There remains, therefore, no further solid excavating work for the glacier to perform, but merely the re-excavation of a part of the old valley out of the gravels (I. *b*), leaving behind many fragments of the same on the slopes, and further, the scooping out of the hollow, 120 m. in depth, in the soft Flinz. It may be noticed that the Flinz is a marly-clay which falls to pieces in water, and although rock in appearance, it would offer less resistance to the course of the glacier, than even loose pebbles.

Staffel Lake and Rieg Lake lie between ridges of Molasse, parallel to the Alps. The oblique partition separating them is formed of huge masses of the gravels (I. *b*), which can hardly have been originally deposited in their present limits. Heim acknowledges, in view of this, that a re-excavation of a part of the gravels in the same northerly direction in which the Alpine valleys become open, is by far the most probable mode of the formation of these lakes. Heim also accepts a similar origin for the now extinct lake of Murnau and the lake Kochel. As, however, regarding these lakes, it is only a question of the re-excavation of basins of dislocation, in which the harder ridges of Molasse on their margins and the islands of the same have *not* been destroyed, we are both entirely of the same opinion respecting them.

On a consideration of the Bavarian highland lakes, Heim conceives the re-excavation of valleys filled with loose gravels, as also the scooping out of depressions in very yielding materials, and thereby the formation of lake-basins through glaciers, possible, as heretofore (comp. "*Gletscherkunde*," p. 382 at top, and p. 386), and in the present instances, as very probable. On the contrary, proofs of the formation of extended basins in hard rock and of the excavation of the same through glaciers cannot be found in this district.

Of the three grounds, which, according to Penck, support the glacial origin of the Lakes of Ammer, Wuerm, Rieg, and Staffel, only the two former are applicable to the Lake of Zurich, and the other large lakes of the Swiss Alpine borderland. But just as little as in the first case, the position of the lakes in the area of glacial deposits, and, in the second, the character of the lake valleys as produced by erosion, can be disputed, even so little can the age of the lakes be brought forward as a proof of their origin.

Whilst namely, on the one hand, the gravel deposits indicated by II. *a* and II. *b* are only thus locally and sporadically developed, so that no conclusion can be at present arrived at as to their former connection, it can neither be proved that the lake valleys are depressions in a former covering of diluvial Nagelfluh, nor that the lake-basins represent hollows in a gravel formation corresponding to I. *b*. There is thus nothing to add to our information respecting their Quaternary, *i.e.* Glacial age. But, on the other hand, the Nagelfluh of the Au represents a probably very ancient deposit, which, by its delta structure, proves the existence of the Lake of Zurich already previous to the commencement of the last glaciation, so that the lake cannot be attributed to its action. At the same time, the position of the rock-terraces of the declivities of the valley afford decisive proof of dislocations which affected the lake valley and produced the basin-shaped depression in it. Penck holds with Heim and Wettstein that there is undeniable evidence of the influence of dislocations in the formation of the basin of the Lake of Zurich, but he is nevertheless of the opinion, that with a more thorough investigation of the Swiss Quaternary gravel deposits, it may perhaps be found possible to discover a parallel between the deposits named I. *b* and II. *b* in the two areas respectively, and he holds the view that the lake-basin originally produced by dislocation may be to a greater or lesser degree excavated by glacier action. Heim also does not question the fact of a certain, though relatively small, amount of the scooping out of the lake-basin being due to the glacier.

Penck holds that to re-excavation may very probably be attributed the formation of the lakes of the Glatt valley, of the Greifen Lake and Pfaffikon Lake, in the same way as in the case of Rieg Lake and Staffel Lake, whilst Heim is disposed rather to explain the origin of these two lakes of the district of the Glatt valley to the blocking-up action of moraines.

There is, therefore, no real difference of opinion between us touching the Lake of Zurich and the Lakes of the Bavarian highlands, either as regards the facts or the conclusions from them; and as in the present case, so also does it often happen, that by a more exact conjoint examination, differences become of much less importance than they appear to be from a distance.