NOTES OF A GEOLOGICAL EXCURSION IN SWITZERLAND.

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WE propose in the following pages to give a short sketch of some geological phenomena observed by us on excursions made during and after the meeting of the International Geological Congress, at Zurich, in 1894. On these excursions we were under the guidance of able Swiss geologists, and our thanks are more especially due to Dr. A. Heim, Dr. A. Baltzer, Prof. E. Renevier, Prof. H. Golliez, and M. Lugeon. An extremely useful little guide-book to Swiss Geology was provided for us, and is referred to in the following pages as the Livret-Guide: a copy will be found in the library of the Geological Society.

PART I.—BY PROF. McKENNY HUGHES.

Earth Movements.—The first point to which we wish to direct attention is the extent of recent earth movements which have directly affected the existing physical geography of, at any rate, some parts of central Switzerland. On the margin of the Lake of Zurich, Dr. Heim pointed to certain beds of glacial and alluvial origin, which he contended prove either a reversal of the direction of transport of material or a subsequent change in the inclination of the ground on which that material was deposited. The top of Uetliberg consists of a conglomerate, locally called Deckenschotter, which rests upon a stiff lead-coloured boulder clay full of scratched stones. It was so compact that it commonly stood in a cliff or steep slope, and in wet weather the surface became reduced to a sticky unctuous clay, with which some of our party entered into close personal relations, realising that the mass was rather to be regarded as a clay with scattered boulders than a gravel with the interstitial part filled with clay, a process which has frequently taken place subsequently to the deposition of the gravel, and has sometimes caused the deposit to be wrongly described. About this mass, however, there could be no mistake. It was a genuine Boulder Clay in its original state. The rock is made up of the coarser fragments winnowed out of the boulder clay, and compacted by a calcareous cement derived from the fragments of limestone of which the conglomerate is so largely composed. This conglomerate belongs to an age of valley denudation after or coinciding with the recession of the ice, when heavy rain and melting snow caused frequent floods and the rapid destruction of older superficial deposits. The transport of material must have been down valley and no deposits could have been laid down in the upper reaches of the valley at a lower level than the synchronous deposits farther down the same valley. Now, along the margin of the Lake of Zurich there are gravel beds, some of which so far as they can be traced continuously are seen to be inclined down valley. There are also ledges cut by valley denudation in the Miocene which form conspicuous features along the lake, and it was pointed out that some of these terraces rise to higher levels in the direction of the present fall of the valley, and in pursuance of this line of argument it was sought to identify the conglomerate on the top of Uetliberg with a gravel terrace seen at a much lower level on the south side of the lake near Horgen, that is to say, higher up the valley than Uetliberg. This identification was questioned by some geologists present, but even if this example was not sufficiently clear to carry conviction, we may regard it as an illustration of the kind of evidence which has led such competent observers as Professors Heim and Penck to the conclusion that this whole region in front of the higher mountain ranges of Switzerland has suffered unequal and very appreciable movements of elevation and depression since the last great extension of the Alpine ice.

The bearing of this upon the theory of the glacial origin of rock basins is perhaps the most interesting question involved. If it can be shown that the upper part of the Lake of Zurich has been depressed along an axis of movement in comparatively recent times, and that in this case a rock barrier has been formed by the relative uplift of the region about its outfall, and if such movements are common along the foot lands of mountain regions, it destroys at once the principal argument for the glacial origin of rock basins which is founded on the observation that they generally occur below or along the flanks of glaciated mountains.

An examination of the map of Switzerland, with the knowledge that earth movements along N.E. and S.W. axes have been repeated down to, geologically speaking, recent times, must suggest that the lakes are connected directly with those movements, as they occur so constantly along a N.E. and S.W. belt of country from the Lake of Constance to the Lake of Thun.

Denudation.—We pass on now to consider the denudation which has accompanied the earth movements of which we have spoken, and as we look round from Uetliberg, on the top of which we find the very recent gravel forming the Deckenschotter, we can have no doubt as to the enormous extent of this denudation. We wonder where the material has all gone to! What area of contemporary depression got filled up while the upward movement that facilitated denudation went on here? If we feel a doubt as to whether these vast changes have been brought about in the recent times to which all the evidence seems to point, we remember the proofs offered of earth movements, and look upon the amount of waste as corroborative evidence, seeing that such movements must directly influence denudation. However averse we may be to all attempts at giving a numerical estimate of these great periods of time where so many various conditions are known to have prevailed affecting all the elements on which our estimate could be founded, still we must carry away from Uetliberg a wholesome impression of the vastness of the operations with which we have to deal when we think that, on that isolated relic of a ridge at that great height above the lake, we are standing upon a patch of valley alluvium of later date than the last great age of Alpine ice.

But unless we suppose that the age of earth movements had ceased, those on which we were speculating at Zurich were only proportionate to, or perhaps we might say small compared with those which had obviously occurred in the preceding periods over the same area. The mass of water-sorted material of which the Rigi is built up implies a direct submergence in Tertiary times to a depth at least as great as the total thickness of the continuously deposited strata, *i.e.*, 8,000 or 10,000 feet, and they are now again elevated to a like height above the sea. The great diversity of the constituents proves that considerable earth movements and vast denudation had previously taken place to expose the edges of such a variety of rocks to the denuding agents.

Travelling afterwards into the heart of the great mountains, though the evidence of later movement was not seen except in the distribution of the lakes, the proofs of vast denudation were forced on us at every turn. Above Meyringen, for instance, after passing a long way through the gorge of the Aar, we climbed to the top of the great barrier that dams the lower end of the Innertkirchen basin. This barrier we found cut by a valley which has left but a small mark in the top of the steep southern front of the declivity up which the road climbs, but deepens in its northward course. The deep gorge along the western margin has tapped all the water that used to flow through the higher channel. Round the end of this valley, at the level determined by the higher outflow, run terraces marking the former level of the water. Here we have the ancient beach remaining unobliterated through the long ages that elapsed while the gorge was being cut back to tap the waters of the Innertkirchen lake. Shall we wonder that the terraces were so enduring, or that the time required for cutting back the gorge has been so short?

Rock Folding.—The next matter which arrested our attention was the enormous extent of the folds into which the rocks had been forced by earth movements of all ages down to comparatively recent times, and the effects of which we saw in every geographical feature. Heim* has estimated that the sedimentary rocks of the Alps have been crumpled up so that the area occupied by them is only about half the breadth that would be covered if the folds could be straightened out and the beds laid flat. We must not, however, suppose that this means a shifting of the marginal portions of the crumpled area to the extent of the 120,000 metres upon which his calculation is founded, for it is clear that the superficial extension of the folds is at the expense of the thickness of the beds.

We had an opportunity of seeing many of the sections in which the rocks were violently plicated and the sharp anticlinals lay as if they had been thrown over towards the outside of the chain. One limb of the fold was frequently broken and displaced; indeed, we generally felt that too little importance had been attached to the faults which had relieved the intensity of the crumpling, and diminished the actual interval between discordant formations. Along the shores of the Lake of the Four Forest Cantons, as some of us had seen on a previous excursion with Dr. Heim, there were beds sigmoidally folded on themselves, so that the same bed might have been pierced three times in one vertical shaft. These folds were in the Eocene and Cretaceous rocks. The Miocene beds were also folded, but as in them also the intensity of the crumpling increased from north to south, it was not clear how far the more violent contortions of the rocks which were situated farther south may have been due to this fact, and how far it indicated movements in the older rocks previous to the deposition of the Miocene.

Along the east side of the most southerly reach of the lake, where it has the name of Uri, we see the remarkable area described by Heim and Schmidt, where Eocene beds are folded into the Neocomian so as to be seen in section like kernels in a nut, while in places the sharply-puckered rocks run in vertical frills from base to summit As the great lines of disturbance run parallel to the trend of the principal mountain ranges and valleys, we do not notice the intensity of the plications so much when we are travelling in a N.E. and S.W. direction as when our path takes us across the folds.

The dragging out of the beds in one direction, and folding and puckering in the transverse section, is the commonest structure everywhere among violently-disturbed rocks, whether the result is seen in the great folds of the Lake of Brienz, for instance, or in the mullion structure of some schists and gneisses, or on a still smaller scale in the well-known puckered green schist of the Gorner Grat. The supposed tree in gneiss exhibited in the Berne Museum is only a more hornblendic portion of the gneiss curled and drawn as above described. The idea that it was a tree-stem

* *Archives des Sciences*, vol. lxiv (1878), p. 120; *Mechanismus der Gebirgebildung* (1878) vol. ii, p. 213.

found favour because the gneiss was supposed to be a metamorphic sedimentary rock.

In the present state of Swiss stratigraphy, it would be a great convenience if the word *Flysch* were no longer used as a term in systematic stratigraphy, but retained in current language as descriptive of a very common lithological character. It seems to be applied to rocks which have been referred by different authors to every horizon from Trias, at any rate, to Tertiary inclusive, and it will be a long time before the exact age of the variously-altered black shales of the Alps shall have been determined.

In the Rhone Valley, near Vernayaz, we were shown what were considered to be three unconformable junctions of different ages, with a conglomerate at the base of each.

The oldest of these was included in the *Cornes Vertes*, a series of micaceous and chloritic schists of pre-Palæozoic, or perhaps, it was suggested, of Algonkian age. It consists of large rolled fragments and comminuted débris of gneissic rocks, itself having a superinduced schistosity which makes the harder included fragments, especially when chiefly felspar, look like eyes round which the more plastic matrix is moulded.

The next conglomerate formed the basement bed of the Carboniferous system, and the third was referred to the Trias; above it came various beds of Secondary and Tertiary age. It seemed to some of us, when examining this section, that sufficient account was not taken of the great faults which traversed it and somewhat vitiated the reasoning from the present relative position of the rocks.

Deformation in the Rocks.—From the observations above described we were prepared to admit the possibility of meeting with groups of rocks, whose general aspect was so much altered in structure, texture, and even in mineral and chemical composition by crushing, and its concomitant effects, that it would be difficult to identify the several representatives, except by following them through their gradual change, and where in isolated sections the only test of identity might be their syntelism, or constant recurrence of similar sequences. In our traverses we endeavoured to follow such changes of the constituents under the influence of pressure until the rocks were no longer to be recognised as the equivalents of the sediment which they represented in an altered state. This lithological change was gradual, and we found that the ordinary tests of sedimentary origin were sometimes not quite obliterated till long after the rock had approached in general appearance, and even in many details of structure, some of those which we have been accustomed to refer to the more ancient schists and gneisses. For instance, in some cases fossils were still recognisable in schists with longitudinal mullion structure, transverse puckering, and a considerable rearrangement of mineral constituents. Pebbles, which were of such a character as would lead us to expect a spherical or ovoid form, were rolled out and elongated, and showed the general superinduced schistosity of the conglomerate in which they were embedded. Sandstones and grits were converted into massive quartzite, and where the original rock contained in addition to its siliceous grains a considerable quantity of aluminous material, it readily passed into siliceous schists.

As the rocks to which our attention was chiefly directed were referred to the Carboniferous or Poikilitic, we naturally recalled examples in which we were familiar with the kind of local variation in the sediment which we were called upon to accept in explanation of the differences in the character of the Swiss altered rocks, and having experienced no great inconvenience in the use of our old system, according to which we which we left stiff clays in the Thanet Sand, or found that the "Third Grit" consisted of thousands of feet of shale, we tried to avoid any side issues on questions of mere nomenclature, and to follow the evidence offered by our guides, even where it involved our calling a garnetiferous mica schist by the name of the series to which it was supposed to belong, viz., Trias quartzites; for why should not the altered siliceous sand of one area be of the same age as the altered sand full of aluminous and magnesian minerals of an adjoining area.

Here, however, the question arose, was it likely that the sediment did thus change in the direction required by the theory? and as the answer involves a knowledge of the palæophysiography of that part of Europe, which must be based on very wide and very detailed work, we can only recognise the difficulty and pass on to points on which we can offer more definite information.

In illustration of the above remarks, we lay on the table the following specimens:

1. Sand of the Rhone from near Vernayaz, derived first or second hand from gneissose rocks, and consisting of the same minerals in much the same state as those in the conglomerate close by.

2. Conglomerate at the base of the Carboniferous, Vernayaz, containing shaly portions full of carbonaceous matter, and schistose portions which are remanié gneiss.

3. The older conglomerate of Vernayaz mentioned above.

4. A gneissic-looking rock from near Brieg, with very siliceous eyes in places. This, we were told, is an altered conglomerate.

5. Gneiss with garnets, from Berisal.

6. Newer Gneiss with great felspar eyes, Simplon.

7. Older Gneiss, from near Gondo, without the eyes.

These specimens are in the Woodwardian Museum.

Now, in this series it will, we think, be generally admitted that the structure of all is due to mechanical deformation. But it may be expected that some will see evidence of the sedimentary original in specimens 1 to 3 only, that others will admit it in the case of 4, and perhaps of 5, while some will see in 6 only a further stage in the same process. It is the old story. We have gneisses which can be recognised as such as long as the alternations of various mineral aggregates are small enough to be exhibited in any one section, but when the masses in which the granitoid structure entirely prevails or those in which the hornblendic or micaceous constituents predominate are of great thickness, then we hear of schists and amphibolites lapping round the granite; yet the explanation is often suggested by the granite here and there putting on a gneissic character.

The microscope can show that there are interlocking crystals or rounded grains of crystalline minerals, but when these have been broken and crushed and displaced by subsequent movements it can rarely offer any evidence as to whether the rock was originally a granite, an arkose, or even a conglomerate. When an amphibolite schist is seen who can tell from an examination of the rock itself whether it is the hornblendic portion of a gneissic series or some intrusive basic rock of any age with superinduced schistosity; and so also in the case of the mica schist it is not easy to say when we should call a rock a mica schist, and when it is only a fine micaceous gneiss. Sometimes the presence of frequent micaceous layers seems to have caused the rock to yield along them, and thus has spared the intermediate quartz and felspar bands.

On the flanks of such a mountain complex we have in later times the sediment derived from the granites, gneisses, amphibolites, and schists, and this sediment itself crushed and mylonized by subsequent earth movements. Who then shall tell a rolled out arkose belonging to the newer and sedimentary series from a crushed gneiss belonging to the older masses whose own origin, whether altered, eruptive, volcanic, even sedimentary, has been obscured by the change which time has wrought in them?

When we are shown a granite or granitoid rock rolled out mechanically until the harder constituents are fractured and the fragments drawn from one another, while the soft parts are moulded into the interstices or dragged out into films, and in the same region are told that a similar looking gneissic or schistose rock is an arkose, or even a conglomerate of similar composition similarly treated, we cannot but grant the probability, nay, the certainty, that such things must occur in an area so grievously tormented as the Alps, yet to see the proof in any one section cannot be expected. The arkose of Innertkirchen was still an arkose, unless we prefer to call it a brecciated conglomerate, and it lay at the base of a sedimentary series which was only here and there altered by mechanical action, but always recognisable. So the difference between the three principal conglomerates of Vernayaz was to the naked eye sufficiently well marked. The oldest was most schistose and the newest contained the greatest variety of constituents, but all these rocks under the microscope show chiefly the constituents of granites dragged out, broken, and deformed. The sand of the Rhone close by is much like the main mass of these rocks in composition, and if subjected to the same welding that the gneisses and many of the still obviously sedimentary rocks have undergone, must microscopically show the same jumble of parted crystals, moulded mica, and re-set base. Here again, what we did see helped us to accept the probability of much that we were told but did not see.

In some of the rocks, however, the mechanical deformation was not so remarkable as the mineral change. We saw the Rauchwacke losing much of its carbonate of lime and becoming cavernous or knobbly. We were shown by and by a magnesian rock consisting largely of mica with garnets or of hornblende with epidote, and were told that the magnesian silicates and what lime was wanted were in the earthy magnesian limestones from which those rocks were derived. The microscope can tell us nothing of the age or origin of these rocks, but their mineral composition is not inconsistent with the view that some of the garnetiferous mica schists and of the epidote-amphibole rocks may have been derived from a dolomitic series, with alternations of calcareous ferruginous shales, if we could only explain the process or trace the gradual change.

PART II.—By Dr. Hume.

Meyringen—Innertkirchen.—Hitherto the age of the limestone dominating the Haslithal and forming the bold precipices so familiar to those visiting Meyringen, has been referred almost unanimously to the Malm or Upper Jurassic. Last year M. Golliez published a new theory in the official Livret-Guide of the Zurich Congress, regarding the whole of them as Triassic on the following grounds:

1. They are said to bear a strong resemblance to the Triassic limestone of Briançon and the Valais.

2. They contain intercalations of quartzite, gypsum, and sandy dolomite.

3. The relations to the Dogger are said to be such as might be expected of Triassic beds.

Fig. 1 A illustrates the general view as explained by Prof. Baltzer; and Fig. 1 B Prof. Golliez's theory.

The divisions have been combined from a study of two sections, both easily reached from Innertkirchen. The first, the Rothfluh, in the Urbachthal, at the foot of the Engelhörner; the second, the Spisswand, a precipitous cliff rising at the back of the Hof Hôtel to the right of the Aar valley. All the fossils mentioned were obtained by members of our party, and the description is from notes taken on the spot.

(*a*) is the limestone under discussion, which bounds the Haslithal, and is the rock through which the Aar has cut its famous gorge.

(*b*) Highly metamorphosed yellow-grey limestones and slates = Birmensdorferschichten, often very finely banded, and generally rich in sericite.

(*c*) The Eisenoolit, a highly ferruginous oolitic rock, which at the Spisswand contains Belemnites and a doubtful *Terebratula.*

(*d*) Reddish brown sandy limestone with *Ammonites Parkinsoni*, *Amm. Humphresianus,* imperfect Belemnites, and Lamellibranchs.

(*e*) A series of shales referred to the Lias. On the Spisswand below these shales is a pisolitic limestone, which yielded *Gryphæa arcuata*, *Amm. macrocephalus tumidus*, *Terebratula ferovalis*, and *Pecten glaber*. *c* to *e* thus represent Dogger and Lias.

(*f*) Red brown and greenish dolomitic beds, with intercalations of sandstone, considered by most writers as Triassic.

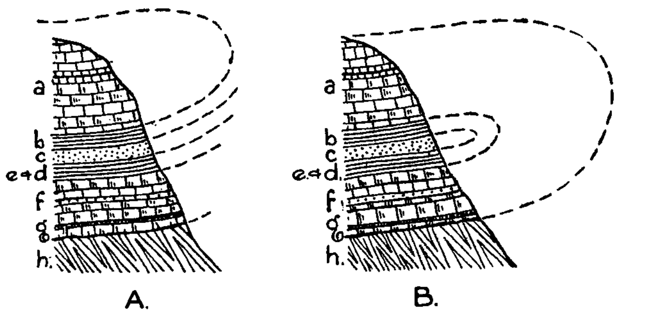

FIG. 1.—SECTION NEAR INNERTKIRCHEN.

(*g*) Röthidolomit, here a grey, compact dolomitic limestone.

(*h*) Muscovite gneisses with two felspars = Innertkirchen gneiss. At first sight, the limestone overlying the Dogger and Lias would be considered as younger or of Upper Jurassic age, but the considerable folding to which all the strata have been subject renders ordinary methods of comparison useless. It is universally admitted that the beds under discussion form part of a great overfold; but whereas Prof. Baltzer submits that great denudation has taken place, removing the superincumbent Triassic strata, Prof. Golliez holds that the return curve takes place at the Eisenoolit *c*, and that *d* and *e* occur above *c* in reverse order, the great thickness of limestone above representing the dolomitic beds, *f*, which are the accepted representatives of the Trias in this neighbourhood.

If this be so, and the Dogger and Lias are folded back over the Eisenoolit, they must be represented by the now highly altered

Birmensdorferschichten, to which Prof. Golliez does not refer. Moesch* has lately shown that the few fossils met with have quite a distinct character, *Ammonites plicatilis* and *Amm. arolicum* being the commoner forms.

Prof. Golliez urges, in support of his view, that these beds are similar to the Triassic beds of the immediate surroundings; but we did not see anywhere in the Haslithal the distinctive porous dolomite, the cornieule, or rauchwacké, which on the Furka, at Zermatt, and on the Simplon, forms such a characteristic member of the Triassic strata. The rocks of that area rather recall the Hochgebirgskalk (Jurassic) farther to the east, or the Malm series which plays so important a part in the chains to the south-west of the Lake of Thoune.

Can the dolomitic beds which form the acknowledged Trias at the base represent the altered limestone which is said to be their equivalent above? While freely granting the possibility of rapid alteration in the characteristics of marine strata, it does seem somewhat difficult to admit that one limb of the overfolded synclinal can consist mainly of dolomite and sandstone, whilst the other displays an overwhelming predominance of limestone, or "marbres."

Moreover, we failed to find in the Aar gorge the intercalations of quartzite, gypsum, and sandy dolomite noticed by Prof. Golliez. At this locality the limestone was very homogeneous, and in general effervesced freely in cold hydrochloric acid. Prof. Golliez has, however, noted an arkose, and Prof. Baltzer found one locality where the behaviour pointed to the occurrence of a dolomite, but holds that a slight roll would be sufficient to bring up the Trias at this point without in any way affecting the main argument. The relations to the Dogger are far more suggestive of Jurassic than of Triassic beds.

Moesch (*loc. cit.*) has also added fresh palæontological facts which strengthen our belief in the validity of the older views regarding the age of these limestones.

Zermatt—Simplon.—It has been already shown in an earlier part of this paper that considerable differences of opinion have arisen regarding the character and extent of the strata (assumed by some to be Triassic), met with to the north of the Bernese Alps, and it is, therefore, with interest that we turn to an examination of those rocks, which, by the greater number of writers, have been admitted to be truly Triassic.

As an example, we would refer to the Zermatt district. An excellent section displayed above the railway close to Zermatt station, gives the key to the interpretation of the complex foldings displayed between this locality and the Gornergrat.

1. The rock exposed near the village itself is of a deep green colour, and markedly schistose in character, to which properties it

* *Beitr. z. Geol. Karte der Schweiz.* Lief xxiv, p. 148.

owes its names of pierre-verte, chlorit-schiste, or pietre verdi, commonly applied to it by Swiss geologists. No fossiliferous bands occur in connection with it, and in adopting a Permian or Carboniferous age for these beds, our guide, Prof. Golliez, has entirely accepted the views of Zaccagna. The latter holds that, in the Ligurian Alps, a broad anticlinal exists, of which Carboniferous strata form the core, these being directly and concordantly overlain by the pietre verdi, which themselves are flanked by younger Triassic rocks.

2. Near the first tunnel met with after leaving Zermatt, the pietre verdi suddenly cease, and are replaced by a series of beds dipping at a considerable angle to the south-east. The lowermost of these consist mainly of grits and quartzites interstratified with a few layers of altered limestone, or cipollino.

3. The siliceous rocks give place to dolomites, gypsum, and carbonaceous marls, including a soft calcareous band, classed by Prof. Golliez as rauchwacke, but differing considerably from the porous dolomitic rauchwacke displayed on the Gelbewand above the Gorner Glacier.

Nos. 2 and 3 have a thickness of only about 30 feet at this point, being then replaced by 4, a dark grey highly calcareous schistose rock, containing much mica and a certain amount of quartz. This is known as "marbres phylliteux." The first lesson that can be gathered from this section is the gradual change in the rock-constitution, in the ascending series there being first a succession of siliceous by dolomitic, and then of dolomitic by purely calcareous members.

No. 4 is displayed for a distance of over a kilometre along the railway, until (at a point where a torrent descending from the lower slopes of the Weisshorn range has cut a deep channel) a series of beds is exposed which exhibits in reverse order the same sequence as that already observed. The dip remains the same as before as regards direction, but is steeper in inclination, and the older strata appear to overlie the younger. The explanation is that we are here dealing with the synclinal portion of a highly-inclined isoclinal fold, the axis-plane of which is dipping on an average 45° to the south-east.

Ascending the torrent the marbres phylliteux are succeeded by a beautiful rose marble, differing from many of the marbles associated with more ancient rocks in the absence of a saccharoidal crystalline structure.

3. A band of dolomitic red marl and gypsum is separated from No. 4 by a thin layer (only a few inches in width) of yellow and red-brown shales, containing an almost colourless mineral, with very strong absorption, which has been identified as glaucophane. Chlorite is also present in some quantity.

2. A chloritic quartzite forms a steeper slope, the whole being capped by a series of micaceous schists, which are taken as representing the pietre verdi at this locality.

In ascending from Zermatt to the Gornergrat, infolded Triassic beds are repeatedly met with, differing considerably in external appearance according as mica is present or absent. The following table shows the general succession from below upwards :

1. Pietre verdi = Permian of Zaccagna.

Type.	*Without mica.*	*With mica.*
2. Siliceous	Massive white quartzites	Silvery micaceous quartzites.
3. Dolomitic	Dolomite, with gypsum, etc.	Micaceous Rauchwacke.
4. Calcareous	Impure marbles and marbres phylliteux	Micaceous cipollinos and schistes lustrés.

2, 3, and 4 are, as above stated, referred to the Trias. The truth of this succession is further illustrated on the Simplon, both between Eisten and Bérisal, and near Refuge V. Also on this pass the relationships the above rocks to the older metamorphic series is also revealed, though little stress can be laid on the evidence here. Below the Triassic quartzites at Bérisal, north of the Hospice, and below cipollinos at Alte Caserne, south of the Hospice follow (1) mica schists, frequently garnetiferous, and of normal character. These form only a comparatively thin band as a separate member, though occasionally rocks of similar nature alternate with the next series.

2. A considerable thickness of dark-green hornblende-schists underlies No. 1, and though varying considerably in texture, and frequently interlaminated with bands of mica-schist, it nevertheless forms a distinct lithological zone.

3. The core of the Simplon axis is mainly gneissose, the gneiss in its upper layers being often most beautifully banded, and containing large felspathic eyes, whilst in the lower portions the rock has a more definite granitic structure. The first type has received the name of Superior Gneiss, or the gneiss of Monte Leone, the second Inferior Gneiss, or Antigorio-gneiss.

By combining the results from Zermatt and the Simplon, we obtain the following succession for the eastern portion of the Pennine Alps, commencing from above :

1. Limestones, Cipollinos, Schistes lustrés, or Marbres phylliteux.
2. Rauchwacke (Corgnieule), Dolomite and Gypsum.
3. Quartzites (massive or micaceous).

Nos. 2 and 3 are not present in the Alte Caserne section.

4. Pietre verdi (with Serpentine dykes), possibly Permian. Not noticed by us on the Simplon.
5. Garnetiferous Mica-Schists.
6. Amphibolites.
7. Ribboned or Banded Gneiss of Monte Leone.
8. Coarsely granitic Gneiss of Antigorio.

PART III.—By Mr. Monckton.

Morcote.—The diagram, Fig. 2, illustrates the explanation of the celebrated Morcote section, given to us by our directors, MM. Golliez and Lugeon.*

Morcote is a small town on the shore of the Lake of Lugano, and on the road from that place to Melide one has a good opportunity of studying the series of igneous rocks shown in the diagram.

Firstly, we find a series of schists along the shore of the lake.

Secondly, there is a great mass of porphyrite resting upon the schist series, and in at least one place a large vein passes up through the schist to the porphyrite.

Thirdly, there are masses, probably laccolites of quartz felsite, and numerous veins pass up to them through both the schist and the porphyrite.

We have, therefore, here igneous rocks of two different ages, both of which not improbably belong to the Carboniferous or Permian periods.

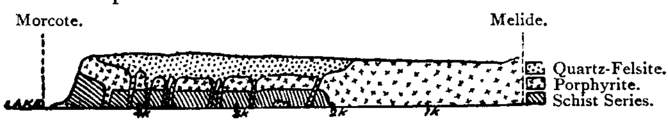

Fig. 2.—Section from Morcote to Melide—Lake of Lugano.

Starting from Morcote, we saw just outside the town, on the Melide road, an exposure of the porphyrite, which we were told was part of the large vein shown in the diagram (Fig. 2). It is a hard, close-grained, blueish-grey rock, consisting of a ground mass of quartz and felspar with porphyritic crystals of plagioclase much altered. There is very little porphyritic quartz, but a good many flakes of a pleochroic green mineral, usually, we think, biotite, but occasionally hornblende, in both cases much altered. A little iron oxide is associated with the green mineral.

The porphyrite vein was seen to be in contact with a micaceous schist which continues at the side of the road for about 200 yards. and we then came to a vein of reddish quartz felsite, and soon after we noted a second similar vein at the milestone four kilometres from Melide. A little farther on we saw two more. A microsection from one of them shows that the porphyritic minerals are quartz, in large, very clear grains, plagioclase, a little orthoclase, and a green pleochroic mineral, apparently altered biotite. There are a few specks of iron oxide associated with the green mineral, the change in which is similar to that noted in the porphyrite. The plagioclase is fairly well preserved, much better

* For a full account of this section and its petrology, see Dr. C. Schmidt in the *Livret Guide*, pl. viii, Fig. 1, and in *Ecclog. Geo. Helvet*, vol. ii (1890-92), p. 1, and Michel Levy, *Bull. Soc. Geol.*, 3rd series, t. i, p. 464 (1873), and t. iv, p. 111 (1875).

than in the porphyrite; one large crystal has become broken up into small fragments, which are separated from one another by intrusion of the ground mass. The ground mass is very fine grained, and seems to be composed of quartz and felspar.

A section cut from the edge of one of these veins shows a more basic rock than in the middle, with a speckled structure close to the edge, flakes of white mica are scattered through the slide which Prof. Bonney suggests are very probably fragmental and derived from the schists.

The rock through which these veins pass is a very micaceous schist, but it changes in character a little nearer Melide, and is then a hard, dark grey, close-grained rock, with indistinct gneissose structure. The microscope shows quartz grains crowded together, forming a ground mass with a felspar very much altered, a ferro magnesian mineral associated with a little iron oxide so much altered as not to be recognisable. It is succeeded by more schists, and at about $3\frac{1}{4}$ kilometres from Melide we find the following succession from south to north along the road.

1. Mica schist with much quartz.
2. White quartz-felsite vein, 18 feet.
3. Black rock forming edge of vein, much decayed, 3 feet.
4. Black rock, apparently altered schist, 1 foot.
5. Schist, 4 feet.
6. White quartz felsite, 18 feet.
7. Decayed earthy bed, $\frac{1}{3}$ foot.
8. Crumpled schists.

A little farther north we find more gneissose rock belonging to the schist series, and forming a point which projects slightly into the lake.

We then pass more schists with at least two more quartz felsite veins, and at the Villa Isidora, two kilometres from Melide, we come to a great talus of red and black porphyrite, and soon after to that rock *in situ* at the roadside, it having come down to the level of the lake. It varies considerably in character, and is always much altered and decayed.

St. Gothard.—The section, Fig. 3, gives a general idea of the geology of the top of the St. Gothard Pass, between Goschenen and Airolo, which places are at the ends of the St. Gothard Tunnel. A series of specimens from the tunnel is preserved in the Natural History Museum, and Mr. Fletcher, with his usual kindness, allowed us to examine them, and compare them with those we collected at the surface. In any such comparison it must not be forgotten that during a considerable part of its length the tunnel is some distance reaching a maximum of two miles to the east of the road.*

Starting from Airolo, we find in the tunnel a brown, yellow,

* An excellent account of the Geology of St. Gothard, by Karl von Fritsch, will be found in vol. xv of the *Beitroge zur Geol. Karte der Schweiz.*

and white softish dolomitic rock called Rauchwacke, which extends for some 80 metres along the tunnel. The specimen, No. 14, at 78 metres, is a breccia, with fragments of greenish schist. We did not find it at the surface, but it may be compared with the breccia in the ravine Val Canaria, some 4 kilometres to the north-east, described by Prof. Bonney.*

As the stratification here appears to be nearly vertical, the question arises whether this breccia is at the top or at the bottom of the Rauchwacke, and, after a careful consideration of the evidence, we are inclined to think that it is at the bottom of that series, and that its component fragments are in all probability derived from the schists now exposed in the St. Gothard to the north. In this conclusion, however, we find ourselves at variance with some able geologists.

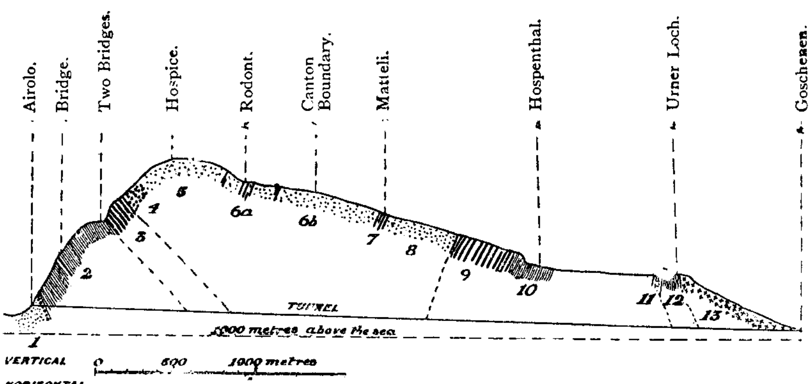

FIG. 3.—SECTION THROUGH THE ST. GOTHARD.

At about 83 metres from its mouth the tunnel passes from the Rauchwacke into schists, and on the St. Gothard road we find ourselves on the schists as soon as we are out of Airolo. The road mounts up through them by a series of zig-zags, and there are many small sections. The schist is light coloured, often full of garnets, and with much mica, black and white. Here and there actinolite crystals in radial bunches occur.

At the top of the first zig-zags we enter a little valley, and the road crosses the river which flows down the pass. On the west of this river there is a section in green hornblende schist, and above are more garnetiferous mica schists. There is a distinct dip to the north in the foliation of these schists.

Near a small house opposite Motta di Dendro, at a level of 1,694 metres above the sea, we noted a good deal of hornblende

* *Quart. Journ. Geol. Soc.* (1890), vol. xlvi, pp. 209, 212, 213.

schist, which is folded into sharply pointed folds, always with a northern dip.

This rock contains numerous garnets up to ½ inch in diameter, and the hornblende schist with some mica schist continues as far as a place where two bridges cross the torrent at a level of rather more than 1,700 metres. There we found a few beds of quartzite in the schist, and the series ends. These, from the edge of the Rauchwacke, are the Tremola Schists of Prof. Bonney.*

He thinks that the association of these variable and well-marked bands is due to original difference of mineral composition, and points to some kind of stratification, and is further of opinion that they are of pre-carboniferous age. Dr. A. Baltzer, on the other hand, thinks that they should be referred to the Lias and Dogger, and he accordingly draws a synclinal between Airolo and the top of the St. Gothard, making the Rauchwacke, which is admittedly of Triassic age, older than the Tremola Schists. Dr. C. Schmidt practically agrees, but draws a double synclinal.†

Our acquaintance with the area in question is scarcely sufficient to enable us to venture on any very decided opinion on this question, but so far as we are able to judge we are inclined to favour the view that the Tremola schists are older than the Rauchwacke, and that we are passing from newer into older formations as we ascend from Airolo to the two bridges.

Above the two bridges the road mounts by more zig-zags, and we find a different series consisting of dark coloured gneiss often with garnets, and in places with dark green hornblende rock. These are No. 3 of Fig. 3, and answer to the Sorescia Gneiss of Dr. F. M. Stapff.‡

We next come to a comparatively white rock, No. 4 in Fig. 3, and the line between the dark and light coloured rocks is very well marked across the ravine up which we are ascending, and after some climbing we obtained hand specimens, one of which furnished a micro-section showing the actual junction of the two rocks. We also took specimens from the two rocks at a little distance from the junction, and have micro-sections from them also.

The dark coloured gneiss is composed of quartz in small grains, brown and white mica, and a quartz-felspar mosaic, and close to the junction there is a good deal of felspar, apparently both orthoclase and a clear striped felspar in very small fragments. The actual junction is marked by a line of flakes and patches of flakes of dark mica.

The white rock is formed of clear grains of quartz and large crystals of orthoclase and plagioclase, usually very full of inclusions.

* *Quart. Journ. Geol. Soc.*, vol. xlii (1886); *Proc.*, pp. 71-109.
† *Livret Guide*, p. 168, Plate viii, fig 1; Plate ix, fig. 3.
‡ *Geol. Mag.* (1892), Dec. III., vol. ix, p. 6.

There is a little white mica. Both rocks have apparently been more or less affected by crushing. The daık mica in the dark-coloured rock is of a somewhat peculiar aspect, possibly the result of contact metamorphism, but it is not easy to say how much is due to that cause and how much to the subsequent crushing; perhaps we may look upon the quartz-feltpar mosaic, which is a feature of the dark-coloured rock, as mainly the result of the crushing.

The white rock is a granite, with but little sign of subsequent alteration, but as we proceed towards the Hospice we find the rock becoming distinctly gneissose in character (5 in Fig. 3), and eventually, close to the Hospice, we find a quarry in the rock known as the Fibbia Gneiss. We were unable to discover the exact line of division between the rocks 4 and 5, and according to Dr. Stapff there is a gradual transition from one into the other.*

The dark-coloured gneiss, No. 3, continues further to the north in the tunnel than in the road, which is here 600 metres west of the tunnel.

The Fibbia Gneiss (5 in Fig. 3) consists of quartz, which is sometimes in large grains, at others in minute fragments closely packed in masses with white mica, probably the result of crushing, of orthoclase in large crystals, with a little plagioclase, and of biotite and muscovite. The Fibbia Gneiss is believed by Prof. Bonney to be an intrusive granite which has been subsequently modified by pressure.†

It continues some way down the northern side of the pass, but at a level of 2,018 metres, where the road crosses the river Reuss, the rock becomes schistose, and intercalations of dark-coloured rock are frequent (No. 6*a* in Fig. 3), but are not, as far as we saw, of very great extent. There are several of these daık patches at Rodont, a ruined house at a level of 1,976 metres. Under the microscope the rock of the dark patches is seen to be composed of quartz grains closely packed together, and of dark and white mica drawn out in lines. A little iron oxide is scattered through the rock. The felspar is, we think, mostly orthoclase, but a striped felspar also occurs. There are some flakes of a green mineral, probably hornblende, some epidote and secondary minerals.

In this dark-coloured gneiss there are intercalations of white gneiss, and close to the wall of the ruin the white and green rocks are intermingled in streaks and patches in the remarkable fashion shown in Plate II, B, which is from a photo taken by one of us on September 21st, 1894. The gneiss from the bridge over the Reuss to Rodont, marked 6*a* in Fig. 3, is the micaceous Guspis Gneiss of Dr. Stapff, and he believes it to be the oldest or deepest

* *Geol. Mag.*, Dec. III, vol. ix (1892), p. 20.
† *Quart. Journ. Geol. Soc.*, vol. xlii (1886), *Proc.*, p. 71.

of the crystalline rocks of the St. Gothard.* Below Rodont the prevailing rock is still a light coloured gneiss (*6b* of Fig. 3), but here and there patches of dark gneiss occur. There is one at a hump of rock on the east of the road, a little below the ruined house, and still farther down at a height of 1950 metres, where the road is cut through a projecting point of rock, quartz bands and dark-coloured patches occur. The line between the dark and the light coloured rock is fairly sharp, but the trend of the foliation in both is in the same direction. Under the microscope, the dark-coloured gneiss is seen to be of much the same character as the gneiss No. 3, and the dark patches at Rodont. The white gneiss consists of quartz, orthoclase, a little plagioclase, and bundles of flakes of light and dark mica. The middle of the plagioclase crystals is usually full of enclosures, whilst the edges are clear. In the large patches of orthoclase are enclosed quartz, muscovite, and plagioclase.

This rock is a porphyritic gneiss, and differs somewhat in appearance from the Fibbia Gneiss.

Some distance lower down we cross the boundary of Cantons Ticino and Uri, and enter a long, narrow valley, at the lower end of which there is a small house named Matteli. Above this house there are intercalations of a greenish rock, No. 7 of Fig. 3, in the light coloured gneiss; they are in the form of narrow, parallel bands, with a N.E. and S.W. trend. Plate II, A, from a photograph taken on September 21st, 1894, shows the way in which they occur better than any explanation in words.

We now enter a second long, narrow valley, called Gamsboden, and about 500 metres down it there is a small mass of schist in the white gneiss, and near the lower end of the Gamsboden the white gneiss No. 8 comes to an end. In the tunnel it does not extend quite so far north as at the surface. This northern portion of the white gneiss, *6b*, 7, 8 in Fig. 3, is the Gamsboden Gneiss of Dr. Stapff. Numerous views as to the origin of the dark and light coloured gneiss have been held by geologists; but the best opinion is, we think, that the dark coloured gneiss is the older rock, that the white rock is a granite which was intruded into the dark coloured rock, the white rock in the photographs (Plate II) being thus veins of granite, and that the whole has since been modified and more or less changed by pressure.

At the lower end of the Gamsboden the road enters a ravine, through which the Reuss flows down to Hospenthal. At its upper end there is a dark-grey gneiss, 9, not unlike that on the south of the pass, 3 in Fig. 3, but as we descend we find the gneiss is mingled with rocks of the character of a schist, and eventually we find ourselves in the Hospenthal Schists, No. 10, which continue down into the Urseren Valley. We do not find it easy to say exactly where the gneiss ends and the schists begin.

* *Loc. cit.*, p. 17.

We have now crossed the massif of the St. Gothard, and we have seen that it consists of a central mass of white gneiss, probably originally a granite, at each side of which we find a grey or dark-coloured gneiss (3 and 9 of Fig. 3), and outside the grey gneiss schists. On the south at Airolo we find Triassic Rauchwacke adjoining the schists, and also on the north of the Urseren valley, we find a little Triassic Rauchwacke as well as beds of Jurassic age.

The dip throughout is very high, and there is a very distinct fan structure, *i. e.*, the beds south of the Hospice dip north, and the beds to the north dip south, those in the centre being practically perpendicular.

At Hospenthal the road turns with a right angle to Andermatt, and as it would not be easy to indicate this on the section (Fig. 3), we have left a blank at this point. At Andermatt the road turns again north, and we reach the celebrated Altkirche section. A small quarry furnished us with specimens of Altkirche marble, the age of which is much disputed. A very full account of the section has been given by Professor Bonney.* Dr. Stapff's views will be found in *The Geological Magazine*,† and the views of other Swiss geologists will be found in *The Livret Guide*.‡

Passing through the tunnel called Urnerloch, we enter the great ravine of Schellingen, which is cut through a light-coloured rock, with a more or less granitoid appearance, called protogine. In it are numerous veins of aplite, and here and there intercalations of dark-coloured gneiss occur. This forms part of the Finsteraarhorn massif.

In the tunnel the protogine begins at 2,000 metres from the northern end, and continues to Goschenen, the station at that end of the tunnel.

* *Quart. Journ. Geol. Soc.*, vol. xlvi (1890), p. 191; vol. l (1894), p. 288.
† *Loc. cit.* and 1894, p. 152.
‡ Pp. 151, 166.