THE GEOLOGY OF THE PORPHYRY DISTRICT OF LUGANO BETWEEN PONTE TRESA AND LUINO.

CONTENTS.

CHAPTER IV.

THE GEOLOGY OF THE PORPHYRY-DISTRICT OF LUGANO BETWEEN PONTE TRESA AND LUINO.

INTRODUCTION.

At the incitation of Prof. Dr. B. G. ESCHER I undertook, in the springs of 1925 and 1926 the geological investigation of the Northern part of the Luganese Porphyry-district. I thus mapped one of the parts of this district, which remained to be revised, since T. HARADA in 1883 published his thesis on the petrography of these regions.

The investigated area is bounded to the North by the Tresa river, at the same time part of the Swiss-Italian frontier, and running from Ponte Tresa on the Lago di Lugano to Luino on the Lago Maggiore; on the West by the shore of the last mentioned lake between Luino and Porto Valtravaglia. The southern border is given by the broken line: Ponte Tresa-Marchirolo-Cugliate-Cunardo-Ferrera-Mesenzana-San Michele-Porto Valtravaglia.

Those parts of the porphyry-district, which have been described by DE SITTER and KUENEN are separated from the area under investigation by a comparatively narrow strip of sedimentary terrains, which P. LEUZINGER (of Bale) has made the object of investigations. Shortly the results will appear of a geological study made by J. VAN HOUTEN (also of Bale University) of the area consisting of mesozoic sediments, which is bounded to the North, East and South by the Valtravaglia and the Valcuvia, and on the West by the Lago Maggiore from Porto Valtravaglia to Laveno.

For the fieldwork I made use of the tavolette Marchirolo, Germignaga and Ghiffa of the Carta d'Italia, scale 1 : 25.000. With the exception of the last mentioned tavoletta these maps are sufficiently accurate as concerns the topography. The new military roads, however, have been drawn in as they were projected, not as they were actually carried out, so that here and there I was compelled to rectify the map, especially in the cases where otherwise the geology would have been at variance with the topography.

As it is probable that in due time a colour-printed map will appear of these regions, with the here mentioned maps as a topographic basis, it will be necessary, before using it in the field, that the following corrections should be made from the one included in this thesis.

Tavoletta Germignaga.

1. West slope of the Mte. la Nave: the road from the Colle della Nave to the road connecting Cugliate and Alpe Paci runs about 110 m higher than drawn on the map, where only a footpath is marked.
2. Regions of Mesenzana: The windings of the road Mesenzana-Mte. San Martino are to be altered as shown on the included map.

Tavoletta Ghiffa.

The road Brissago-San Michele-Muceno has to be completely altered.

The topography of the tavoletta Ghiffa is highly inaccurate. Alterations should be made after J. VAN HOUTEN, as they chiefly concern the area he investigated.

The corrections were made with the aid of a compass and an altimetre, while the distances were obtained by counting paces.

The drawings of the slides in the chapter concerning the petrography have been obtained by using a microprojection apparatus of Leitz, by the aid of which rough outline sketches were made. A list has been given in the appendix with the meaning of the abbreviations used for the slide drawings.

Contributions to the geology of the porphyry-district of Lugano have been given by numerous authors. As a treatment of the older works can be found in HARADA's paper in their chronological sequence, I will confine myself to mentioning his own results.

When, in the course of this paper, it will appear, that my views differ from HARADA's, it must be borne in mind, that I worked several months in a comparatively small part, while HARADA only spent four weeks in the whole of the district, which circumstance places him at a disadvantage as regards his conclusions based on geological fieldwork.

The fieldwork in the South-Western parts bordering on the mesozoic sediments, has been carried out in collaboration with J. VAN HOUTEN. I feel very much indebted to him for his many suggestions and hints, which were of great help to me during my investigations of the mesozoic sediments on the Mte. la Nave and in the neighbourhood of Cunardo.

Prof. Dr. REINHARD in Bale has been so kind as to place the collections of slides and rocks, collected by Kaech in the Southern regions of the Lago Maggiore, at my disposal. I take this opportunity to express to him my sincere feelings of gratitude.

CHAPTER I.

GEOLOGY.

1. Introductory note.

Before giving a description of the rocks occurring in the investigated regions I will trace the general outline of the geological history of these parts. It will be seen that, during the time that volcanic activity reigned in the porphyry-district, this Northern part saw happenings entirely different to those that occurred in the Southern parts.

HARADA (and others) had already recognised certain differences in the rocks of the two parts mentioned. He has not, however, gone so far in his conclusions as to separate both regions on account of the different petrographical character they possess. On the contrary he considered the rock of the Mte. la Nave, called by him the "brown porphyry" a border facies of the granophyre that occurs to the South. This mistake of HARADA's cannot be wondered at, for it is unexpected, that two regions so near to each other, should each have a history so utterly independant as will appear from the following pages. That I myself have been able to come to this conclusion is chiefly owing to the fact, that comparison was made more easy after the exhaustive investigations made in those Southern parts by DE SITTER and KUENEN.

This comparison has brought to light not only that the two regions have not one rock in common, but also, that the rocks in the Northern part were deposited under conditions entirely different from those under which the rocks in the Southern regions were laid down.

The main differences between the two regions concern:

1. The relief of the landsurface before the deposition of the Permian rocks.

2. The sequence of the basic and the acid effusions during the period of Volcanic activity, and the type of eruption.

3. The nature of the rocks.

Ad 1. Both KUENEN and DE SITTER agree that the landsurface, before it was covered by volcanic rocks, must have shown a considerable relief. DE SITTER has been able to give a schematic reconstruction of this landsurface (page 200).

The regions to the North of these parts were not, however, occupied by land but by a shallow waterbasin, of the extension of which I will give no further particulars than that it probably extended more to the North and the East, than to the West, judging from the erosion remnants still left.

Ad 2. The petrographic investigations of KUENEN and DE SITTER have shown, that the so called black porphyry of the former investigators consists of a series of lava's and tuffs, which although they show certain variations in their degree of acidity (porphyrite, quarz-biotite-porphyrite, quarz-porphyry), obviously belong to one period of volcanic activity. This basic period of central eruptions was followed by fissural eruptions of an acid rock, the granophyre.

In the Northern parts however, it is, in the first place, impossible to distinguish two such periods. Eruptions followed each other with irregular intervals and basic and acid rocks alternate quite arbitrarily.

Although I have never been able to trace the eruptive channels of any of the rocks occurring in these parts, I deem it not impossible that they all have come through fissures. I will deal with this matter more fully later on.

Ad 3. The petrographic description of the rocks of these regions will show sufficiently that, although there are also porphyrites and quarz-porphyries, their habitude is so different from that of rocks of the same name, described by KUENEN and DE SITTER, that no more than a cosanguinity can be admitted.

2. Succession and distribution of the rocks.

The formations lying at the base of the sediments and the volcanic rocks are of unknown age. They consist of crystalline schists, folded by Hercynian orogenetic movements and exposed afterwards to denudation.

There is no certainty as to the exact time when these movements occurred. ESCHER, believing the upper-carboniferous conglomerates of Manno to have been folded concordantly with the crystalline schists, concluded that the volcanic rocks, lying uncomformably upon these schists (near Viona and Arosio) are younger and therefore of Permian age. KELTERBORN (22) did not agree with ESCHER and gave as his opinion that the Hercynian movements ended during, not after the Upper-carboniferous period, stating that the uncomformity was older than the folding. On a short visit to Manno with Prof. ESCHER we found the red tuffs, lying on top of the silicified tuff near Viona to be extremely like those that will be described as the red tuffs in the regions of the Mte. la Nave. I will return to this likeness later on.

When volcanic activity set in, the Southern part was occupied by land with a considerable relief; the Northern by a shallow waterbasin, the Permian shoreline running approximately NE-SW coinciding with the general trend of the tract of limestone- and dolomite sediments, which now separates these two parts. This line connects the following places: Ciona (South slope of the Mte. San Salvatore)-Agra-Ardena-Ghirla (in the Valganna) and runs from there in the direction of Laveno.

It is possible that this shore did not stretch much further to the West and turned to the North, as the decreasing thickness of the sediments which were deposited in this waterbasin, and also their facies, point to the proximity of the shoreline.

It is possible to obtain particulars concerning the nature of this coast.

One could imagine the land gradually sloping towards the water and should, in that case, expect a mutual overlapping of the sub-aquatic sediments and the basal tuffite series of the Southern regions, or a passing of the one formation into the other. At least the large effusion of the granophyre should have caused an extension of this lava into the waterbasin. This however, has most probably, not happened. It seems namely, that there was no gradual slope; on the contrary, there is sufficient evidence of the slope having been comparatively steep and high.

To the North of Marzio, in the bed of the Dovrana river, the Triadic dolomites repose immediately upon the fundamental crystalline schists. The same has been observed by LEUZINGER and KUENEN (page 143) in the neighbourhood of Bedero. DE SITTER concluded to the existence of a mountain range from his observations in the regions East of the Valganna (pag. 198) as may be seen on his diagrams (page 200) and sections.

The observations mentioned, combined with the fact that to the North as well as to the South several hundreds of meters of volcanic formations are interposed between the fundamental schists and the Triadic sediments, leads to the conclusion that a chain of hills must have existed there, where the Trias reposes on the crystalline schists. It was this chain, which prevented the granophyre from flowing over into the Northern waterbasin.

The shore stretched parallel to the general trend of the fissures, through which the granophyre came to the surface; this direction is also identical with the directions of faults and of the tectonic axes of both the Hercynian and the Tertiary orogenetic movements (fault of Brusimpiano-Cabiaglio). I am therefore of opinion, that this coastline came into existence through vertical movements which caused the subsidence and the submersion of the Northern regions. These movements must have been post-carboniferous and prae-triadic.

Towards the East this chain of hills, thus acting as a barrier, became probably less pronounced. For on the East slope of the San Salvatore-peninsula, above Alla Ferrera (North of Melide), immediately south of the Salvatore-syncline, the conglomerates and sandstones of San Martino can be seen reposing immediately upon a thick sheet of porphyrite (See ESCHER's section through the Salvatore-peninsula, bibl. no. 15).

These conglomerates and sandstones are identical with those of the Mte. la Nave regions. On the North- and West side of the Mte. San Salvatore they repose upon the fundamental crystalline schists.

This occurrence on the Salvatore-peninsula, which is the only one where rocks of the Southern parts are found together with rocks of the Northern regions, gives us some hold concerning the relative age of the rocks of both parts. The subsidence of the Northern part must have taken place during, or immediately after the deposition of the lava's in the South, where after the sandstones and conglomerates were laid down. It is not impossible that this subsidence stood more or less in connection with the volcanic activity in the Southern parts: the discharge of magma from the subjacent igneous body may have been in part responsible for this downward movement along prae-existing lines.

There is evidence that the subsidence and submersion mentioned were more intensive in the Western part of these regions. While in the Mte. la Nave-district we find a complex of more than 280 m. of sediments and volcanic rocks between the schists and the triadic dolomites, there are, on the North side of the Mte. San Salvatore (Cape San Martino) only some 80 m. of conglomerates and sandstones between the schists and the Trias. As these conglomerates of San Martino and those of the Mte. la Nave-District are so exactly alike, that there can be no doubt of their having been originally deposited on the same level and at the same time, the conclusion is arrived at, that, after their deposition, the subsidence of the Mte. la Nave regions must have continued for a longer time. Thus it seems that we may consider the San Salvatore regions to represent the Eastern border of this waterbasin. Further to the East the thick layers of conglomerates on the Lago di Como give evidence of another similar waterbasin.

There is no certain evidence left of how far the water extended towards the North. Possibly the red clays of Viona above Manno are to be regarded as erosion remnants of deposits in the same lake, or lagune, whatever this water may have been. It is more likely however, that they formed part of early-Permian volcanic deposits (Silicified tuffs, red clays, basic and acid eruptiva), the erosion of which provided the material for the deposits in the Mte. la Nave regions.

The following facts are in favour of this last supposition.

1. The red clays of Viona are devoid of pebbles, while those of our regions contain in large quantity irregularly dispersed layers of conglomerates. Thus the Mte. la Nave tuffs may have been transported along together with pebbles, derived by the erosion from other strata and deposited together with them.

2. The deep red-brown colour of the clays and tuffs in the Mte. la Nave district cannot be accounted for, without assuming that they already possessed it before their transport and deposition by the rivers. This red colour, so typical for the lateritic wheathering of the landsurface in tropical and subtropical climates, must necessarily date from the time when the material lay open to the air. That this lateritic alteration should have taken place after their deposition during a time of emersion is highly improbable. There is no evidence whatever of such an emersion, for the deposits follow each other without the slightest sign of any break or unconformity. The first time they reappeared at the surface, was during the recent period of denudation, which began after the tertiary orogenitic movements.

Thus the rivers streaming down from the North brought their sediments into this shallow waterbassin.

It proved necessary to subdivide these sediments into three groups.

Basal sandstone-tuff-series {
3. Lithic tuffs.
2. Red tuffs.
1. San Martino conglomerates and sandstones.

I. THE SANDSTONE-TUFF SERIES.

1. The San Martino conglomerates and sandstones.

This formation is of a brown-red colour, generally contains much mica, and is rich in subangular quarz pebbles derived from the fundamental schists (vein-quarz).

Fig. 1 shows a section in the neighbourhood of Bosco, where the road from Fabiasco to Bosco crosses the third tributary of the Grantorella river. In some of the strata occur irregularly shaped pieces of limestone. From the fact that they are neatly arranged between the

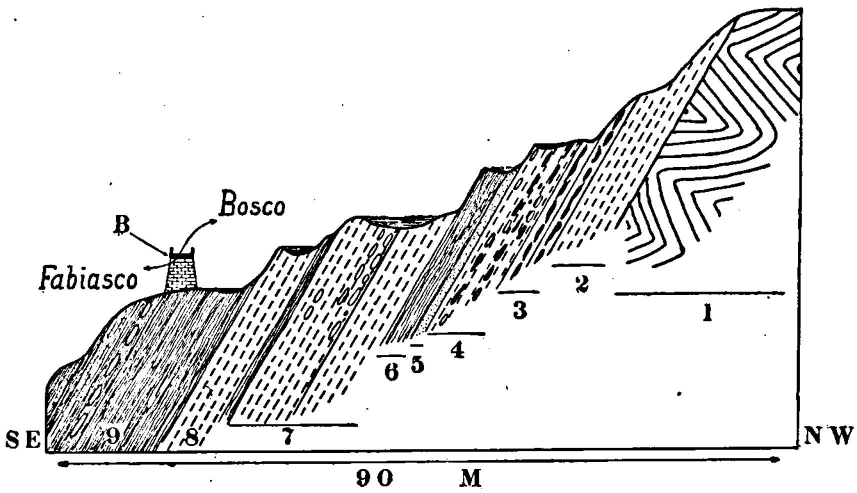


Fig. 1.

Section through the San Martino beds in the bed of the Vale delle Selve. 1: fundamental schists. - 2: micaceous red sandstone. - 3: red sandstone with inclusions of limestone. - 4: greyish-red sandstone with similar inclusions. - 5: white sandstone. - 6: micaceous clay. - 7: sandstone with pebbles of vitroclastic tuff. - 8: red sandstone. - 9: red tuffs. - B: bridge.

layers, thus occurring in special horizons, it seems clear, that they are pebbles. On the other hand I found several such pieces showing more or less the irregular form of branches, some of them reaching a length of 60 to 80 cm. with a diametre varying from 5 to 15 cm. As they are brittle, it seems unlikely, that they should have been brought there by water transport, sothat the question arises, whether they are not concretions. They will be fully dealt with in the microscopic description of the rocks. I found these fragments in many places; in the San Martino conglomerates, Cape San Martino, Lugano; almost immediately above the fundamental crystalline schists; in the mentioned tributary of the

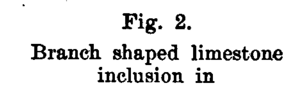


Fig. 2.
Branch shaped limestone inclusion in the San Martino beds. Scale 1/12.

Grantorella (see section); in a small Northern tributary of the Tresa river, running East of Casa Demenech and West of the Dogana Fornasette, some 20 m. below the spot where this tributary is crossed by a fault. The conglomerates also contain badly rounded pebbles of crystalline schists and gneises.

Higher up they begin to contain very well rounded pebbles with conchoidal fracture. Within a lustrous red brown groundmass many clear quarz crystals are visible; these rocks are silicified vitric quarz-porphyry tuffs. They vary in diametre from a few centimetres to 3 dm.

2. The red tuffs.

As soon as these pebbles begin to appear the sand matrix of the conglomerates becomes more and more clayish. Locally white sandstones alternate with these sandy clays. The higher strata of these layers, which always have a certain amount of quarz and mica, contain, together with the pebbles of vitric tuff, other pebbles of crystal tuffs, also well rounded, and of porphyrite with more irregular forms.

In the above mentioned tributary of the Tresa river (Casa Demenech), as well as in another tributary, near Casa Selvacce (NW. of Cremenaga) I found within the red clays layers wholly composed of peculiarly twisted stems, consisting of the same red sandy, somewhat micaceous clay (fig. 3*a*). Their diametre is elliptical (fig. 3*b*). They can easily be separated from each other, but, because of their softness and fragility, cannot be transported without crumbling to pieces. It seems to me that their form suggests that vegetable matter, transported and deposited by the rivers, was replaced by the clay material with the preservation of the outward form, while the elliptical shapes are due to the pressure of the overlying beds.

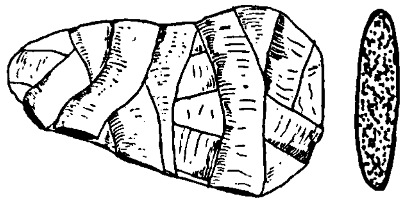


Fig. 3*a*. Fig. 3*b*.

a: Imprints of vegetable matter in the red tuffs.
b: Section through one of the "stems". Scale 1/1.

3. The lithic tuffs.

These strata lie conformably upon the red clays. They have a dark green colour and contain inclusions of rounded pebbles of porphyrite. At their base they are a solid rock without any stratification; higher up a more pronounced bedding sets in.

Having described the general habitude of the sediments I will now attempt to reconstruct the relief of the waterbasin with the aid of the included table, where the thickness of these formations is given at different places, describing at the same time their local facies.

	Cremenaga	Voldomino	Bosco	Grantola	Mesenzana	San Michele
Lithic tuffs	0 (?)	0	30	30	20 (?)	0
Red clays	6 (?)	80	150	100	80	50
San Martino beds	?	10	80	5	20	0 (?)

As may be seen, the San Martino beds are best developed near Bosco. At Cremenaga they have already disappeared by the erosion.

At the railway station in Grantola the red clays can be observed lying within 5 m. above of the fundamental schists. Here the conglo-

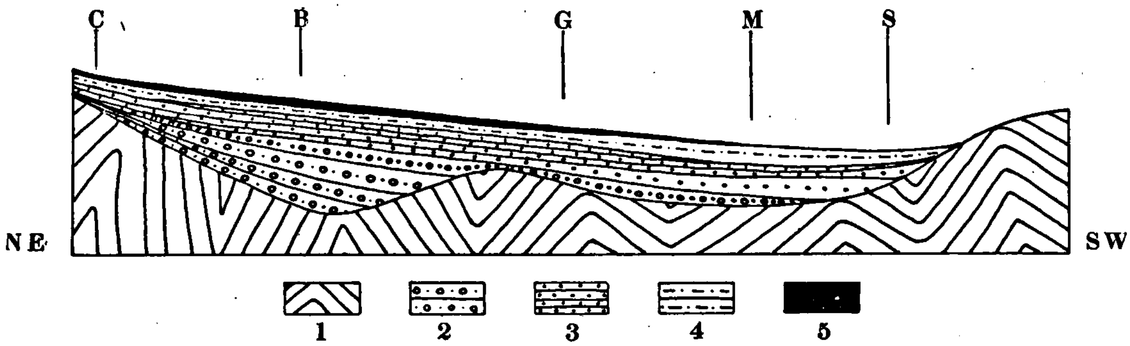


Fig. 4.

Schematic section through the waterbasin after the deposition of the Sandstone-tuff-series and the felsophyre.
1: fundamental schists. 2: San Martino sandstones and conglomerates. 3: red tuffs. 4: lithic tuffs. 5: felsophyre.
C: Cremanaga. B: Bosco. G: Grantola. M: Mesenzana. S: San Michele.

merates are scarcely developed as such: they are represented by sandstones with only a few small pebbles. More to the North East of the station there are good outcrops showing the red clays lying almost directly over the schists.

In the Torrente Chiezone, West of Mesenzana, this formation is chiefly developed as a sandstone with only a few layers of conglomerates with small pebbles. It reaches a thickness of ± 20 m. More to the West the formation disappears below the Triadic dolomites, which form an anticline, and reappears below the village of San Michele. Here the red clays crop out, but not the underlying conglomerates. It is probable that they were never deposited here.

The red clays reach their greatest thickness near Bosco. To the North, the East as well as to the West this thickness decreases. When they are well developed, many layers of white, fine-grained sandstones, grits and conglomerates are intercalated between them. These layers occur only very locally and their thickness seldom exceeds 4 or 5 m. It was therefore impossible to draw them on the map.

More to the West these intercalated strata disappear as well as the conglomerates. The red clays of San Michele are almost free of quarzsand and do not contain any pebbles.

The lithic tuffs seem to have occupied only the centre of the basin.

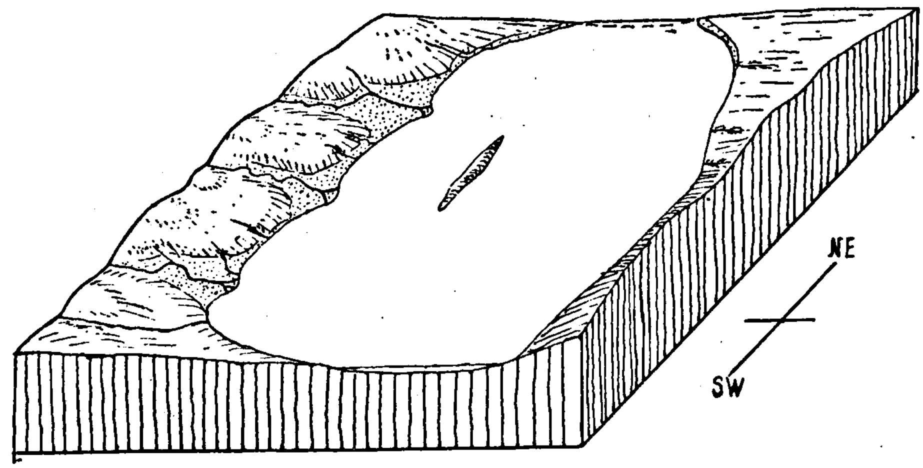


Fig. 5*a*.

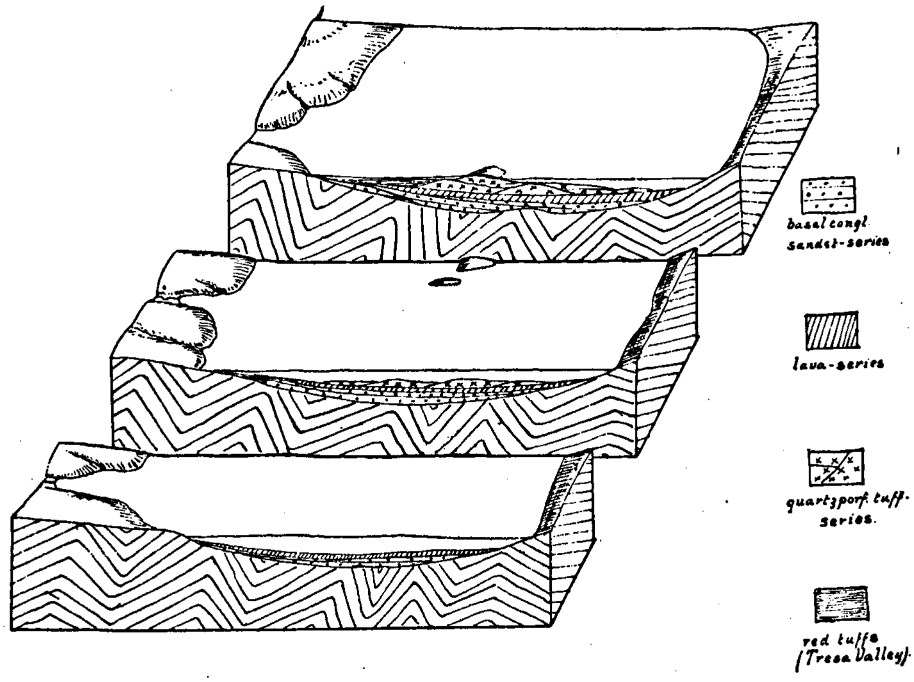


Fig. 5*b*.

a: Schematic reconstruction of the Permian waterbasin at the beginning of the subsidence.

b: The same waterbasin after prolonged subsidence and filled up with the Permian sediments and volcanic rocks.

Near Voldomino good outcrops of the red clays are covered by the felsophyre; the lithic tuffs are absent.

In the neigbourhood of Bosco (West slope of the Mte. la Nave), near Cugliate (South slope of the same); near Grantola (West slope of the Mti. di Castelvecchio) and to the South of Mesenzana the lithic tuffs are well developed.

At the last mentioned locality no good outcrops were available, thus rendering the measurements unreliable.

Fig. 4 shows a schematic section through this waterbasin after it was filled up by the described sediments, while the block diagram (fig. 5*a*) shows a hypothetical and very schematically drawn reconstruction of the landsurface at the beginning of the subsidence.

From the circumstance that the conglomerates are scarsely developed over a short distance to the NE. of Grantola and have a thickness of only 5 m. at the station of that village the conclusion can be drawn, that we have to deal with a culmination in the bottom of the waterbasin.

A second conclusion that is arrived at, is, that all the sediments were deposited by rivers that came from the North, or, probably more exactly, from the North-West.

The reasons in favour of this conclusion are:

1. The San Martino beds contain conglomerates in so far as they lay to the North of the mentioned culmination, which acted as a barrier. To the South of this barrier the conglomerates play a minor part: the beds are chiefly developed as sandstones that decrease in thickness and finally disappear further to the South.

2. The red tuffs for which this barrier was no obstacle, show a decreasing amount of conglomerates, when they are followed to the South, as well as a decrease in the dimensions of the pebbles.

3. The pebbles in the red tuffs, derived from volcanic rocks (vitric quarz-porphyry-tuffs, porphyritic tuffs, porphyrites) were subjected to a carefull microscopic examination. Not one single volcanic rock of the Southern regions was found; and a comparison with Kaech's slides of the Porphyry-district lying at the South of the Lago Maggiore led to the same negative results.

That these rocks should have come from the East is improbable on account of the presence already referred to of other waterbasins in that direction.

Thus the only remaining alternative is that of their having been transported from the North or from the North-West.

In that case it is obvious that in those North-Western regions volcanic activity had already manifested itself before this was the case in our parts.

From the sequence of the deposits a sketch may be drawn of what happened in the North-West.

It is probable that in those parts the eruptions occurred during the sedimentation of the San Martino conglomerates.

The latter are (at least in the here described regions) rich in pebbles of gneis, schists, and veinquarz, while the sandy matrix contains mica. At the time of their deposition we may imagine rivers running over the denuded surface of the hercynian mountains, carrying with them the weathered soil of that land surface.

In the then following sediments pebbles of vitric quarzporphyry-tuff occur in the lower strata, and such derived from more basic rocks in the higher horizons.

Possibly the porphyrites came, first of all, into existence, the acid eruptions occurring later. In that case the rivers must have cut through this complex of volcanic rocks, reaching first the acid vitric tuffs, which explains their having been deposited as pebbles in the lower strata. In a later stage the waters reached the porphyrites, thus causing them to repose in the higher strata of our waterbasin.

Another possibility might be that the rivers, at the beginning, did not stretch as far back to the North-West as to reach the possibly already existing volcanic regions. These were reached afterwards, whereafter their rocks were transported.

Whether, from the more irregular shape of the porphyrite pebbles it may be derived that the place of their origin was nearer to our district than the regions where the vitric tuffs were originally deposited, is questionable. The pebbles of the latter are very hard and compact, but, because of their flintiness, are easily broken, sothat splitters are easily to be detached from them. The porphyrite pebbles however, are not only very hard, but also extremely tough, sothat this rock would need a considerably longer transport to reach the same degree of roundness as the vitric tuff pebbles. I therefore believe that the pebbles of both rocks must have travelled over practically the same distance.

4. The Conglomerate of Germignaga.

Before passing to the description of the volcanic rocks and their distribution, there still remains one sediment to be mentioned: the conglomerate of Germignaga. I have not mentioned this rock before, because it stands apart from all the other conglomerates.

This conglomerate is found wedged in between the schists and the Triadic dolomites on the West side of the hill of la Canonica. The main differences between this rock and the conglomerates of the San Martino type are the following.

1. It lacks the red-brown colour, which is so typical for the latter.
2. It contains different pebbles to those of the other conglomerates.

A first exposure is found on the road from Germignaga to Porto Valtravaglia, about 40 m. to the North of the limekiln near the Villa Clarissa. Mentioned in the order of frequency, we find: quarz (more than 50 %), gneis, granite (not showing any resemblance to that of Baveno) and pegmatite.

A second outcrop is found between the two tunnels of the railroad Luino-Porto Valtravaglia. This exposure represents a higher horizon and contains pebbles of quarz and crystal-tuffs.

A third outcrop shows the conglomerate over a distance of some 50 m. on the road from Germignaga to Bedero Valtravaglia. Here the contact with the underlying schists can be studied. There is found to be no clearcut plane of contact: the schists pass gradually from a solid rock into a breccia consisting of irregular fragments free from any foreign cement. This breccia becomes more and more mixed with thin layers of sandstone. At last the latter predominate and begin to contain the pebbles already mentioned. In this sandstone I found what might resemble the imprint of some tree-fragment.

Where this conglomerate borders on the dolomite I found indications of the presence of the red tuffs, the soil showing the typical red colour, namely at the entrance of the quarry in the dolomites.

The following conclusions may be drawn from these observations.

The fact that the schists pass imperceptibly into a basal conglomerate points to the possibility that this part of the ancient landsurface was, during a short time, the border of the waterbasin.

The breccias occurring at the bottom should represent the quickly submersed weathered soil of the surface, the conglomerates lying on top of them being the delta deposits of some small river, arrising elsewhere than the rivers mentioned before. Afterwards this delta was covered by the outer fringe of the red clays, which, by that time, had reached this part of the basin. Thus the conglomerate of Germignaga seems to be of about the same age as those of San Martino.

5. The Lavas occurring in the Sandstone-tuff series.

The first manifestations of volcanic activity *in situ* occurred during the sedimentation of the red clays. Between the layers of these clays I found two lava flows consisting of basaltite. One can be found to the South of Mesenzana and is an Enstatite-basaltite.

The other crops out in a small tributary of the Tresa river, about ¾ km. to the West of the Swiss village of Ponte Cremenaga, and is an augite-basaltite. These lava's have no large extension. The basaltite South of Mesenzana is about 20 m. thick where it is crossed by the road from that village to the Mte. San Martino. It thins rapidly to the West, less so to the East. On the opposite side of the Valtravaglia, to the East of Grantola, good exposures of the red tuffs do not show any trace of this basaltite. On the road from Grantola to Cunardo a thin layer of quarz-porphyry is found in the lithic tuffs [1]).

II. THE LAVA SERIES.

1. The Felsophyre.

After the deposition of the lithic tuffs another period of volcanic activity set in. It began with the effusion of a large sheet of a vitrophyric lava, which, by devitrifying, became a felsophyre. This sheet is remarkable because of its large extension. It probably occupied an area of some 125 square km. at the least, of which, after the tertiary folding and the subsequent period of denudation, about 20 square km., at the most, is left.

Near Voldomino, where this rock has an almost perpendicular position,

[1]) Because of the thinness of this sheet I have not put it on the map.

it is a conspicuous feature in the landscape, as it stands right out from the underlying red tuffs, which, because of their softness, have been carried away by erosion. Its thickness varies from 2 to about 300 m. On the South slope of the Mte. la Nave and in the Tresa valley quarries have been made in this rock for building purposes on account of the compact structure and the absence of joints. The railway stations of Cugliate, Marchirolo and Arbizzo-Cadegliano are built of this rock. At the top as well as at its base this rock is occasionally rich in amygdales filled with zeolites. The dimensions of these amygdales do no not exceed one cm.

2. Porphyritic lavas.

Upon this felsophyre follows the wellknown vitrophyre of Grantola. HARADA found an exposure of this rock in the neighbourhood of this village in the Mti. di Castelvecchio [1]) and on the South slope of the Mte. la Nave he found pebbles of this vitrophyre in some brooks. This vitrophyre is only a local superficial facies of a quarzbearing porphyrite, which has approximately the same extension as the underlying felsophyre. The vitrophyre I have found as such at the spot, mentioned by HARADA in the Mti. di Castelvecchio; on the North slope of these hills, SW. of Fabiasco; on the West slope of the Mte. la Nave, below the Colle della Nave; on the South slope of the same mountain to the North of Cugliate; to the South of Mesenzana on the road from that village to the Mte. San Martino. I found pebbles of it in many of the rivulets that descend from the South slope of the Mte. la Nave (Rio Marana, Rio Dovrana). This porphyritic lava reaches a thickness of from 2 m. to some 30 m. It is usually found to be wheathered to a red rock in which white phenocrysts of a zeolitised plagioclase are clearly visible and crumbles immediately, when knocked with the hammer. To the North of Cugliate this lava is interbedded between two layers of an Hypersthene-basaltite.

In the Tresa valley, to the South of the Dogana Fornasette, near the bridge of the line Ponte Tresa-Luino an amygdaloidal augite-porphyrite reposes upon the felsophyre, together with other porphyritic lavas.

Upon these lavas lies a complex of well stratified red tuffs, differing from the basal sandstone-tuff formation by the absence of mica. They alternate with other porphyritic rocks. On the Northern bank of the Tresa river, opposite the two tunnels, I found large boulders of a flinty rock, rich in large amygdales, containing agate, which also occurs on cracks. Pebbles of this rock occur in the small tributary of the Tresa, running from the Dogana Svizzera to the South. As these pebbles occur nearly as far up as the source of this tributary, the solid rock probably reposes at the base of the red tuffs mentioned, and on top of the porphyrites. It is a lithic tuff, consisting of fragments of a devitrified vitrophyre, which may be identical with the vitrophyre of the other

[1]) HARADA mentions the Monte Selva. As I could not find this name on the military map, it seems, that it has fallen into disuse and that it has been substituted by the name of Mti. di Castelvecchio.

regions. As the felsophyre, the quarz-bearing porphyrite and the other porphyritic rocks represent a period of almost constant volcanic activity, during which the eruptions are characterised by effusions (not by explosion), I have united these rocks under the name of the Lava-series.

III. THE QUARZ-PORPHYRY-SERIES.

Upon this formation follows another, which I have called the Quarz-porphyry-series, because it consists in the main of quarz-porphyry and its vitric tuffs. This is the formation, called by HARADA the "brown porphyry".

The quarzporphyries occupy a considerable part of the surface of our regions. On the West side of the Southern slope of the Mte. la Nave this rock crops out as a pink rock, rich in phenocrysts of quarz and orthoclase, with an aphanitic groundmass. Another biotite-quarz-porphyry reposes on top of it, directly under the layers of the Werfenian.

The solitary church of San Paolo, to the East of Alpe Paci, stands on a formation of red brown vitric quarzporphyry tuffs, while on the North side of the Mte. la Nave lithic tuffs prevail.

The Mti. di Castelvecchio consist, for the greater part, of the same lithic tuffs, which occasionally take on the character of conglomeratic tuffs.

To the South of Mesenzana, along the road already referred to, that leads to the Mte. San Martino, good outcrops, showing vitric tuffs, are to be observed.

The quarzporphyry-series was not deposited in the Northern parts of the waterbasin: in the Tresa-valley they are lacking. To the South of the Dogana Svizzera the red tuffs already described take their place.

At San Michele the felsophyre is directly overlain by the Triadic sediments. So the quarzporphyry was not deposited here. The large boulders of quarzporphyry I found in the bed of the Torrente Froda, beneath the felsophyre, must have been brought there by the Ticino-glacier as part of its moraine. More to the North large tracts of the volcanic rocks are exposed, from which these boulders may have been derived. These exposures will be dealt with in the chapter on the tectonic geology.

In the Vale Rone, 500 m. to the South-West of San Michele, a small erosion remnant of the felsophyre can be found (strike N-45°-W, dip 90°). It is separated from the Triadic dolomite by a thin layer of Werfenian sandstone.

I have not succeeded in finding much regularity in the distribution of the rocks which constitute this formation. They are not stratified, nor have I found any clastic sediments intercalated between them. The tuffs do not show evidence of having been brought into this basin by rivertransport. The inclusions in the tuffs are not rounded but show angular forms. Loose quarz crystals show very fine signs of magmatic corrosion, which have not lost these delicate forms, that, most probably, would have been destroyed during their transport. The absence in the tuffs of any material (sand, clay, pebbles) from outside these regions points to their having been deposited on the spot of their origin. Eruptions of porphyritic rocks also played a part during this stage of volcanic activity, though only very locally. Two layers of an Augite-porphyrite are exposed between Derzaga and the Rio Marana (South slope of the Mte. la Nave). Another Augite-porphyrite is to be found 250 m. to the North of Casa Chini (South-West slope of the Mte. la Nave).

A third porphyrite I found to the West of Mesenzana between Pianazzo and Cavoiasca, immediately beneath the Werfenian.

The quarzporphyries belong to the last effusions of this period of volcanic activity. These lavas must have come partly to the surface of the water as little islets. These islets were forthwith attacked by the surf, for large well rounded boulders of the pink quarzporphyry are found upon the crystal tuffs at Derzaga, immediately beneath the Werfenian (see fig. 6).

Type of eruption.

Before passing to the further geological history I must add some remarks concerning the type of eruption that brought the lavas and tuffs to the surface. Considering the large area, formerly covered by the felsophyre, it is highly probable that the volcanic vents through which the effusion of this lava took place, were fissures. The same can be said of the porphyritic lavas, of which the vitrophyre is a superficial facies.

Whether the eruptions that gave birth to the quarzporphyries were of the central- or of the fissure-type, is an open question. My opinion is that these rocks were produced by the same fissures, though I have no definite reasons to support this supposition.

Now it is a most peculiar fact that not a single one of those hypothetical fissures is to be found, while on the other hand, ESCHER, KUENEN and DE SITTER all found the actual channels through which the granophyre came to the surface in the foliated mica schists in the Southern regions.

It seems strange, that here, where nearly $^4/_5$ of the Permian sediments and their cover of volcanic rocks have disappeared, no such feeders have been exposed by the denudation, in the manner as is the case in the Southern parts.

It might be supposed that the actual scene of the extrusions lay to the North of the Tresa-valley and that the lavas came hither, flowing down into the waterbasin. But it is not conceivable that they should have spread out to such an extent; nor have fissures ever been found round about these regions, that could be looked upon as the vents; and finally the porphyrite lavaflows remain to be accounted for. The presence of such thin and constricted flows is an indication that the scene of volcanic activity must not be sought elsewhere.

I therefore conclude that the feeders of the lavasheets are still hidden underneath the present layers of Permian sediments and volcanic rocks and I will proceed to point out the most likely places where they would appear if their present cover could be removed.

The fissures must have stretched in a direction NE-SW, parallel to that of the feeders of the volcanic rocks in the South, parallel also to the tectonic lines of the hercynian and the tertiary movements.

The line along which these feeders probably stretch, when projected on the map, is broken, because of transverse faults. This projection on the map connects the following places:

Mte. Mezzano-Mte. la Nave-Casa Chini; from Fabiasco, parallel with the first mentioned line, to somewhat to the North of Ferrera; on the opposite side of the Valtravaglia, from a point about 500 m. to the North of the village of Cassano to the Mte. Ganna.

IV. THE TRIAS.

The close of the volcanic episode in the geological history of these regions coincides with the general subsidence of the whole of the area at the beginning of the Mesozoic period.

The transgression of the Werfenian in other regions is marked by a further subsidence of our parts for they were already submersed. This renewed subsidence at the beginning of the Trias resulted in a rejuvenation of the erosion in the Northern coastal regions, during the short time before they were also submerged. This rejuvenated erosion caused the rivers that came from the North as well as from the South, to bring down new deposits of sandstones and conglomerates.

At Derzaga the Werfenian is developed as a layer of red sandstone with small quarz pebbles.

1: Red-brown quarz porphyry tuffs.
2: Bluish-grey quarz porphyry tuffs.
3: Conglomerate containing boulders of pink quarz porphyry.
4: Red sandstone with angular quarz pebbles.
5: Marls passing gradually into limestone and dolomite.

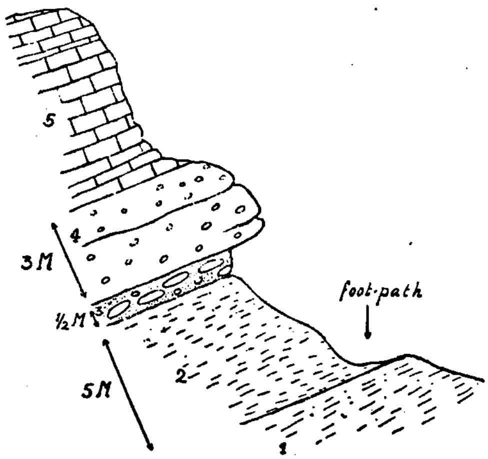


Fig. 6.

Section through the Werfenian at Derzaga.

At Voldomino this formation is represented by a white sandstone, 2 m. thick.

Near Mesenzana we find a compact conglomerate of angular quarz pebbles cemented by micaceous quarz sand; it is obviously composed of the detritus of the fundamental schists from the Southern regions.

In the Mti. di Castelvecchio the quarzporphyry-series is separated from the Triadic dolomites by a complex of thin alternating layers of a greyish clay, of marl and sandstones. The marls become more and more rich in lime and pass imperceptibly into the limestones, and the latter into dolomites. This facies of the Werfenian, some 5 m. thick, represents that of the deepest parts of the waterbasin.

What has been left of the Mesozoic sediments by the erosion is only some 150—200 m. of the oldest strata of the Trias. About 12 to 20 m. above the Werfenian I found, almost everywhere, a horizon containing Diplopora Annulata in the Ladinian (or Anisian?) dolomite. They are the only fossils I have found in the Triadic strata.

Notwithstanding the intensive dolomitisation of these rocks layers of extreme thinness are found. Such a complex of layers of paperlike thinness is sometimes seen to change, over a distance of a few meters, into one thick bank. The colour of these dolomites varies from white to bluish-grey. In spite of their richness in magnesia many limekilns are found in these regions, only providing for the local needs, however.

In the numerous small faults, slickenside planes and fissures, dolomite crystals are found.

CHAPTER II.

GLACIAL GEOLOGY.

As the glacial history of the investigated regions cannot be considered but in close connection with that of the surrounding parts, I have endeavoured to give a treatment of the whole of the regions lying between the Lago di Lugano and the Lago Maggiore.

In the wellknown work: "Die Alpen im Eiszeitalter" by PENCK and BRÜCKNER a general treatment is given of the glacial history of the Insubrian lakes (Lago Maggiore, Lago di Lugano and Lago di Como).

During the time that this area was flooded by the ice, its Western parts were covered by the Toce- and the Ticinoglaciers. The latter sent off a diffluent branch over the pass of the Mte. Cenere near Bellinzona, which branch covered the western part of the Lago di Lugano. The basin of the Lago di Como was occupied by the Addaglacier, which sent off a branch through the Porlezza-arm of the Lago di Lugano, joining the Cenere-glacier, then to turn towards the South, to fill up the Eastern part of the Lugano-lake.

The areas lying in between the lakes were also covered for the greatest part by these ice masses, with the exception of the highest mountain ridges, which showed above the ice sheet as nunataks (see map in ALB. HEIMS "Geologie der Schweiz", I, Tafel X, page 214). (Bibl. n^{o}.19).

As far as the regions are concerned that lie in between the Lago Maggiore and the Lugano-lake, not very much was known till 1925. All PENCK (Bibl. n^{o}. 13) writes on this subject (Bd. III, page 811) is:

"Während die Tal-entwicklung im Comosee-gebiet ganz und gar von der Diffluenz des Addagletschers beherscht wird, liegen am Langensee (Lago Maggiore) die sachen verwickelter......... Es wird noch weiterer Untersuchungen bedürfen um das dortige Gewirre von Tälern in seinen Bestandteilen aufzulösen."

The first contribution to a more detailed knowledge was given by KUENEN (28) for the Southern parts. He recognized that the area investigated by him had been covered by an ice-sheet, that consisted of three glaciers: they were the diffluent offshoots of another, the Valcuvia-glacier, which, in its turn, was a branch of the Ticino-glacier. These three glaciers became confluent again (at different spots) in the Valganna-glacier, which, in itself, again sent off two diffluent branches: to the East (North of the Poncione di Ganna), and to the South-East (in the direction of Arcisate).

To this statement of KUENEN I wish to add that the Northern (Ferrera-) branch of the three mentioned offshoots did not turn into the Valganna, but flowed further towards the East, to join the Cenere-glacier.

It was a diffluent glacier from this Ferrera-branch that surmounted the Ghirla-watershed and descended into the Valganna.

We will see, that the further application of the principle of diffluency on the other parts of this area will give the key to an explanation of this rather intricate net of valleys.

On fig. 7 diagram *a* I have tried to give a schematic reconstruction of the prae-glacial landsurface of the regions between the Lago di Lugano and the Lago Maggiore, seen from the West. The prae-glacial hydrography can be described as follows.

1. *Consequent valleys,* occupied by rivers running North-South, according to the general slope of the Alps. They were represented by the valley of the Ticino in the West; in the East by the valley that was afterwards occupied by the Cenere-glacier; and by the Valganna-river in between.

2. *Subsequent valleys,* that contained the tributaries to the aforementioned rivers. They stood more or less at right angles to the consequent valleys and sometimes coincided with faults (Tresa).

The Tresa-river of prae-glacial times had an Easterly course and had its source somewhere to the South of the Dogana Fornasette.

In those times the Mte. Martica still stood in connection, via the Mte. Roccolo, with the group of the Mte. San Martino. This connection consisted of the watershed between the Valtravaglia and the Valcuvia. The Valtravaglia had a North-Westerly course and was fed by the Grantorella and the Chiesone, near its mouth by the Torrente San Giovanni on the left, and possibly by another small tributary on the right.

The valley of Pralugano and the valley of Brinzio contained tributaries to the Valganna-river, which had its origin on the Ghirla-watershed.

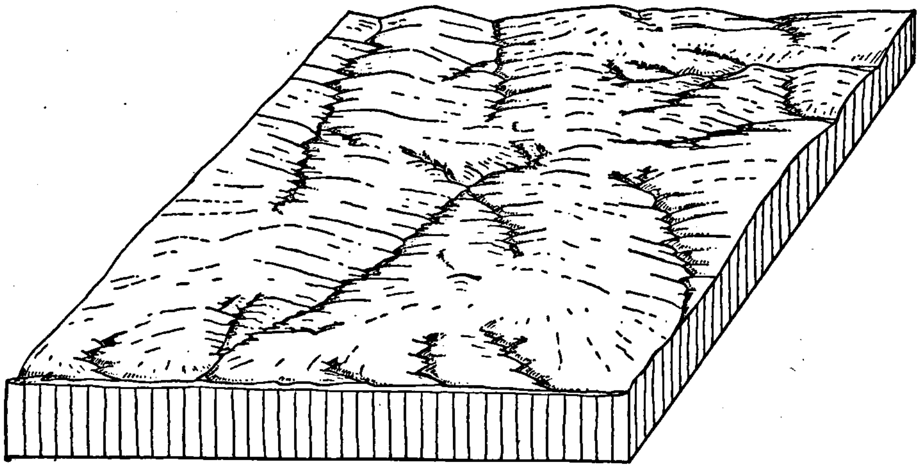
Another valley stretched from Fabiasco in an Easterly direction (Lisascora) joining the Margorabbia, which came down from the Ferrera-watershed, flowing Eastward.

It has to be borne in mind, that these rivers, at the beginning of the ice-age, had not all reached the same stage of erosion. The waters of the Tresa, Valtravaglia and the Valcuvia, which were all tributaries to the main waterveins that drained the Alps, reached a certain level at their base of erosion after travelling over a comparatively short distance. The distance to be covered by the Valganna-river to reach that same level in the South, was considerably longer, so that this river and its tributaries had not cut as deep into the surface as the first mentioned rivers.

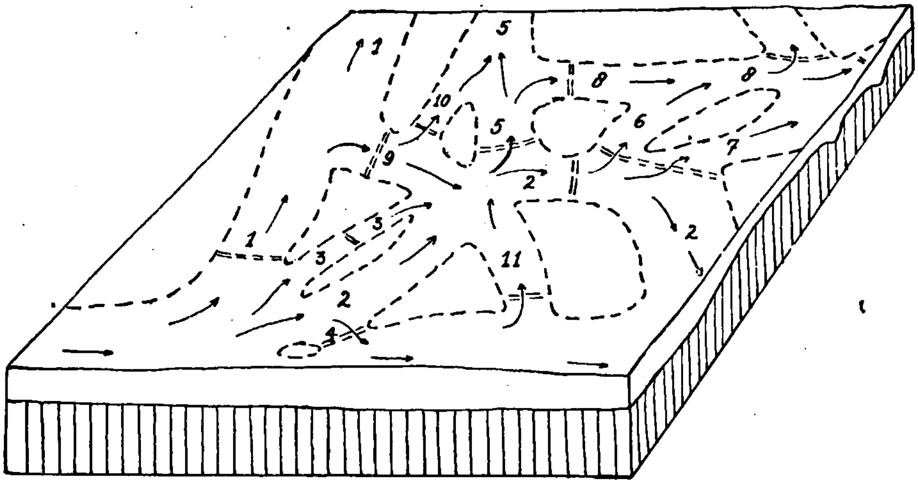
During the periods of glaciation the whole area was covered by ice with the exception of a few summits in the Southern parts, as a result of the sloping of the ice surface towards the South. These summits were: the Mte. Piambello, the Poncione di Ganna, the Mte. Martica-Chiusarella, the Mte. Campo dei Fiori, the Mte. Minisfreddo, the Mte. San Martino-Mte. Nudo. We must imagine this covering of ice as a sheet moving slowly Southward. Within this sheet the ice moved in different directions, following the valleys which it filled up.

Fig. 7.

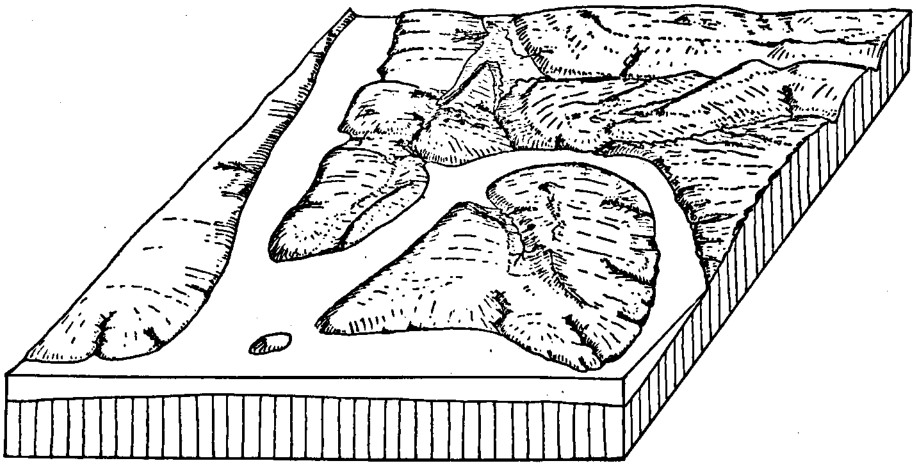
Schematic reconstruction of the landsurface, seen from the West, —



a. Before the glaciation;



b. During the glaciation;



c. After the glaciation.

Fig. 7 diagram *b* shows this ice sheet, the dotted lines on the surface of which indicate the borders of the prae-glacial valleys occupied by the ice-flows, while the course of the ice is indicated by arrows. The prae-glacial watersheds are represented by dotted double lines.

On this diagram we see how the Ticino glacier sent off two branches into our regions: a Northern branch (1) which passed over the watershed of the Tresa and flowed forth towards the East; a Southern branch (2) occupying the valley of the Margorabbia (Valtravaglia), flowing over the shed which separated this valley from that of the Valcuvia and regaining the Ticinoglacier near Laveno. Another lobe (3) was sent off by the Valtravaglia glacier, which lobe ran parallel to its feeder and joined it again near Grantola. The ice of the Valtravaglia glacier was forced over four watersheds. The first one (4) is represented by the saddle in the spur between the Mte. Pian Nave and the hill of la Canonica near Bedero Valtravaglia. Here a small ice-flow came back to its original feeder. The three others (5, 6 and 7) have been mentioned by KUENEN: they are the feeders of the Valganna glacier (8). Part of the Tresa glacier (1) surmounted the saddle of the Colle della Nave (9) passing down the valley of the Grantorella, and joining the Valtravaglia glacier near Grantola, after branching off into the valley of the Lisascora (10) to join the Ferrera glacier (5). Another tongue was sent off by the Ticino ice over the saddle of San Michele (11), joining the Valtravaglia glacier at Mesenzana. Whether the Eastern parts of our regions were covered by ice from the Cenere-glacier or not, is a question of priority. It depends upon whether the here described area was already covered by the Ticino-glacier ice, when it was reached by the Cenere ice. It seems to me, that the Ticino glacier must have stretched a considerable way to the South, before it reached such a height as to be able to surmount the Cenere watershed near Bellinzona and to send off this diffluent branch. I am therefore inclined to believe, that, when the Cenere glacier reached these regions, the valleys were already flooded with the Ticino ice, which joined the Cenere ice near Ponte Tresa.

The following facts are in favour of this supposition.

1°. The Monte la Nave complex consists of four summits lying on a line NE-SW. The three Northern summits have ellips-shaped contours, the long axes of the ellipses stretching in a direction NW-SE. The three saddles in between show the typical forms of having been modelled by ice erosion. It is obvious that the ice came from the NW, not from the SE, as, in that case, the Cenere glacier, coming from the North, would have turned back sharply to the NW, which is unlikely.

2°. The hanging valley of Marchirolo joins the ancient glacial trough of the Cenere glacier over a glacial threshold at its lowest point. This fact points to the Ferrera glacier having occupied this valley, instead of the Cenere ice invading it, as in that case there would have been no threshold.

When the ice sheet retreated, it left many traces of its presence behind: terminal moraines along the Southern slopes of the Alps, outwash plains reaching far into the plain of the Po-river; a thick layer of ground-moraine on the once ice-covered mountains; the landscape shows forms typical of glacial erosion: "roches moutonnées", overdeepened trough-shaped valleys, etc. Some of the prae-glacial watersheds have almost disappeared. A typical example of such an almost imperceptible watershed is that in the Valcuvia. It slopes so gradually towards the North and the South, that only the brooks running in opposite directions give evidence of its presence. The prae-glacial draining system has undergone many alterations. Of the two tributaries to the Valganna one now runs in the opposite direction: The Rancina is at present a tributary to the Valtravaglia. The valley of Pralugano remained a tributary to the Valganna river (Margorabbia), which, however has reversed its course. Running northwards through the lakes of Ganna and Ghirla, it cuts its way through the Ghirla-watershed and turning to the West, it joins the Rancina in the Valtravaglia, after having descended the steep Ferrera-divide in two cascades [1]).

The reason why the rivers at present run in a direction opposite to their prae-glacial course has been described by PENCK and other authors.

The overdeepening of the prae-glacial valleys by glacial erosion decreased towards the south as a result of the thinning out of the ice-sheet in that direction. Thus the bottom of the trough sloped upwards and the retreating icetongue left a lake in its place, the water not being able to find a way out to the South. As soon however, as the receding glacier had left behind it the praeglacial watershed (considerably lowered now by ice erosion) and as soon as the level of the lake had reached this ridge, the water began to flow over and cut in through the rock, thus lowering the level of the lake, and draining the inundated valley towards the North. The lakes of Ganna and Ghirla are the remnants of a larger lake, which occupied almost the whole of the Valganna: from the Miniera in the South (from where the ground slopes upwards towards Olona) to Ghirla in the North, with a sidebranch in the valley of Pralugano.

The Margorabbia, having thus succeeded in passing the Ghirla-barrier, went through the same process before cutting through the Ferrera-shed.

KUENEN (28) has pointed out, that in the case of the Rancina river, the cutting in through the watershed already happened in an interglacial period [2]). The same has been the case with the Margorabbia. Just before the river descends along the second series of falls near Ferrera, the gorge

[1]) The Margorabbia here descends some 180 M. over a distance of 1250 M. The first series of cascades begins at a height of 430 M., about 250 M. to the SW. of the station of Cugliate. It drops 70 M. over 300 M. of its course. The second series begins at a height of 310 M. near Ferrera, with 60 M. descent in 350 M. distance. The waterpower is utilised in an artificial silk factory in the Valtravaglia. The falls of Ferrera belong to the finest scenery in these parts.

[2]) It would perhaps be preferable to use, in this case, the word "interstadial" (PENCK), instead of "interglacial". At the close of an ice-period the general retreat of the ice consists of a series of receding and readvancing movements. Times of temporary retreat are called by PENCK "interstadial periods". It seems to me that the incisions of the Rancina and the Margorabbia came into existence during such interstadial periods.

broadens to a basin with steep sides, wherein unmoved groundmoraine is found, which points to the fact that during the last glacial stadium the ice filled up the already existing gorge [1].

The history of the Tresa-valley is more complicated than that of the other valleys in our regions. It is somewhat difficult to explain the fact that this river reversed its course.

The Tresa is the drainer of the Lago di Lugano into the Lago Maggiore. It leaves the former at Ponte Tresa and flows towards the West in a broad valley till one KM. to the West of Cremenaga, where it encounters an obstacle in the form of the praeglacial watershed which slopes gradually down in the direction of the Lago Maggiore.

The river has cut its way through this watershed in a narrow gorge and with a winding course, the nature of which will be explained later on. It joins the Margorabbia shortly before the latter flows out into the Lago Maggiore.

As the Tresa represents the link between the two lakes, it is clear that we cannot solve the problem of its history, without extending the sphere of our considerations to the glacial and post-glacial history of the Lago di Lugano and the Lago Maggiore.

When the last glacial period was coming to its close and the ice retreated towards the North, the large basins of the Insubrian lakes were filled up to a much greater extent than they are at present. The walls of the terminal moraines encircling the Southern parts of the lakes acted (and still act) as a barrier, damming up the water to a higher level than they do at present.

The maximum height of this level depends upon the minimum height of the terminal moraines in the South. As soon as the water reached the lowest part of the terminal moraines it could flow over their ridge and cut into it. Usually these lowest parts in the morainic hills must have consisted of the breaches made by the glacier stream, when the terminal lobe was stationary at its maximum extent. Judging from PENCK's section (Bibl. 13, Bd. III, page 790), where the youngest terminal moraines attain more than 400 M. maximum, and somewhat more than 360 M. minimum height, the water in the Lago Maggiore reached a level of about 350 M., or 150 M. higher than the present level (202 M. at Germignaga, 196 M. at Sesto Calende in the South.) In consequence many parts of the lake country that are above the present level were inundated, as shown in Fig. 7 diagram *c*.

The group of mountains consisting of the Mte. San Martino, Mte. Pian Nave, Mte. Nudo, and the Pizzoni di Laveno, was an island, the water entering the Valtravaglia and the Valcuvia, thus surrounding these mountains. The lower parts of the hanging valleys of the Grantorella and the Chiesone were inundated, thus forming small inlets. The hill of la Canonica (Bedero Valtravaglia) showed above the water surface as a little island. The Tresa-valley was wholly submerged and connected

[1]) At Ferrera a weir is in course of construction in order to turn this broad gorge into a reservoir for the water-turbines of the silk-factory down in the Valtravaglia, so that in due time the groundmoraine will no longer be visible.

the lake of Lugano with the Lago Maggiore, which lake was also dammed up in the South by the terminal moraines deposited by the Adda- and the Cenere-glaciers.

The many rivers coming down from the mountain sides and cutting into the ground-moraine, brought down and deposited this material in the inundated valleys as deltas. The bulk of these deposits has disappeared at present by the post-glacial erosion, where they were laid down in the valleys. Where they came to repose at higher levels they can still be found.

The hanging valley of the Grantorella shows a glacial "threshold", where it opens into the Valtravaglia. This threshold acted more or less as a barrier for the fluvio-glacial sediments, that were deposited behind it in the above-mentioned inlet. At present the Grantorella and its side-rivers have cut deep gorges into these sediments and in the underlying Permian and prae-Permian rocks (fig. 8, *a* and *b*). It further cut through the barring threshold and now joins the Margorabbia at the level of the same (fig. 8, *b*, dotted line).

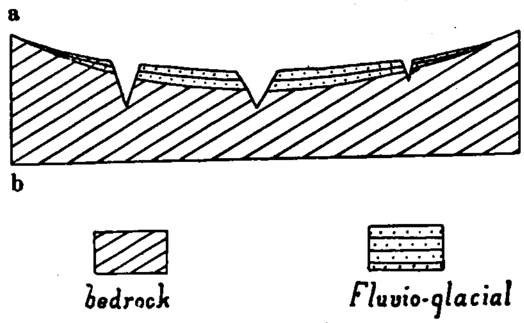


Fig. 8*a*.

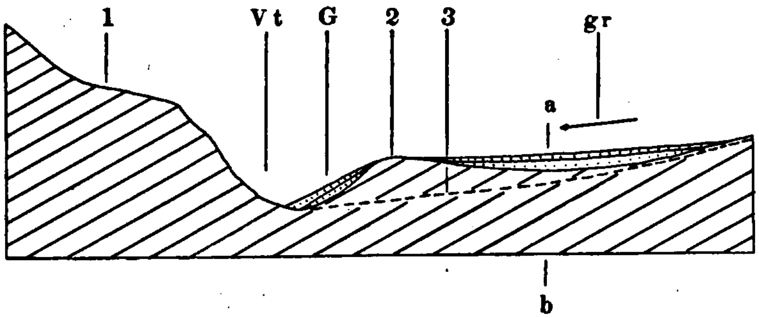


Fig. 8*b*.

Schematic sections at right angles to each other through the valley of the Grantorella.
1: Praeglacial valley; - 2: Threshold; - 3: Present level of the Grantorella; gr: Grantorella; - G: Grantola; - Vt: Valtravaglia.

In the Western part of the Tresa-valley the same fluvio-glacial deposits are still left on the bottom of the glacial trough. The Tresa has cut a deep gorge through them into the older formations. The village of Biviglione stands on these sediments. More to the East they can only be traced as little patches on the slopes of the valley: to the South of Cremenaga, near Avigno, etc. Luino, Voldomino and Creva are built on terraces of the same deposits. They are also found in the valley of the Torrente San Giovanni, to the South of Germignaga. This river has not yet succeeded in cutting through them into the underlying dolomites and schists.

The fluvio-glacial shingle terraces of Porto Valtravaglia along the shores of the Lago Maggiore were deposited during the same stage. They are perfectly horizontally bedded, and consist of fine-grained sandy material with pebbles that are not derived from the neighbouring slopes, which points to their contents having been transported from the North along the shores. These terraces are found up to the level of 350 M. along the slopes of the Mte. Pian Nave and cover an area of some 6 square KM. PENCK (Bd. III, pag. 814) writes on this subject:

"Bemerkenswert ist, dass die Schotter von Porto Valtravaglia bis zum Seespiegel herab horizontal geschichtet sind; zur Zeit ihrer Entstehung kann daher der Langensee nicht bis zu seiner heutigen höhe gespannt gewesen sein, während uns die Ablagerungen am Comosee gleichzeitig ein höheres See-niveau überliefern."

After the deposition of these sediments the ice must have returned once more to the South; they are covered everywhere by a thin layer of ground-moraine. In the Tresa-valley as well as in the valley of the Torrente San Giovanni the terraces are found to have been strongly folded by the pressure of the ice and are covered by the moraine. Especially in the bed of the Torrente San Giovanni this phenomenon can be observed very distinctly [1]). This last glaciation must have lasted only for a comparatively short time and did not reach the extent of its predecessors. This conclusion is to be arrived at from the fact that the glacier, of which the erosive power is sufficiently intensive to overdeepen valleys in the hardest rocks, would have removed these terraces consisting only of fine layers of loose sand.

Thus it appears that the fluvio-glacial sediments mentioned are interstadial deposits, a conclusion corroborated by PENCK's observations in the Torrente Caldé near Porto Valtravaglia (Bd. III, pag. 813).

When the ice had made its final retreat the water once more inundated the valleys, this time however, not reaching its former level, as there are no deposits to be found upon the morainic cover, except for a thin layer of fluvio-glacial outwash from the mountain slopes in the vicinity [2]).

[1]) The folding of the sediments by glacial pressure has only occurred there, where the ice was compelled to flow upwards. In the Tresa-valley the stowing effect of the ice upon these deposits can be observed there, where the trough slopes upwards, before reaching the highest point of the watershed. The same can be observed in the bed of the Torrente San Giovanni, which slopes down towards the North, while the ice entered the valley from that direction.

[2]) It is sometimes difficult to discriminate this thin layer of outwash from the underlying groundmoraine, as the latter passes imperceptibly into the former. Both layers are equally rich in boulders; the outwash layer does not show any sign of

During the previous stages of inundation as well as during the postglacial one it is highly probable that all the lakes were drained towards the South. The amount of water that came into the basins may not have exceeded the present amount [1]), the higher level being merely the result of the series of terminal moraines acting as a weir, over the lowest ridges of which the water flowed away and into which it cut its bed.

The further developments seem to have depended almost entirely upon the stage of erosion, reached by each of the drainers of the lakes, on the moment that the retreat of the ice towards the North had gone so far that the Tresa-valley was freed of its ice, thus establishing the connection between the Lago di Lugano and the Lago Maggiore.

The outlet which had been quickest in the vertical erosion of its bed, in the present case the Ticino river, must necessarily attract to itself the drainage of both lakes. The result was that the channels that formerly emptied the Lugano lake towards the South, were now left, this lake now becoming no more than a tributary to the Lago Maggiore, its water draining through the valley of the Tresa into the latter.

Meanwhile, as a result of the Ticino in the South cutting deeper and deeper into its bed, and the level of both lakes being reduced more and more, that of the Tresa reached the prae-glacial watershed, lowered and remodeled by glacial erosion. It was then, that this river began to cut into this highest part of the glacial trough. Judging from the almost perpendicular slopes in this part of the valley, especially where the riverbed has been cut into the micaschists, it is obvious that the eroding force has done its work very quickly.

Remarkable in this part of the valley is the rather sinuous course of the river, which, before entering this gorge, and after leaving it, runs on comparatively straight. At first thought it might appear that we have to do with an antecedent river, the original meanders of which were entrenched during the forming of the gorge. This however, is not the case. Whatever may have been the former course of the Tresa, the present one is entirely due to the tectonic features, which, in these parts, are rather intricate.

Before entering the gorge the Tresa flows in the soft red clays of the basal sandstone-tuff formation. It is then forced to turn towards the South by a barrier consisting of a much harder rock, namely felsophyre; thereupon the river turns to the West, running in the fault, which separates the micaschists on the left from the softer Permian rocks

stratification, only that the flat boulders are invariably found lying on their flat sides in the upper layers, whereas in the groundmoraine they are found in every possible position. A further difference exists in the fact that the cement of the upper layers is not as compact as that of the groundmoraine, the latter containing much clay which renders it a yellow colour. In the upper layers the clay has been washed away during the transport, with the result that here the matrix is white.

[1]) According to PENCK and other authors the large extension of the ice during the ice age was not due to an increase in the atmospheric downfall, but to the fact that owing to a lower average temperature a greater percentage of this downfall remained fixed in the form of snow and ice.

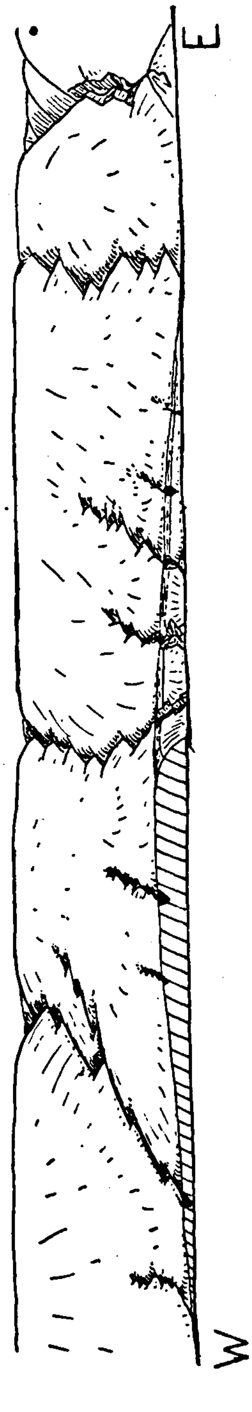


Fig. 9.
Schematic section along the Tresa-valley, showing the glacial threshold and the postglacial erosion of its Eastern half.

on the right bank. Near the bridge of the line Luino-Ponte Tresa the river follows another fault to the North, shortly afterwards to turn once more to the West, flowing within the soft red clays on the left, while the harder micaschists crop out on the right bank. One km. further towards the West the gorge is once again more strongly pronounced, the river having re-entered the hard micaschists. At Creva the large group of cotton factories is build upon a thick deposit of interstadial terraces. Here the bottom of the glacial trough definitely disappears beneath them and the Tresa flows forth in the open valley, joining the Margorabbia near Germignaga.

It seems peculiar that the Tresa enters its gorge at the point where the watershed is highest; one would expect the incision to begin more to the East and the height of its slopes gradually to increase towards the West, to reach a maximum at the spot where the river actually enters it at present.

As a matter of fact this may really have been the case in the beginning, for the surface of the watershed can be traced quite distinctly along the Northern slope of the valley, with a decline towards the East, till somewhat to the East of Ponte Cremenaga (fig. 9).

The reason why one half of this prae-glacial shed has almost completely disappeared lies in the fact that this part of it consists of the already mentioned Permian clays (see the geological map), this soft formation falling an easy prey to the erosion. The slopes and the meadows at the bottom of the valley consist wholly of these red clays and no moraine is found on top of them. This fact gives evidence that the incision of the Tresa in its former watershed occurred in post-glacial times. If we bear in mind that this incision at the beginning only concerned the highest parts of the shed, and that the gorge was lengthened in proportion with the increasing of its depth, we may assume that the red clays were, from the beginning on, more strongly attacked and transported away. Thus it is highly probable that a steep sloped gully never actually came into existence in this part.

Before finishing this chapter some more local details concerning more especially the area of my investigations may be mentioned.

Standing on the summit of the Mte. San Martino, from where the best view over these regions can be obtained, the landscape presents itself to the observer as a group of large "roches moutonnées", separated from each other by broad trough-shaped valleys. Along both sides of the Valtravaglia a trough-shoulder can be traced some 280 M. above the bottom of the valley. The ancient valley can be seen distinctly as a flat terrace extending along both sides of the trough. On the left side its breadth varies from 600 to 750 m. On the right side it is somewhat less pronounced. Its incline towards the North-West shows that the course of the prae-glacial river was the same as that of the present one. The glacier has traced many furrows into the rock, the surface showing many elliptical hills, some of which attain a height of some 20 m., the hollows in between being filled by minute lakes, which, for the greatest part, contain boggy material.

On the right hand side of the Valtravaglia a narrow and shallow trough runs parallel with the main valley. This is the branch (3) of the Valtravaglia glacier, that diverged near Voldomino, to converge again with it near Bosco and Grantola. The village of Montegrino is situated on the highest part of this valley, which is, at the same time, the post-glacial watershed, from which the Vale Maina flows down to the North-West, the Vale Fiorina to the South. Along the road which has been built in this shallow trough, connecting Voldomino, Montegrino, Bosco and Grantola, occasionally fine glacial striae show through the thin layer of groundmoraine, where the latter has been washed down recently. Where the schists have been exposed during a longer time the ice-scratched surface disappears quickly.

The average amount of overdeepening of the Valtravaglia may be estimated at some 330 m.[1]).

The Monti di Castelvecchio are a group of "roches moutonnées"; their North slope forms an uninterrupted chain of hills, that is the Southern border of the Lisascora-valley. The more or less elliptical hills with an East-Westerly direction vary in height from 20 to 70 m. The hollows in between are filled with peat-moss.

The prae-glacial valleys in the Eastern parts of our regions have not been overdeepened to the extent of the Valtravaglia. Along the Southern border of the valley of Cugliate-Marchirolo a glacial shoulder can be traced with a rather steep decline towards the East.

During the inundation stage the level of the Lugano-lake did not reach the lower part of the hanging valley of Marchirolo. The rivers, coming down from the slopes of the Mte. la Nave, brought a delta of outwash

[1]) As the valley is partly filled with alluvial drift a maximum thickness of some 50 m. must be allowed for these sediments, before the actual bottom is reached. This number, added to the above mentioned number of 280 m., gives a total of 330 m.

into the lake. Just as in the case of the Grantorella, these deposits were also laid down in a hollow behind a glacial threshold (mentioned on pag. 140). Between Marchirolo and Viconago the Dovrana river has cut deep into its former sediments. Before this river reaches the glacial threshold it flows with a winding course over a distance of some 150 m. in a broader gorge with steep sides and a flat bottom. It seems that here the water was for a short time stagnant, while it flowed over the ridge of the threshold, before cutting into the same.

With the lowering of the base level of erosion the rivers of these Eastern parts have cut deep gorges into the underlying crystalline schists. The intensive manner, in which the slopes have been attacked by the erosion shows that the lake must have lowered its level rather quickly. The bottom of the hanging trough-valley of Marchirolo, so far as it extended along the South-Eastern slopes of the Mte. la Nave and the Mte. Mezzano, has almost wholly disappeared, except for a narrow ridge along these slopes, which is much interrupted by the post-glacial gullies. The villages of Marchirolo, Arbizzo, Viconago and Cadegliano are situated on this ridge. On the South slope of the Mte. la Nave an example of stream pyracy can be observed. The upper part of the Rio Piana, a tributary of the Grantorella, once made part of the Lisascora, which, in recent times, has been beheaded by the Piana.

A few remarks concerning the contents of the groundmoraine must be added to this description of the glacial geology. It consists of a yellow, clayey sand, in which the erratic boulders are irregularly embedded. These boulders vary in dimensions from a few cm, to some 70 cm.

Still larger boulders of about two m. and more in diameter, are found upon the groundmoraine, not in it. They were transported on the ice surface, and left behind after the retreat of the glaciers. The bulk of the boulders are rocks derived from the Penninian Alps, for instance: shales from the Val Tremola near Airolo. Another constituent of the groundmoraine is Amphibolite from the zone of Ivrea-Bellinzona.

Glacial striae are only found on dolomite-boulders; on the other rocks they have disappeared.

Because of this loose cover of groundmoraine on the harder rocks, landslides are common occurrences in these regions, especially during the rainy season. During the spring rains in 1926, which in that year were exceptionally heavy [1]), many landslides were the result of the groundmoraine cover becoming imbibed with water and sliding down over the surface of the harder and less impregnable rocks, sometimes involving large stretches of road in the downsliding movement.

[1]) The Lago di Lugano inundated the lower streets of Ponte Tresa and entered into the houses, a fact, which, according to the inhabitants, had not occurred since 1901.

CHAPTER III.

PETROGRAPHY.

I. THE FUNDAMENTAL SCHISTS.

Introductory remarks.

By far the greatest part of the regions investigated is occupied by rocks of unknown age, consisting of arenaceous and argillaceous sediments, which underwent dynamic metamorphism during the hercynian epoch of orogenesis, or perhaps in a still earlier period. This dynamic metamorphism caused the sediments to be altered into schistose rocks, which, in proportion to the amount of arenaceous and argillaceous material, bear a quarzitic or a micaceous character.

Generally speaking it can be said, that in the Eastern part of our regions quarzitic rocks previal, while in the middle and in the Western parts micaschists are more abundant. They pass gradually into one another; in so far as a border can be traced between the two, its approximate trend runs in a direction NE—SW and may be supposed to connect the village of Avigno (Tresa-valley) with the summit of the Mte. Bedeloni, from there to pass on in the direction of Mesenzana. Another border runs appoximately from the village mentioned towards the West in the direction of Bedero Valtravaglia.

The shore of the Lago Maggiore closes this triangle[1]). Inside this triangle micaceous rocks prevail, rich in garnet and tourmaline; outside of it the rocks bear a more quarzitic character, although micaceous rocks are by no means rare. Tourmaline is not found here, while garnet plays a subordinate part. In these rocks many quarz veins are observed, both injected between the folded layers, and as broad veins reaching a width of 1 m. and running straight through the schists, regardless of the schistosity. In these veins tourmaline is occasionally met with in large crystals, which reach a length of several centimeters. Such veins are rare in the micaceous rocks. Injection quarz is found everywhere.

Whether the border mentioned must be regarded merely as the boundary between the micaceous and the argillaceous rocks, or whether the occurrence of the one rock beside the other must be explained by faults, cannot be ascertained. I myself am inclined to believe that the first explanation suffices, if we assume a hercynian anticline, the axis

[1]) This distinction between quarzitic and micaceous schists has already been recognised by previous authers, as can be seen on TARAMELLI's geological map of "I Tre Laghi".

of which runs in a direction NE—SW, with a dip to the North-East. In that case the triangular form of the boundary between the two rocks is accounted for by the quarzitic rocks being younger than the micaceous schists.

A fact in support of this supposition is that outside the triangle the rocks belong to a higher zone as concerns the degree of metamorphism: the Epi-zone; while the schists inside the triangle show, by the abundant presence of a hydrothermal mineral as tourmaline, and also by their texture, that they must be regarded as belonging to the Meso-zone. It must be emphasized however, that the distinction is not a very pronounced one: on the whole it can be said that the rocks concerned represent the transition types from Meso- to Epi-zone.

As a description of each of the specimina collected in the field, would lead too far, I will confine myself to describing the different types, whereafter some of the most typical rocks will be dealt with.

A. The quarzitic rocks.

General description.

The constituent minerals of these rocks are chiefly represented by quarz and biotite or muscovite, while orthoclase, plagioclase and garnet play a minor part. The texture is granoblastic, while the structure is more or less schistose.

The quarz always shows undulatory extinction, which it may have acquired as a result of the alpine folding. In some of the specimina, where a more homogeneous extinction was seen, I made an attempt to measure the positions of the quarz-individuals with regard to the direction of the pressure and of the schistosity with the aid of the Fedorov-stage, in order to see, whether the "Quarz-Gefüge-Regel" of TRENER was followed.

Five of the rocks were thus subjetced to examination.

Of four the results were not very satisfactory, the various c-axes pointing in all possible directions.

In one case only, namely in a quarzitic gneis from the neighbourhood of Viconago the positions of the c-axes proved to be more or less distinctly confined to one plane, namely the plane, which is at right angles to the plane of the schistosity and which contains the line representing the direction of the pressure.

W. SCHMIDT [1]), who subjected similar rocks from the Eastern Alps to the same examination, did not only find this plane, but was also able to ascertain, that therein two directions are favoured. In these a maximum of c-axes to the surface unit is observed, namely in the direction of the pressure and at right angles to it. These maxima were not present in the rock from Viconago.

As we have seen, these rocks do not belong to the Katazone, where the absence of unilateral pressure might explain the absence of orientation.

I am therefore inclined to believe that the alpine folding must have

[1]) 1. W. SCHMIDT. Gesteinsumformung. — Denkschr. Naturhist. Mus. Wien III.
2. W. SCHMIDT. Gefügestatistiek. Tschermacks Min. und Petr. Mitt. 38. 1925.
3. B. SANDER. Zur Petrographisch-tektonischen Analyse. II Teil, Jahrb. Geol. Bundesanst. Wien 75. 1925.

caused a mechanical deformation of these rocks, that so disturbed the original. structure, that the quarzes no longer follow the rule of TRENER.

Epi-Garnet-Albite gneis. Casa Selvacce (NW. of Ponte Cremenaga, Tresa-valley).

This rock consists chiefly of biotite, muscovite, quarz and garnet; Plagioclase and orthoclase play a minor part. Accessory constituents are magnetite and zircon. A secondary mineral is sericite.

The quarz is more confined to lenticular bands or elongated "eyes" in between the layers of mica, than that it forms continuous layers, although these are not altogether absent. In some of these lenticular bands garnet is found, showing sieve structure.

The biotite is partly bleached, and is more confined to those parts of the rock, where the shearing movement had a comparatively small effect. Muscovite and sericite, on the other hand, are observed especially round the quarz-eyes, and everywhere else, where gliding and shearing were strong. Occasionally solitary crystals of muscovite are seen to stand at almost right angles to the direction of the schistosity, as a sign of the recrystallization going on after the pressure had relaxed.

During recrystallization the ferric oxide of the original sediment has been reduced to magnetite, showing elongated forms.

The texture is lepidoblastic, the structure schistose.

B. The micaceous rocks.

General description.

The chief constituents of these rocks are: quarz, muscovite, biotite, orthoclase, plagioclase, garnet and tourmaline. Apatite, magnetite and zircon are found in varying quantities.

The garnet reaches dimensions of ½ cm. in diameter.

Tourmaline is either observed in small groups, or in solitary needles, reaching a length of ½ cm. at the most.

The texture is mostly more or less flaky (lepidoblastic), while the structure is schistose.

Secondary folding is more frequently observed in these rocks than in those mentioned before.

Meso-gneis-quarzite. Bosco.

The rock consists chiefly of quarz; further of some muscovite, orthoclase and a little plagioclase and scanty individuals of biotite and garnet.

The latter occurs in irregularly dispersed minute grains, mostly greyish-black in colour, because of a large amount of black inclusions, giving it a dusty appearance.

Accessory constituents are apatite, which is found in short, irregularly shaped prisms, a little magnetite, and zircon, showing comparatively long prismatic forms and occurring both within the biotite (pleochroic haloes) and between the quarz grains.

Secondary minerals are leucoxene, limonite and chlorite. The rock shows a typical mosaic structure. The texture is granoblastic.

Meso-biotite-alkalifelspar gneiss. Brissago.

This rock consists of the following minerals: plagioclase, orthoclase, quarz and biotite.

Accessory minerals are: apatite, zircon and epidote. The plagioclase,
Accessory minerals are: apatite, zircon and epidote.

The plagioclase, of which six individuals were measured with the U-stage, shows the common twinning law combination of Albite, Carlsbad A and Roc Tourné. The composition varies between 4 % and 8 % of An. A slight zoning is observed, the border being slightly more calcic than the centre, thus showing reversed zonal structure.

The orthoclase is highly sericitized.

Slight strain shadows are observed in the quarz.

The biotite contains much colourless epidote in grains of various sizes and irregular shapes. Round these grains pleochroic haloes are observed.

Zircon is never found within the biotite, but among the other constituents, as well as apatite.

The texture of the rock is granoblastic, tending to the lepidoblastic.

The structure is distinctly schistose.

The recrystallization went on after the relaxing of the pressure: originally bent layers of biotite now show angular forms: straight biotite individuals having recrystallized and following the bended forms of the layers as a whole in a broken line.

Meso-biotite-alkalifelspar gneis. Roggiano.

The constituents are quarz, orthoclase, plagioclase, biotite, muscovite and garnet; accessory minerals are magnetite, apatite and zircon. Secondary minerals are chlorite and calcite.

A well developed recrystallization schistosity is observed. Both the felspar and the quarz show elongated forms. Occasionally "eyes" consisting of one or more elongated individuals of orthoclase, full of oblong inclusions of quarz, muscovite and magnetite are wedged in between the bands consisting of biotite and muscovite.

Tourmaline is found in different positions, regardless of the schistosity. It varies in dimension from one to several mm.

The garnet shows irregular forms with the well known sieve-structure.

The quarz shows strain shadows and contains small inclusions arranged in rows, the trend of which is more or less parallel to the schistosity.

Meso-alkalifelspar gneis. Grantola.

As far as texture and structure are concerned this rock resembles the one just mentioned.

The mineralogical composition differs in so far, that the amount of biotite decreases and that the orthoclase and plagioclase have increased considerably. Also microcline is found among the felspar constituents.

The plagioclases are slightly altered to sericite. Their composition, obtained with the aid of the U-stage, is:

Nr.	Ind.	Twinning law	Percent. of An.
I	1—2	Albite	4 %
II	1—2	Albite	3 %
III	1—2 2—3 1—3	Albite Carlsbad A Roc Tourné	4 % 4 % 4 %

Occasionally on the border of the microline myrmekitic intergrowths of this mineral with quarz are observed.

Garnet occurs in irregularly shaped grains and contains no inclusions.

Strain shadows are well developed. The schistosity is not distinct. The texture is granoblastic.

Meso-garnet-albite gneis.

The constituent minerals are: quarz, orthoclase, plagioclase, muscovite, brown biotite, garnet and tourmaline.

Accessory minerals are: magnetite, apatite and zircon.

In this rock asymmetric folding is very distinct. Broad layers of mosaic quarz, which shows feeble strain shadows, containing a few narrow, feebly undulating layers of muscovite, which render the structure schistose, alternate with equally broad streaks of mica, which show an intensive folding. They contain much garnet and a dusty sericitic felspar, probably orthoclase. In the cores of the microscopic folds the orientation of the mica individuals is quite arbitrary. It is here that most garnet crystals are found. Their occurrence is chiefly confined to such places, in the mica zones, but they also occur sparsely within the quarz zones.

The biotite has been chloritized.

Apatite and magnetite occur chiefly in the micaceous bands; zircon is found both in the mica- and in the quarz-layers.

Tourmaline is observed between the muscovite as well as between the quarz individuals.

The texture of the rock is lepidoblastic, the structure schistose.

Meso-garnet-muscovite gneis. Neighbourhood of Montegrino. (Plate 31, fig. A and B).

This rock consists almost wholly of large crystals of garnet, enveloped in thick layers of muscovite.

The garnet contains elongated inclusions of limonite, the general trend of which shows that this mineral was turned somewhat during its crystallization. In the "eyes", wherein the garnet is enveloped, the mica is slightly stained by limonite.

The layers of muscovite are folded and contain much tourmaline, while magnetite is found in between the muscovite individuals, showing elongated forms. Where the muscovite recrystallized, crystals were formed more or less at right angles to the schistosity. Magnetite individuals enclosed in such crystals have still retained their original position (Plate 31, fig. B).

Quarz only occurs in this rock as injection quarz, while Albite is found occasionally

The texture is lepidoblastic; the structure distinctly schistose.

II. THE SANDSTONE-TUFF SERIES.

A. The San Martino sandstones and conglomerates.

1. The sediments.

As has already been mentioned in the first chapter, this formation varies from fine grained sandstones to fine conglomerates. They are brownred in colour owing to the fact that each quarzgrain is enveloped in an extremely thin epidermis of limonite. Besides quarz, mica, derived from the crystalline schists, is a component of this rock, together with very sparse fragments of felspar. Calcite is found on the many narrow cracks and slicken sides of the rock.

2. The pebbles.

The bulk of the pebbles is quarz, while small fragments of gneis and granite are found almost everywhere in great quantity. They all possess somewhat angular forms.

On page 125 I mentioned some peculiarly branch-shaped inclusions in the San Martino series. The microscope (fig. 10) reveals that they

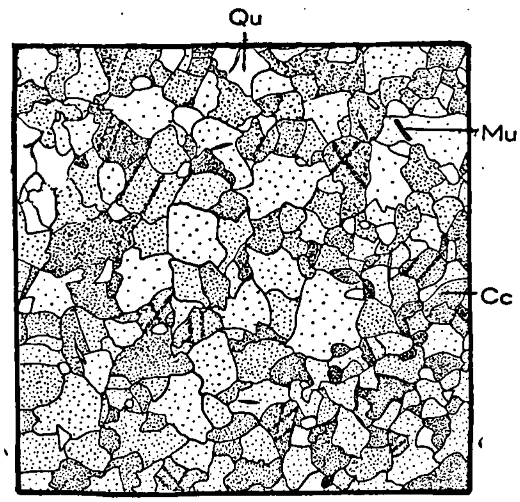


Fig. 10.

Limestone. Inclusion in the San Martino beds.
Nicols +. 20 ×.

consist almost wholly of calcite in angular crystals, interspersed with fragments of quarz and muscovite, rarely with plagioclase, derived from the schists. The calcite has a somewhat undulose extinction.

The question arises whether these inclusions are a primary or a secondary deposit. Their peculiar shape and their softness points to their having been formed *in situ,* but a fact which seems difficult to account for is that they are greyish-white, while lying within the red-brown sandstones. Although I am by no means certain about the nature of these objects, I am inclined to regard them as concretions. The circumstance that they occur in horizons does not, in my opinion, weaken this supposition, as it is a well-known fact that the same is the case with other concretions, for instance flints.

B. The red tuffs.

1. The sediments.

As I have already pointed out in the first chapter, the variety of sediments in this formation is so great, that I was compelled during my fieldwork, to confine myself by the taking of handspecimens, the purpose not being to examine each layer separately, but to draw some conclusions concerning the general petrographic character and facies of the sediments that filled up the shallow waterbasin which occupied these regions during Permian times. Nevertheless some twenty different rocks were gathered, which could be classified as belonging to three types, namely:

a. red clays containing conglomerates;
b. vitric tuffs;
c. crystal tuffs.

a. The red tuffs.

Megascopically this rock is already sufficiently described by its name. Occasionally it is light green in colour along the numerous cracks and slicken sides, especially where these are more abundant than is usually the case. HARADA (Bibl. 2, page 47) ascribes the green colour to the fact that the rock contains a chloritic substance, of which the colour becomes more prominent when the ironhydroxide (which is responsible for the red colour) is withdrawn by the water circulating along the cracks. This however cannot be the case. In the slides of this rock I could never detect the smallest particle of chlorite and there is, in my opinion, no question of iron-hydroxide being withdrawn from it. The green colour is entirely due to the more intensive hydratization of the soil by the permeating water, the ferro-hydroxide being altered into ferri-hydroxide. As the rock is not only entered into by the water along its cracks, but also contains the same in its many pores, many green spots are observed on a closer examination. I believe that this fact led HARADA to his statement of chloritic matter being finely distributed throughout the whole rock.

Microscopically the rock is seen to contain numerous angular fragments of quarz, decomposed felspar, and minute splinters of colourless mica, possibly a bleached biotite. Another constituent, which is allways present in varying quantities, is volcanic ash, remaining dark between crossed nicols. All these fragments are cemented together by limonite, while the interstices and cracks are occupied by calcite. Pseudomorphs of zeolitic matter after felspar are not rare. The limonite and calcite occupy the bulk, probably from 80 to 90 % of the rock.

The variations in the contents exist in the circumstance that the amount of crystal fragments decreases towards the South-West. The red clays between San Michele and Musadino for instance are almost devoid of these constituents. Near Creva, along the footpath leading from the cotton-factories to the road Voldomino-Montegrino, the red clays contain numerous zeolitised plagioclase crystals, which give the rock a somewhat porphyritic aspect because of their white colour.

b. The vitric tuffs.

Of these there are numerous types from which I have chosen three of the most typical.

1. Vitric tuff from the Chiesone river (Mesenzana) (fig. 11).

The rock crops out in the bed of the river as a layer of some 4 dm. thickness. Megascopically it resembles the red clays very much, except

Fig. 11.

Vitric tuff showing inclusion of porphyrite (1). Round this inclusion the groundmass is almost free of limonite.
Ordinary light. 20 ×.

that some crystals and crystalfragments are visible. Under the microscope the rock is seen to contain a large amount of volcanic ashes, cemented together by limonite and very little carbonaceous matter. A few plagioclase crystals in a good state of preservation are present together with a few inclusions of a porphyrite with less fresh, tabular felspars as phenocrysts. The measurement of one of the plagioclases gave as result 30 % An. (Twinning law: Albite).

Under crossed nicols the slide remains dark, except for very narrow zones immediately round the ash particles. They consist of a light green chlorite and are the result of the beginning of the chloritization of the ashes. Where the latter are ringshaped, this zone is also found on the inside of the ring.

On the many cracks in this rock calcite has been deposited.

2. Vitric tuff from the road Cugliate-Colle della Nave, near Fabiasco (fig. 12).

The rock occurs as a thin layer of 4 dm. thickness at a point where the road bends inwards for the first time to cross a small river. It is

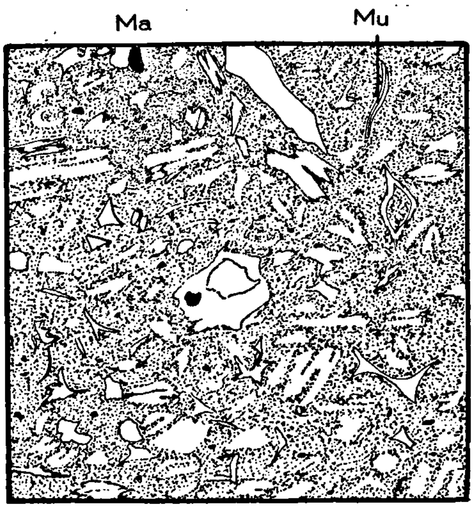


Fig. 12.

Vitric tuff.
Ordinary light. 20 ×.

brown-red in colour, while in habitude it resembles a very fine-grained sandstone. Under the microscope a dense mass of volcanic ash is observed together with minute fragments of quarz, green biotite, muscovite and felspar, cemented together by limonite. The ash-fragments are devitrified, showing a crypto-felsitic structure. The biotite is still fresh; its pleochroism is dark-green to yellow-green.

3. Vitric tuff from a small quarry on the road Bosco-Fabiasco, 250 m. to the South-West of point 551.

This rock I have been able to trace almost everywhere; it occurs furthermore in the Piana river between layers of the red clays; another outcrop can be found in the bed of the left tributary of that river, which comes down from the hill marked 580 of the Monti di Castelvecchio;

on the road from Mesenzana to the Mte. San Martino it occurs some 100 m. past the outcrop of Enstatite-basaltite; on the footpath from Creva to the road Voldomino-Montegrino it is found as a conspicuous white bank in between the layers of the red clays.

It is a remarkable fact that this rock is quite free from any limonite and carbonaceous matter, and further that its thickness is every where found to be practically the same, namely ± 1,5 m.

Megascopically the rock gives the impression of being a white, very fine-grained sandstone with larger crystals and crystal-fragments of felspar.

Under the microscope rare phenocrysts of quarz and plagioclase are found within a colourless groundmass.

The quarz shows signs of corrosion; the plagioclase is fairly well preserved. Two measurements with the U-stage of plagioclases from different outcrops gave the following results:

Ind.	Lamellae	Twinn. Law.	Perc. of An.
I	1—2	Carlsbad A	27 %
II	1—2	Albite	30 %

The groundmass shows under crossed nicols a microfelsitic structure. If in ordinary light the diaphragma is closed as far as possible and the tube of the microscope is lifted or lowered a little, the true nature of the rock is revealed more distinctly [1]). It is then observed to consist of numerous very minute ash-fragments.

The outcrop near Mesenzana consists of a coarser ash-material showing a feeble double refraction, while the cement shows a microfelsitic structure; this circumstance renders the identification of the rock as a vitric tuff more easy, the ashes showing off against the cement as more or less dark patches under crossed nicols.

These petrographic particulars, combined with the persistency of this rock over a large area; its constant thickness; the fact that it is free from limonitic cement; render it highly probable that the ash-material came to subsidence after aerial transport. Had such not been the case, one would expect to find the ashes mixed with mineral fragments and detritus in the form of limonite, as is the case with the other vitric tuffs of which I have mentioned two examples. Judging from the

[1]) I wish to recommend this method, which, in doubtfull cases, like the one mentioned here, is very efficient and may be decisive. The ashes as well as the cement of SiO_2 are colourless; during the devitrification no iron matter has been secreted, rendering the border of the ashes distinct. The only difference between the ashes and their cement exists in the refraction-index of the ashes being slightly greater than that of the SiO_2. This slight difference is not so easily to be observed in intensive light. It is therefore necessary to observe in subdued light, while the lifting and the lowering of the tube serves to make an artificial border round the ash-material with the line of BECKE.

fact that the ashes have not been altered and from the low amount of Anorthite in the plagioclase, we may conclude that the eruption that produced the material of this tuff, was an acid one: probably it was a quarzporphyry that came to the surface. Peculiar is the total absence of biotite and orthoclase in these tuffs.

Concerning the whereabouts of the eruption there is no evidence. The circumstance that, judging from the contents of the layer below and on top of this one, ash material was brought down into the basin, points to the fact that this eruption, too, occurred somewhere in the North, but the presence of loose crystals between the ashes gives evidence that the whereabouts of the eruption must not be sought too far away.

c. *The crystal tuffs* (fig. 13).

Crystal tuff from casa Castello, some 600 m. to the North of Cugliate, at the level of 625 m.

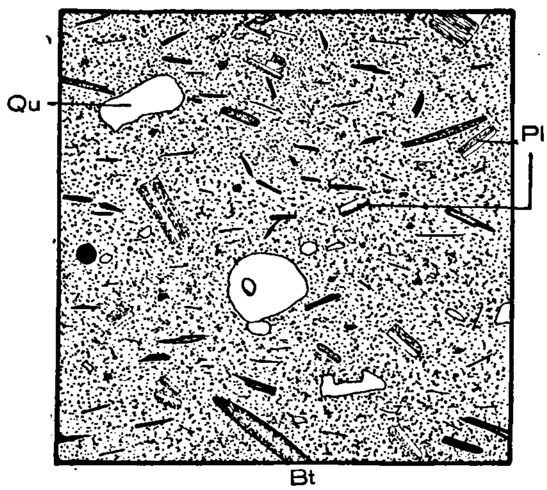


Fig. 13.

Crystal tuff. Layer in the red tuffs to the North of Cugliate. Ordinary light. 20 ×.

This rock being the only outcrop on that part of the slope of the Mte. la Nave, its accurate position between the other layers could not be ascertained.

Megascopically it is a grey rock in which, with the aid of a pocket lens, very few small quarz fragments can be detected; it is fairly hard but, when wheatered, crumbles easily.

The microscope reveals a large amount of crystals and crystal fragments. Phenocrysts of quarz showing corroded forms are scarce. Laths of plagioclase and biotite abound, both decomposed to a high degree. Of the biotite nothing remains but accumulations of ore, in the shape of the biotite, sometimes still containing colourless remnants of this mineral; the plagioclase is scarcely visible when observed with ordinary light, its colour being only a shade darker brown than that of the "groundmass". Between crossed nicols the laths show off very distinctly against the latter, as a result of their having been altered to a mass of a colourless mica, the orientation of which is such that the original twin-lamellae have been preserved. The brown colour of the groundmass is due to limonite. Pyrite and pseudomorphs of limonite after that mineral are abundant.

Crystal tuff from point 569, North of Cugliate.

This rock occupies a position immediately beneath the lithic tuff series and megascopically resembles that of casa Castello in its structure. The chief difference consists in the fact that less quarz is present and that the biotite has become chloritized. Plagioclase is less abundant and altered into zeolites. The "groundmass" consists of a palebrown mass of limonite and chlorite.

Hornstone from Grantola.

As I have already mentioned in the first chapter, the San Martino-beds are lacking near Grantola. At the station of that village the red clays with their conglomerates can be observed to repose almost immediately upon the fundamental schists. At this outcrop, immediately beneath the schists, a layer can be found of ± 1 dm. thickness. It consists of a flinty rock of a dark colour and full of cracks filled with calcite. Microscopically its structure reminds of the wellknown Jurassic radiolarite hornstone of the Northern Alps.

The rock consists of originally amorphous SiO_2, which has crystallized to chalcedony. The structure is microfelsitic. Irregularly dispersed in the rock are very minute black globules, most probably limonite; round these globules the otherwise colourless rock is pale-brown; where the globules abound the whole rock has assumed this colour. It seems too, that the crystallization was, somehow, influenced by the presence of the globules, as the microfelsite shows a coarser structure where the rock contains more limonite. Broad cracks run through it containing angular fragments of the rock, recemented by calcite that is impure with limonite.

It seems to me that the nature of this rock implies that it cannot be an original deposit. As the overlying red clays are the detritus of a lateritic cover somewhere to the North, this means that they were already freed from their original content of SiO_2. Thus it seems that a renewed hydrolysis took place of Na-, K-, and Ca-alumo-silicates that occurred in these red clays in the form of orthoclase, plagioclase and ash-material, transported hither together with the lateritic matter. The result of this hydrolysis must have been that the hydroxides of Na, K and Ca, probably turned into carbonates, were partly washed away, with the exception of the calcite that settled in the many cracks and also formed pseudomorphs after many minerals as orthoclase, plagioclase, volcanic ashes. The solid colloids of alumic- and ferric hydroxide remained and the SiO_2 in sol-form was deposited deeper down on the fundamental schists and secreted as chalcedony.

The spot mentioned is the only one where I found this hornstone, and it must be remembered that it is at the same time the only spot where the red clays repose almost immediately upon the schists. Although it is improbable that the hydrolysis should only occur at one spot and not at any other, no such layer was found elsewhere. This may be due to the circumstance that the red clays repose everywhere else on the San Martino beds, which, because of their consisting of impregnable sandstones and conglomerates, did not allow the formation of a layer of chalcedony. The SiO_2-sol filtered through into the pores of this formation and was secreted as chalcedony in these pores, thus forming a cement between the quarz-fragments.

Although I believe this conception to be the most probable, I will leave open the possibility that the presence elsewhere of such a layer of hornstone escaped my notice, the exposures not always being sufficiently favourable, to prove its absence with sufficient certainty.

2. The pebbles.

Introductory remarks.

The pebbles in the red clays occur in local patches, not more than one pebble thick, irregularly dispersed in this formation. The size of the pebbles is larger in the Northern parts than in the Southern. We find quarz-porphyry-tuffs and porphyrites and their tuffs. The former are to be found in the lower strata, the latter are restricted to higher horizons. Both kinds of rock occur together in the intervening strata.

HARADA (Bibl. 2 page 46) mentions that he found fragments of the red porphyry (granophyre) in the lowermost layers of the tuff-system and concludes therefrom that the red tuffs must originate from that rock. With our present knowledge of these regions, a knowledge which HARADA could not then possess, it is certain that this cannot be the case. In the first place the granophyre is younger than the tuffs, and then we have ample evidence that all the tuff material was deposited by rivers coming from the North or from the North-West. I believe HARADA's granophyre-fragments to be in reality the many somewhat decomposed inclusions of a red granite in the San Martino beds.

The pebbles in the red tuffs can be divided in:

a. Quarzporphyry pebbles (occurring in the lower strata).
b. Porphyritic pebbles (found in the higher horizons).

a. The quarz-porphyry pebbles.

These rocks contain, without exception, volcanic ashes. They can be devided into:

1. Vitric tuffs, consisting chiefly of ashes, wherein crystals only play a subordinate part.
2. Crystal tuffs, the bulk of which consists of crystals, while occasionally ashes occupy the room in between.
3. Lithic tuffs.

The vitric tuffs.

Vitric tuff from pebbles in the red tuffs in the Tresa-valley (fig. 14).

Megascopically this rock is not recognisable as such. It is flinty; in a dense red groundmass phenocrysts are found of large round clear quarz-crystals, measuring about 3 mm. Further phenocrysts are orthoclase and biotite.

Under the microscope the true nature of the rock is revealed (Plate 32*a*). The photograph needs no further explanation concerning the structure of the rock. I will therefore pass on to further particulars. The ashes are wholly devitrified and partly (especially the larger individuals) decomposed. During the devitrifying process limonite was secreted, which now fills the interstices in between, and is the reason that the ash particles show off distinctly against a dark background; it is at the same time the constituent that gives the rock its red colour.

The devitrifying process is such that the borders of the ashes show a pseudospherulitic texture, the many fibres standing at right angles to the border of the ash-particles. This part of the ashes contains limonite; the inner part is quite free from this mineral and usually shows, between crossed nicols, a mosaic of quarz, such as is found in micaschists. In larger individuals chlorite is found instead of quarz. The border has a weaker refraction index than the quarz and the chlorite and probably consists of felspar matter.

The quarz occurs in large clear crystals and has been corroded.

The orthoclase can scarcely be distinguished from the quarz because of its extreme clearness and of its entire lack of cleavageplanes. Many of the orthoclases show Carlsbad twins.

Plagioclase is present in fragments and is wholly decomposed. It has been altered partly into a mineral with a low double refraction; its

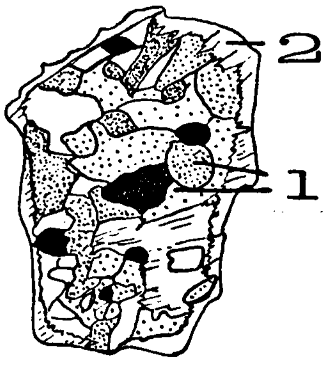


Fig. 14.

Pseudomorph of quarz and zeolites after plagioclase.
1: quarz; 2: zeolites. Nicols +. 40 ×.

refraction is lower than that of the mosaic of quarz occupying the remainder of the crystal (fig. 14). Most probably it is a zeolite.

Biotite is found in long cleavage fragments and in a good state of preservation; its pleochroism is from dark green to brown green.

The rock represented on Plate 32a does not differ very much from the one here described, except for the plagioclase being only partly decomposed. A measurement with the U-stage gave the following result:

Ind.	Lamellae	Twinning law	Percent. of An.
I	1—2	Albite	30 %

It is remarkable that the last mentioned rock shows patches which are quite free from limonite, the result being that the ashes are scarcely visible and have to be made distinct by using the method described in the note on page 159.

Vitric tuff from pebbles in the red clays in the Tresa-valley (fig. 15).

Megascopically this rock resembles the former, with the difference that the phenocrysts are scarcely visible.

Under the microscope fragments of quarz, orthoclase and plagioclase

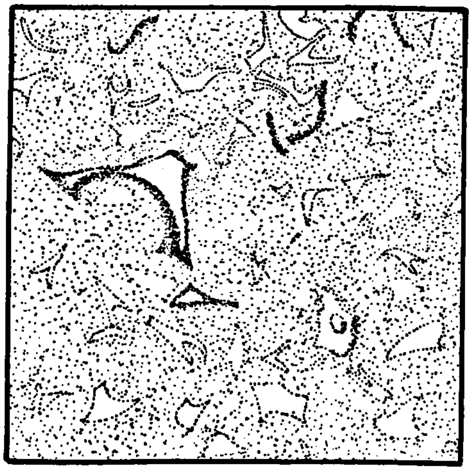


Fig. 15.

Vitric tuff. Pebble in the red tuffs.
Ordinary light. 20 X.

are found within a groundmass consisting of ashes. Between crossed nicols the ash-structure disappears almost completely, the whole showing a microfelsitic texture. The visibility of the ashes in ordinary light is due, as in the former case, to a border of limonite. Occasionally ash fragments of larger size show off against the background of finer ash because of their being bordered by a broader strip of limonite, consisting of innumerable globules of that mineral.

The plagioclase has been decomposed in the manner described for the former case.

Vitric tuff pebbles in the red clays near Voldomino (fig. 16).

This rock is of a grey colour and shows phenocrysts of quarz, orthoclase and plagioclase in a groundmass of which the ash-structure is fairly

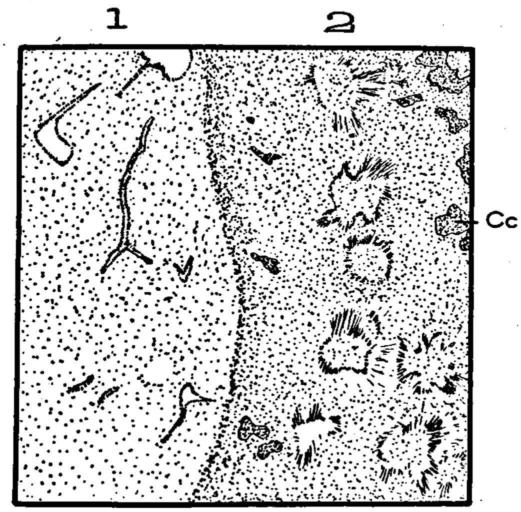


Fig. 16.

Vitric tuff (1) showing inclusion of devitrified felsophyre (2) with pseudospherulites. Ordinary light. 20 ×.

distinct under the microscope in ordinary light. The ashes are devitrified and show a pseudospherulitic structure (fig. 16*a*), the interstices occupied

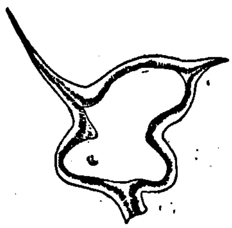


Fig. 16*a*.

Enlargement of ash-fragment. 60 ×.

Fig. 16*b*.

Corroded quarz crystal with part of the devitrified base still adhering. Inclusion in vitric tuff. Nicols crossed. 20 ×

by microfelsite. The phenocrysts have obviously been derived from a felsophyre, of which rock small fragments still adhere to them, and which also occur as inclusions. Their texture occasionally tends to the granophyric, especially round the phenocrysts of quarz and orthoclase.

Vitric tuff from pebbles in the red clays at the station of Grantola.

The last description also applies to this rock, with the only difference that the ashes scarcely show off. Between crossed nicols they are more distinct because of their pseudospherulitic devitrification.

The quarz is highly corroded while the original glass substance in its sinuous inlets shows a spherulitic texture (fig. 16*b*).

The plagioclase is almost wholly decomposed, the original twin-lamellae occasionally preserved in a mass of calcite and zeolites. The orthoclase is still fresh and sometimes shows Carlsbad twinning.

Vitric tuff from pebbles in the red clays near Bosco (fig. 17).

Megascopically this rock is greyish-white with phenocrysts of clear quarz and of decomposed plagioclase. Under the microscope one is scarcely

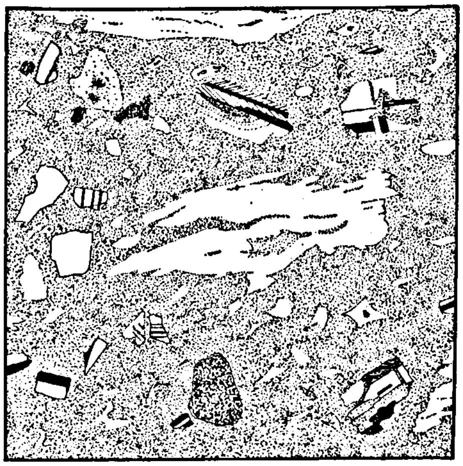


Fig. 17.
Vitric tuff. Pebble in the red tuffs. Inclusions of lava-fragments.
Ordinary light. 20 ×.

able to see the highly corroded quarz crystals show off against the colourless groundmass. This lack of ferric matter is also the cause of the invisibility of the bits of ash.

Both the ashes and their cement show a very feeble double refraction, the former with pseudospherulites, the latter of a cryptofelsitic texture. Small inclusions of lava fragments with a spherulitic devitrification are present. Pseudomorphs of calcite and chlorite after plagioclase are fairly abundant, while fresh orthoclase is observed in minor quantities.

Pumice tuff. Pebble in the red clays in the Grantorella river, Grantola. (fig. 18).

The difference in the ash structure between this rock and that of the other vitric tuffs is at once obvious. This well stratified tuff consists chiefly of larger and smaller fragments of pumice showing fluxion structure with many gass pores drawn out in the direction of the flow. In between other fragments of the more common type are found.

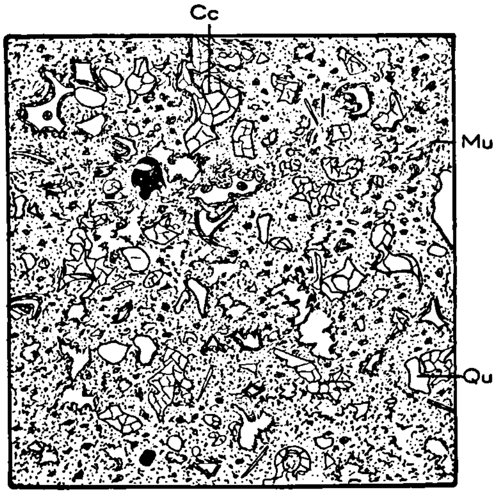


Fig. 18.
Pumice tuff. Pebble in the red tuffs to the North of Cugliate.
Ordinary light. 20 ×.

While the latter must be regarded as fragments of a finely dispersed lava-froth, the ashes here described must be considered to be shattered pumice. In this case the lava had already solidified at the surface, to be blown up by an explosion of gasses that occurred afterwards.

Quarz occurs in idiomorphic corroded crystals.

Plagioclase is wholly decomposed and calcite takes its place.

The whole rock has been intensely carbonatised. Calcite forms pseudomorphs after the ash fragments. Only the original cement in between these fragments has remained and is observed as a cryptocrystalline mass with a weak double refraction. Small inclusions of a vitrophyric lava with a pseudospherulitic devitrification are occasionally present.

The crystal tuffs.

Crystal tuff. Pebble in the red clays near Voldomino (fig. 19).

Pebbles of this rock occur in great quantity in alle the conglomerates of the lower strata of the red clays. They are recognised by their extreme richness in quarz- and felspar crystals lying within a dark red, aphanitic lustrous base.

Under the microscope it appears that quarz, plagioclase and orthoclase occupy more than 50 % of the rock. The quarz is idiomorphic and corroded and shows the original pseudospherulitic groundmass in its corrosion-inlets. Usually it contains no inclusions.

Orthoclase occurs as idiomorphic crystals and in fragments and frequently shows twins after the law of Carlsbad, more seldom after that of Baveno. In ordinary light the orthoclase is scarcely to be distinguished from the quarz, because of its clearness and its lack of cleavage planes. Under crossed nicols and with sufficient enlargement it is seen to consist of a set of extremely fine lamellae. On the Fedorow-stage such crystals are seen to possess two planes of optical symmetry, in which an optic axis seems to appear. This phenomenon has also been observed by KUENEN in the orthoclase of the granophyre of the Southern volcanic regions (Bibl. 28, pag. 175—176) and was explained by Prof. REINHARD as due to the fact that the orthoclase is a cryptoperthite. For the explanation of the pseudo-optic axes I therefore refer to the publication of KUENEN.

Plagioclase is found in minor quantities. Two measurements with the U-stage gave the following results:

Ind.	Lamellae	Twinn. Law.	Perc. of An.
I	1—2	Carlsbad A	15 %
II	1—2	Albite	15 %

Biotite occurs in fragments and is somewhat scarce. It has almost entirely been replaced by limonite.

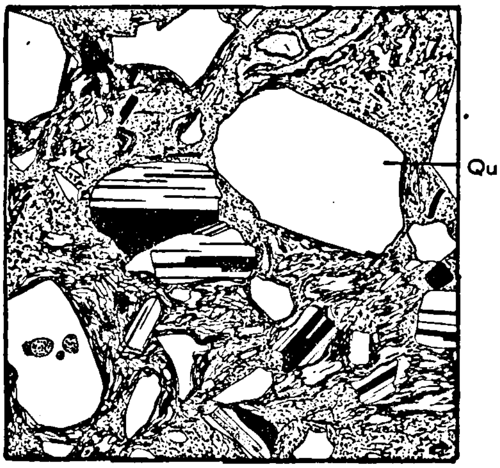


Fig. 19.

Crystal tuff. Pebble in the red tuffs.

Occasionally small inclusions occur of an originally vitrophyric lava, which by devitrification has crystallized to a mass of spherulites. Such globules are sometimes arranged in long rows, following the trend of the fluxion structure of the rock.

The groundmass consists of ash-material, similar to that of the rock described as a pumice-tuff (page 166). The arrangement of these fragments in between the crystals is such, that it sometimes resembles a fluxion structure. The ashes are devitrified but the structure is rendered almost invisible because of the abundance of limonite which renders the groundmass a dark brown.

Crystal tuff. Pebble from the red clays in the Grantorella river. Grantola (fig. 20).

The rock has a gray colour and shows a large amount of quarz and biotite. Under the microscope the following minerals are found.

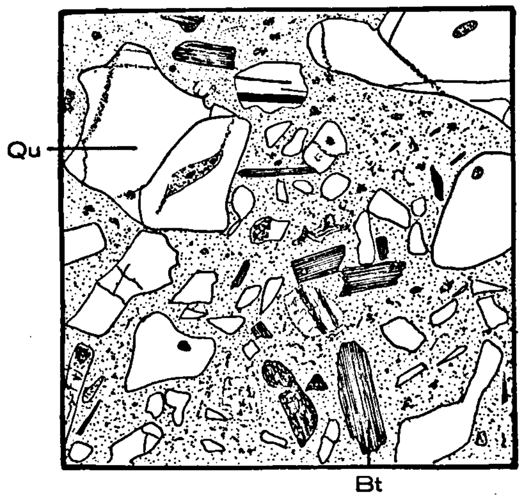


Fig. 20.

Quarzporphyry-tuff. Pebble in the red tuffs.

Quarz in idiomorphic corroded crystals and in fragments.

Orthoclase in minor quantities and in a good state of preservation, occasionally showing Carlsbad twins.

The plagioclase is wholly decomposed and has been replaced by zeolites and calcite.

Biotite occurs in fragments. Its pleochroism is: dark green (almost black) to light green.

Zircon occurs in large crystals, always surrounded by a dark brown zone of limonite.

The groundmass consists of ashes and lava fragments. The latter are derived from a vitrophyre, devitrified to a mass of pseudo-spherulites which occasionally pass into a micrographic intergrowth of quarz and orthoclase. In this rock phenocrysts are found of the same biotite, decomposed plagioclase and zircon.

Crystal tuff. Pebble from the red clays. Line Grantola-Cunardo. (fig. 21).

This rock resembles the former one, but contains still more quarz,

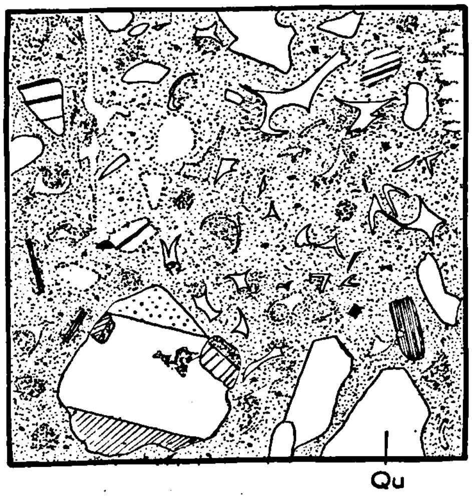


Fig. 21.

Quarzporphyry-tuff. Pebble in the red tuffs.

of which phenocrysts occur, measuring 4 mm. in diametre. It is very clear and occasionally contains inclusions of biotite.

Orthoclase is found as described in the former rock, while the plagioclase is better preserved. Two measurements with the U-stage gave as result:

Ind.	Lamellae	Twinn. Law.	Perc. of An.
I	1—2	Albite	26 %
II	1—2	Albite	± 23 %

The biotite is the same as in the former rock. It contains much zircon, round which no pleochroic haloes are found.

Many of the here mentioned minerals still have fragments of the original groundmass attached to them, while some are wholly enveloped in it. This base has developed a minute spherulitic texture.

A few small inclusions derived from the fundamental schists are present. The groundmass consists of ashes and also of small fragments of the pseudo-spherulitic base mentioned.

The Lithic tuffs.

Lithic tuff. Pebble in the red clays. Chiesone river, Mesenzana.

This rock consists of angular rock fragments measuring from one to three mm. in diameter. These fragments are cemented together by the material of a crystal tuff.

The rock fragments are vitric tuffs, consisting of devitrified ashes showing spherulitic texture under crossed nicols and cemented by a cryptocrystalline groundmass. Phenocrysts of highly corroded quarz and of orthoclase are found in between the ashes.

The crystal tuff which is observed in between the fragments contains crystals of quarz and quarz fragments, orthoclase, highly decomposed plagioclase and a fresh brown biotite and muscovite. Pyrite is found in large quantity both in the vitric tuff and in the crystal tuff-matrix.

Conclusions.

Judging from the contents of the rocks hitherto described, it is obvious that, with the exception of the crystal tuff mentioned on page 167, they are quarzporphyry-tuffs. From the fact that this tuff contains more plagioclase and also dark minerals, we may conclude that this rock is more melanocratic than the others and that we have probably to deal with a quarz porphyrite or dacite.

B. The porphyritic pebbles.

Porphyrite. Pebble from the red clays. Southern tributary of the Chiesone river near Alpe Cavoiasca (fig. 22).

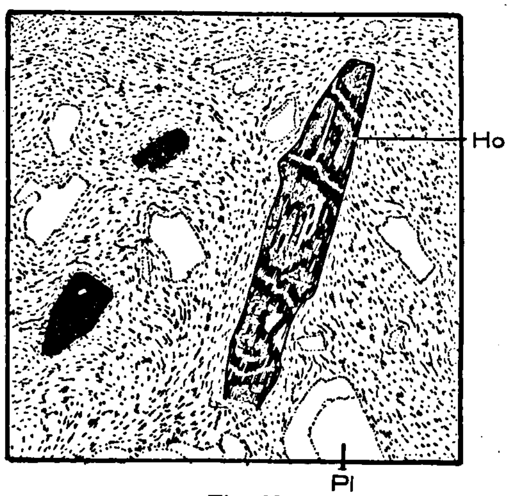


Fig. 22.
Porphyrite. Pebble in the red tuffs.
Ordinary light. 20 ×.

Megascopically the rock presents a grey mass containing some few black needle-shaped minerals, the nature of which can only be ascertained microscopically.

Under the microscope the following minerals are observed as phenocrysts.

Plagioclase, almost wholly decomposed and altered into a mass of zeolites with the polysynthetic lamellar structure occasionally still visible.

Magnetite, partly altered into limonite, forming pseudomorphs after a dark mineral, which, judging from its form, may have been an augite (fig. 22*a* and *b*). Within-, or in the neighbourhood of these pseudomorphs apatite occurs in needles, which show a good cleavage parallel to (0001) and also parallel to the prism (fig. 22*c*). This mineral shows a yellow colour and is slightly pleochroic from yellow brown to pale yellow.

Another pseudomorph of limonite after a dark mineral occurs in the shape of the needles mentioned, which reach a length of 6 mm. and more. It probably was an amphibole (fig. 22).

The groundmass is very fine grained and chiefly consists of small laths of plagioclase and limonite pseudomorphs after one of the two

Fig. 22*a* and *b*.
Pseudomorphs after augite.
Ordinary light. 40 ×.

Fig. 22*c*.
Apatite.
8 ×.

dark minerals mentioned. Apatite abounds. The whole shows a distinct fluxion structure as a result of the subparallel arrangement of the plagioclase laths.

Quarz-bearing porphyrite. Pebble from the red clays. Southern tributary of the Chiesone river near Alpe Cavoiasca (fig. 23).

The rock has a greyish white colour with little green patches; under the microscope it is observed to possess the following constituents.

Plagioclase as phenocryst varying in size from one to three mm. It is almost wholly altered into zeolites. Its border, colourless in ordinary light, shows an irregular mass of this mineral between crossed nicols.

The central part, a dirty yellow in ordinary light, appears to consist of the same mineral, discoloured by limonite, with the preservation of the original twinning lamellae. It thus seems that the plagioclase possessed zoning. A somewhat less decomposed individual was measured with the following result:

Ind.	Lamellae	Twinn. Law.	Perc. of An.	
			Ind. 1.	Ind. 2.
I	1—2	Pericline	48 %	55 %

An idiomorphic dark mineral occurs in large quantity. It is completely decomposed either to magnetite, calcite and zeolites, or to mag-

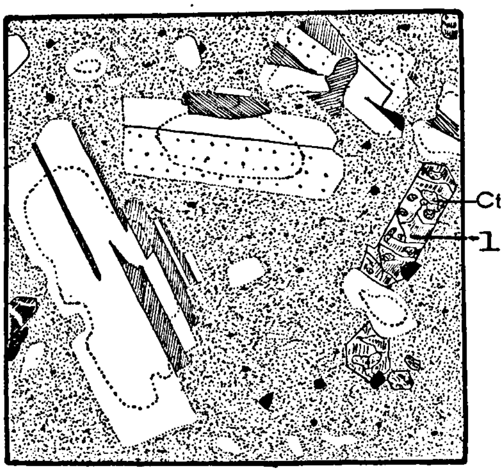


Fig. 23.

Quarzbearing porphyrite. Pseudomorphs of calcite and villarsite after augite. 1: villarsite. Pebble in the red tuffs. Ordinary light. Nicols + for the plagioclases. 20 ×.

netite and a mass of subparallel fibres of a green mineral resembling serpentine, with the difference that it is strongly pleochroic from dark blue-green in the direction of the strongest absorption to pale green at right angles to it.

Its double refraction is high, while the refraction index is stronger than that of plagioclase. The optical character is negative, the extinction angle is probably very nearly 90°. Presumably this mineral is villarsite, a variety of serpentine. The fibres have grown out from the cleavage cracks of the original mineral, which presumably was an augite.

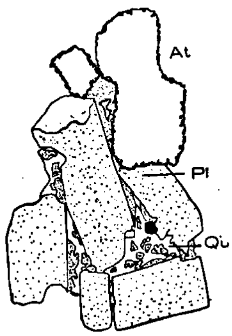


Fig. 24.

Inclusion in quarzbearing porphyrite showing graphic intergrowth of quarz and plagioclase and decomposed pyroxene. Ordinary light. 20 ×.

This mineral usually occurs together with magnetite and encloses much apatite.

A brown, partly decomposed biotite is rarely observed.

The groundmass consists of plagioclase and the same augite, altered like the phenocrysts. The interstices are occupied by quarz which shows simultaneous extinction over more or less large patches and sometimes suggests a graphic intergrowth with the plagioclase.

I found in this rock some "enclaves homoeogènes", consisting of the same plagioclase and augite, a little biotite, apatite and magnetite, while quarz forms a graphic intergrowth with the plagioclase in more or less narrow zones round the latter (fig. 24). It seems that this rock represents the hypabyssal facies of the same porphyrite. It is remarkable that here the plagioclase lacks the above mentioned border. We may conclude therefrom that the plagioclase phenocrysts and the augites were derived from the hypabyssal rock and that, during the effusive stage, the plagioclase acquired its border. The presence of free quarz in this rock, the constituents of which show that it is not saturated with SiO_2, is somewhat peculiar. Possibly this constituent was acquired during the intrusion of the magma through assimilation of other, more acid rocks.

Amygdaloid-Porphyrite. Pebble in the red clays. Southern tributary of the Chiesone river near Alpe Cavoiasca (fig. 25).

The rock has a red colour and shows a well developed flow structure

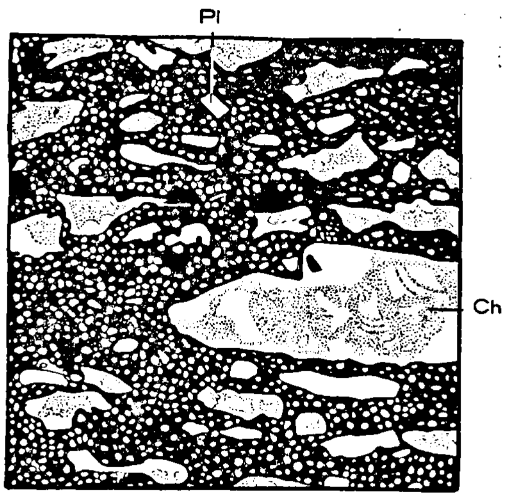


Fig. 25.

Porphyrite with amygdales. Pebble in the red tuffs.

Ordinary light. 20 ×.

caused by drawn-out cavities, which are filled by red agate and colourless chalcedony.

Microscopically the base appears to consist of an amorphous mass of limonite. Many amygdales, the smaller ones round, the larger drawn out to an extension of one cm. and more, are filled with calcite, zeolites and chiefly with agate and chalcedony.

The only phenocryst constituent is plagioclase, wholly zeolitised, while the original twin lamellar structure has been preserved. Occasionally this mineral shows the well known regularly dispersed inclusions of glass, the latter being wholly altered into an irregular mass of zeolites.

Lithic Porphyrite-tuff. Pebble in the red clays. Southern tributary of the Chiesone river near Alpe Cavoiasca.

Megascopically white zeolitised plagioclase, together with amygdales filled with agate are seen in a dark red groundmass.

Under the microscope it appears that this tuff is unquestionably derived from the above mentioned porphyrite. It contains plagioclase, to which the same description applies; the only additional constituent consists of a pseudomorph of calcite and zeolites after a dark mineral, of which the shape suggests a pyroxene.

Inclusions of various sizes with amygdales occur together with fragments of chalcedony from the larger cavities.

The cement consists of a dense mass of limonite and carbonaceous matter.

C. The Lithic Tuffs.

Introductory remarks.

As has already been mentioned in the first chapter, the name was given to this formation because lithic tuffs make up the bulk. Occasionally other tuffs occur in between in comparatively thin layers of 50 to 70 cm. thickness, but these have only a very local extension and are confined to the central parts of the ancient Permian basin. Many pebbles are found in the lithic tuffs as well as in the others, not however in patches of conglomerates, but chiefly as irregularly dispersed inclusions.

1. The sediments.

Lithic tuff. Near Grantola, Mesenzana, Alpe Cognolo (Mte. la Nave), in the bed of the Grantorella river (fig. 26).

This rock has a dark green colour and megascopically already betrays its character through many inclusions of irregular shape and sizes being visible, which are poor in quarz and rich in decomposed plagioclase and dark minerals.

Under the microscope the following constituents are revealed.

Lithic fragments and loose crystals and their fragments are cemented together by a groundmass consisting of volcanic ashes, calcite and chlorite.

The lithic fragments chiefly consist of porphyrites. Some of them resemble porphyrites occurring as pebbles in the underlying red clays and may very probably have been derived from the same rocks. The usual type is represented by a rock containing phenocrysts of decomposed plagioclase and a chloritised dark mineral, probably an augite, within a groundmass of subparallel laths of the same minerals. Another porphyrite is represented by a rock with many amygdales filled with chalcedony, the groundmass consisting of a dark brown glass in which a flow structure is indicated by long laths of plagioclase. Other inclusions have no phenocrysts but show a cryptocrystalline base with irregular patches of calcite. In ordinary light a fluxion structure is still distinct.

As a detailed description of the many inclusions would lead too far, I have selected some of them from different slides, as is shown in fig. 26. Inclusions of quarz porphyry are rare in this rock. I only found one, showing a microfelsitic groundmass with phenocrysts of corroded quarz and decomposed plagioclase.

The crystals and the fragments of such are chiefly represented by plagioclase and biotite, while quarz is only found in minor quantities as large corroded individuals.

The plagioclase is usually replaced for the greatest part by zeolites and a little calcite; the original twinning has been preserved. One

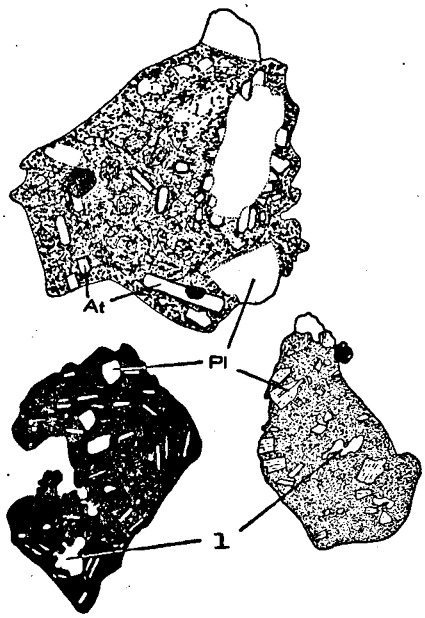


Fig. 26.
Inclusions of porphyrite in the lithic tuffs.
1: amygdales.
Ordinary light. 20 ×.

individual, which still allowed a determination with the U-stage, showed the common twinning law combination of Albite, Carlsbad A and Roc Tourné with an An-percentage of 42. The plagioclase frequently encloses biotite and apatite, the latter occurring in long needles. The brown biotite is fresh and contains much zircon, the latter not showing pleochroic haloes. Zircon also occurs as separate crystals within the groundmass.

The latter consists of a mixture of small splinters of all the minerals mentioned together with volcanic ashes of typical form and remaining dark under crossed nicols. The interstices are occupied by patches of chlorite and calcite. In the rock from Alpe Cognolo I found the ashes wholly altered into chlorite.

Lithic tuff. Road Grantola-Cunardo; Valley of the Rio Campiago. (fig. 27).

The rock occurs as a greenish white layer within the tuffs first mentioned. Megascopically it cannot be recognised as such. Fresh biotite and quarz are visible.

Under the microscope the rock is seen to consist almost wholly of angular inclusions of the volcanic rock, already mentioned in the former

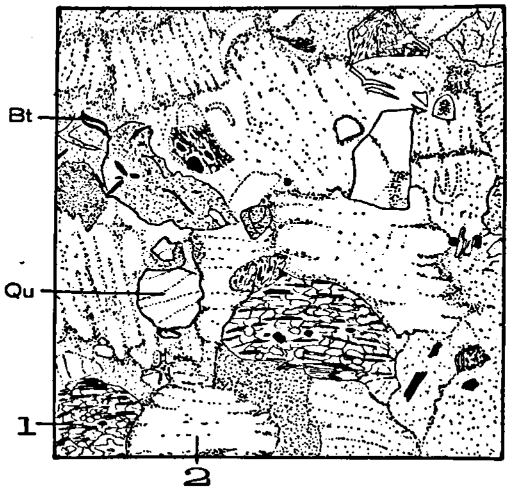


Fig. 27.

Lithic tuff. 1. inclusion of schist; 2. inclusion of devitrified lava. Ordinary light. 20 ×.

tuff: it shows a crypto-crystalline base with a flow structure and has no phenocrysts.

Other inclusions belong to the fundamental micaschists, in which the biotite has been altered into chlorite. Small porphyrite inclusions are only to be found occasionally.

The following minerals are found as separate crystals.

Plagioclase in a fairly good state of preservation, twinned after the laws of Albite, Carlsbad A and Roc Tourné and containing 34 % of Anorthite.

Brown biotite occurs in bent and somewhat twisted fragments, being compelled to adapt itself to the irregularly shaped inclusions.

Quarz occurs in large corroded phenocrysts.

Zircon is found occasionally in between the other fragments, together with fragments of apatite.

Volcanic ashes are found in small quantities as devitrified fragments.

Crystal tuff. Footpath Cugliate-Alpe Paci.

The rock has a white colour and megascopically shows some small white fragments of zeolitised plagioclase and black lustrous biotite fragments.

Under the microscope the same minerals are observed together with small fragments of quarz. The plagioclase still shows the original twin-lamellae; the brown biotite occasionally encloses zircon.

These fragments occupy some 20 % of the rock. The base is a crypto-crystalline mass consisting of zeolites, a little chlorite and limonite and some undefineable matter.

Crystal tuff. Road Grantola-Cunardo.

Megascopically this rock resembles the former one very much. Under the microscope the following minerals are observed. Quarz in angular fragments; a dark green biotite which was bent and twisted; muscovite, probably derived from the schists; plagioclase, almost wholly decomposed and altered into calcite and zeolites. Apatite occurs in the biotite and as small loose fragments. Here also the crystals do not occupy more than 30 %, at the most, of the rock. The base consists of zeolites, calcite, a colourless mica and a little chlorite, together with small splinters of quarz and decomposed plagioclase.

Crystal tuff. Road Grantola-Cunardo.

The rock is of a dark green colour with small brown-red patches, quarz is occasionally observed.

Under the microscope the following constituents are observed.

Quarz in small quantity and showing corroded forms; plagioclase in fragments and altered into zeolites, limonite and calcite; biotite altered into chlorite; masses of chlorite, magnetite and zeolites forming pseudomorphs after a mafic mineral; zircon; devitrified volcanic ashes, showing a microfelsitic texture. The base consists of a mixture of chlorite and undefineable matter.

Inclusions derived from the fundamental schists and from porphyrite are present, but not in such quantities that the rock deserves the name of a lithic tuff.

2. The pebbles.

The pebbles in the lithic tuffs do not show any petrographic variations. They are all porphyrites and the description of the porphyritic rocks found as pebbles in the higher horizons of the red clays, applies to them also.

Conclusions.

Thus it appears that, while the lithic tuffs were deposited, the material brought into the basin consisted chiefly of the detritus from porphyritic and dacitic rocks. There is a distinct difference between the contents of the red clays and the lithic tuffs, namely that those of the former are essentially more acid than of the latter.

D. The conglomerate of Germignaga.

As a full description of the mode of occurrence of these conglomerates has been given on page 130, I will pass at once to the pebbles.

These have for the greatest part been derived from crystal tuffs of which the matrix consists of volcanic ashes. The crystals and their fragments are:

Quarz, idiomorphic and usually corroded.

Plagioclase, always decomposed and altered into a mass of zeolites, calcite and quarz.

Orthoclase, occasionally showing Carlsbad-twins.

Brown biotite, partly altered into chlorite and limonite.

Zircon, usually found within the biotite.

In some rocks the volcanic ashes are devitrified showing spherulitic texture; in others these fragments remain dark between crossed nicols. This base of ashes is sometimes coloured pale brown by limonite, or pale green by chloritic matter.

Occasionally small inclusions derived from the mica-schists are present, while those of a felsophyric rock are not rare.

Amongst the pebbles in this conglomerate I found one deserving a special description (fig. 28).

While the above mentioned rocks are of a dark grey colour, this one shows a milky-white, lustrous and slightly transparent matrix, in which

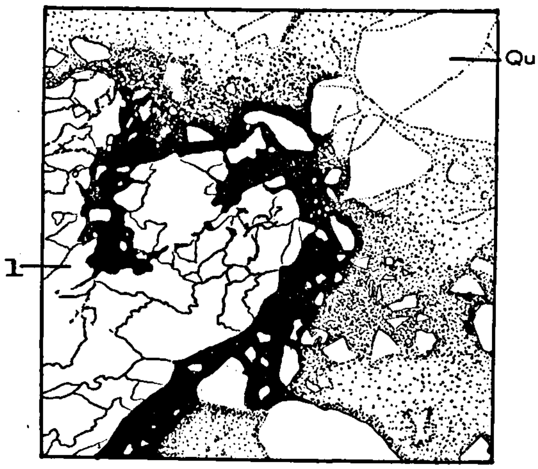


Fig. 28.

Crystal tuff. Pebble in the conglomerate of Germignaga.
1: inclusion of schist. Ordinary light. 20 ×.

angular quarz crystals are seen in great abundance. Under the microscope it appears that quarz occupies more than 60 % of the rock. It occurs in fragments varying in size from minute elongated crystal-splinters to such of ½ cm. in diametre. Orthoclase occurs in minor quantities. Zircon is present in large quantities and occurs in idiomorphic prismatic crystals and in minute fragments. Inclusions derived from the fundamental schists are not rare.

The base, when observed in ordinary light, appears to consist of a colourless siliceous matter which is full of minute inclusions, partly consisting of fragments of zircon, partly of limonite, while the greater part cannot be identified. Besides these inclusions there are very small ring-shaped amorphous particles, probably of glass, usually occurring seperately but also united to small groups.

The distribution of all these inclusions throughout the groundmass is very irregular. Occasionally they occur in such a quantity that the matrix becomes opaque. The latter consists of a crystalline mass with a granular texture. It has replaced the dark minerals in the rock, for instance the biotite of the micaschists and then has the appearance of invading these inclusions. In such cases the opacitic matter abounds in it.

Although I have no definite conception of the nature of this rock, I might venture the suggestion that it has been a vitric tuff of which the siliceous base has been altered into the here described groundmass.

III. THE ERUPTIVE ROCKS OF THE SANDSTONE-TUFF SERIES.

It has already been mentioned in the first chapter that, during the deposition of the red clays, the first effusions of igneous rocks occurred that are now found *in situ*. The layer chiefly consisting of volcanic dust described on page 158, might perhaps be included in this chapter, but for the possibility that its material was a product of eruptions that happened somewhere outside the here described regions. Apart from this rock I found exposures of three different effusive rocks, the description of which will now follow.

A. The lava's occurring in the red clays.

1. Enstatite-basaltite (basalt without olivine and with a mesostasis of glass) [1]). (Plate 32*b*).

The rock is found on the road from Mesenzana to the Mte. San Martino, 500 m. to the South of Mesenzana. Its colour is dark grey, almost black; it shows a fine grained, somewhat lustrous mass consisting of plagioclase and augite crystals, neither exceeding a length of 1 m.m.

Under the microscope it appears that the constituent minerals are well preserved. Between groundmass and phenocrysts the distinction is not very strongly pronounced, but certainly does exist. Both phenocrysts and groundmass consist of idiomorphic crystals of plagioclase and an orthorhombic pyroxene; the interstices are occupied by a glass base, which generally contains a large amount of crystallites, probably of the same pyroxene. Of the accessory minerals magnetite occurs in fairly large quantities. The texture of the rock tends to the ophitic and sometimes is slightly fluxional.

The plagioclase has somewhat elongated tabular forms and shows well developed twinning. A pronounced zoning is observed, a basic centre with slightly rounded forms being surrounded by a more sodic border; recurrence in the composition of the zones is rarely observed, while sub-zones are only occasionally present in the border zone. The following measurements were made with the U-stage.

Ind.	Lamellae	Twinning Law	Percent of An. centre	border	Particulars
I	1—2 2—3 1—3	Albite Carlsbad A Roc Tourné	92 % 93 % 93 %	63 % 62 % 63 %	Phenocryst
II	1—2	Baveno	92 %	—	Phenocryst
III	1—2	Albite	91 %	—	Groundmass
IV	1—2	Pericline	92 %	61 %	Groundmass
V	1—2	Carlsbad A	92 %	—	Groundmass
VI	1—2	Manebach	91 %	64 %	Groundmass

[1]) 1901. VIII Congrès Géologique Internationale 1900. Deuxième fasc. Lexique Pétrografique, page 1038.

The plagioclase further contains many small inclusions of magnetite and of glass.

The orthorhombic pyroxene is enstatite. It occurs in idiomorphic crystals, is almost colourless and shows no pleochroism. A measurement of five individuals on the U-stage according to BERECK's method of the characteristic extinction, gave as result an optic axial angle varying between 68° and 71°. In three of these five crystals the optic axial angle could also be obtained by direct measuring, the result almost tallying with that obtained by the indirect method. The optical character is positive.

A pale green pyroxene: diopside, occurs in minor quantities, frequently in parallel intergrowth with the enstatite.

Magnetite is found in idiomorphic crystals as well as in a somewhat elongated skeletal form. It is peculiar that this mineral does not belong to the very first products of crystallization, as is usually the case. It sometimes partly envelopes augite as well as plagioclase.

The groundmass consists of glass filling up the interstices. It is full of globulites and crystallites, the latter forming long rods sometimes reaching a length of three mm., from which sometimes other rods protrude as shown in fig. 29*a*.

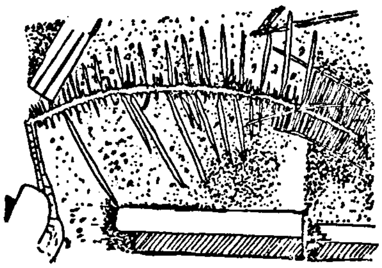


Fig. 29*a*.

Fig. 29*b*.

a. Crystallites of monoclinic pyroxene with globulites in groundmass of glass. Enstatite-basaltite.

b. Arrangement of globulites and augite-crystallites in the groundmass of Enstatite-basaltite.

Usually these crystallites are isotropic; sometimes they show a weak double refraction with an asymmetric extinction varying between 20° and 45°. This combined with the fact that they are sometimes observed connected with the monoclinic pyroxene (fig. 29*a*) leads to the conclusion that these crystallites are augite. The globulites are irregularly dispersed through the glass base. The latter, when free from such inclusions, is colourless or a very pale brown. When globulites abound, the glass is of an opaque black colour. The arrangement of the globulites in a fringe-like manner, as shown in fig. 29*b*, is not rare. Occasionally the glass has been replaced by a brown or green mineral, probably belonging to the chlorite-group. Within this mass perlithic cracks have sometimes been preserved in the original glass. On the convex side of these cracks the chloritic mineral seems to be isotropic, while on the concave side it shows a high double refraction and a well developed spherulitic texture. Thus between crossed nicols the false impression is sometimes obtained of this chloritic mineral filling up original vesicles in the lava. When magnetite or augite occur in the mesostasis of glass their immediate surroundings are free from colouring, globulites or crystallites.

2. Basaltite (basalte without olivine). Northern tributary of the Tresa-river near Casa Genestrato, 750 m. to the West of Ponte Cremenaga (fig. 30).

This rock is exposed as a layer of 1.50 m. thickness in the red clays in the bed of the tributary mentioned and could not be traced

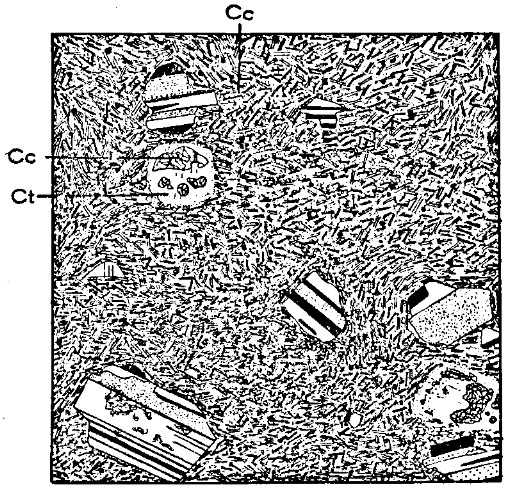


Fig. 30.

Basaltite from Casa Demenech,
Tresa-valley.
Nicols +. 20 ×.

further to the West nor to the East. It is dark grey showing a few phenocrysts of a clear plagioclase and a decomposed dark mineral within an aphanitic groundmass.

Under the microscope it appears that the rock consists of plagioclase, a decomposed mafic constituent and a large amount of magnetite in idiomorphic octahedrons, reaching a diameter of 0.5 mm. The groundmass shows a well developed fluxion structure as a result of the subparallel arrangement of the plagioclase laths which reach a length of 0.2 m.m. Sometimes the structure tends to the ophitic. The texture is holocrystalline panidiomorphic and porphyritic.

The plagioclase phenocrysts are sometimes tabular, sometimes prismatic and reach a length of 2 mm.; they are fresh in appearance. Polysynthetic twinning is frequent. They do not show any zoning except for a narrow border, which is considerably more acid than the centre, as the measurements with the U-stage show.

Phenocrysts.

Ind.	Lamellae	Twinning Law	Percent of An. centre	border
I	1—2	Albite	85 %	56 %
	2—3	Carlsbad A	84 %	57 %
	1—3	Roc Tourné	85 %	57 %
II	1—2	Albite	86 %	58 %
	1—3	Roc Tourné	85 %	58 %
	1—4	Carlsbad A	85 %	58 %
	2—3	Carlsbad A	86 %	59 %
	2—4	Roc Tourné	85 %	58 %
	3—4	Albite	86 %	59 %
III	1—2	Pericline	83 %	58 %

The crystals have been partly resorbed and the acid zone has grown round the irregular border of these phenocrysts. The composition of this zone is, most probably, the same as that of the groundmass plagioclases. Although the latter could not be measured on the U-stage with sufficient exactness because of their small size, I managed to obtain the twinning laws and the Anorthite percentages of three of the larger groundmass individuals.

Groundmass.

Ind.	Lamellae	Twinning Law	Percentage of An.
I	1—2	Albite	63 %
II	1—2	Albite	55 %
III	1—2	Carlsbad A	58 %

The percentage values are not accurate and we must assume that the groundmass plagioclase contains on the average about 59 % of Anorthite. This value, compared with that found for the sodic border of the phenocrysts points to the latter being a product of the eruptive phase.

The mafic constituent of this basaltite has been completely altered to a fibrous mass of light green chlorite, calcite and magnetite. The original mineral was partly resorbed, so that the shape of the crystal does not give certain evidence about its original composition. It reaches a length of 1.5 mm., as a phenocryst and also occurs in the groundmass. It may have been augite or hornblende.

The two effusive rocks occurring in the red clays which I have endeavoured to describe, might have been called porphyrites. I preferred, however, to give them the name of basaltites, because of the high percentage of Anorthite of their plagioclases, which belong to the Bytownites. In the enstatite-basaltite a sodic border zone, containing on the average 62 % of An., occupies only a comparatively narrow zone. The room occupied by plagioclase substance of both percentages may not be far from 40 % for the sodic border, to 60 % for the calcic centre, which reduces the average composition of the plagioclase from 92 % to ± 80 % of An., the composition of basic labradorite. This fact combined with the presence of enstatite points to the hypabyssal parent magma having the composition of a gabbro, not of a diorite. The composition of the glass mesostasis not being known, only a quantitative analysis can settle this matter beyond dispute. In the case of the basaltite from the Tresa-valley the proportion of the two plagioclase substances may be roughly estimated at 30 % for the phenocrysts. This means that the amount of 85 % An. of the centre of the phenocrysts must be reduced to 67 % of An. for the average composition of the plagioclase in this rock.

Thus it appears that this rock is somewhat more sodic than the first mentioned one, but still must be called a basaltite because of the high percentage of Anorthite in the phenocrysts, of which the composition in the normal porphyrites averages that of 60 % of An. It must, however, once more be emphasised, that the remark about a quantitative analysis applies also to this case.

B. The lava's occurring in the lithic tuffs.

1. Quarz-porphyry. Layer of 1.50 m. thickness in the lithic tuff on the road Grantola-Cunardo at the second and the third winding, 400 m. to the South-East of Grantola.

Megascopically the rock shows phenocrysts of quarz and felspar in a dense groundmass of a pale brown colour, in which occasionally inclusions of other rocks are found.

Under the microscope the following minerals are observed:

Quarz in large idiomorphic and corroded phenocrysts.

Orthoclase, partly decomposed and occasionally twinned.

Plagioclase, completely zeolitised with preservation of the original twinning.

A brown biotite in scarse, somewhat twisted individuals.

Magnetite, apatite and zircon in minor quantities.

The groundmass is a devitrified glass base. When observed in ordinary light it seems a homogeneous glass substance; between crossed nicols it is seen to possess a crypto-felsitic texture. It is then that a distinct fluxion structure shows up, as a result of strained vesicles filled with quarz becoming visible and of glassy strained bands having become devitrified. Occasionally the flow structure is also visible in ordinary light because of accumulations of iron matter in between the strained bands, which in this case are more twisted and bent than usual and contain more vesicles. Here we are confronted with inclusions derived from the surface of the same lava flow, which once again became involved in the flowing movement of the deeper parts, thus becoming welded together with the still fluid lava.

The quarzporphyry further contains inclusions derived from a porphyritic rock, in which a flow structure is rendered distinct by the subparallel arrangement of the plagioclase laths.

IV. THE LAVA-SERIES.

A. The Felsophyre.

In the first chapter it has already been mentioned that this rock occupied almost the whole area which took part in the subsidence of the Permian age.

HARADA has given an excellent description of the felsophyric rocks of these regions. The rock described on page 37 of his paper as a felsophyre is similar to that which I am about to deal with here.

The rock varies in colour from a pale grey to all shades of violet, sometimes becoming so dark that it is almost black. Usually a flow structure is distinct, because of a number of differently coloured twisted and waved bands, or as a result of inclusions from other rocks, chiefly derived from micaschists and porphyrites and from the underlying red clays, being arranged in a subparallel position. Flow structure is also a result of elongated pores, sometimes reaching a length of several centimeters.

The whole mass, whether showing flow structure or not, possesses an aphanitic texture, of which can only be said, that it shows variations in its degree of fineness. When the maximum degree of coarseness is reached, minute miarolitic cavities are visible with the naked eye.

The felsophyre is vey poor in phenocrysts. Orthoclase is occasionally found in idiomorphic crystals of a milky white, or bluish translucent colour, reaching a length of 2—3 mm. In an exposure near San Michele I found the rock to be comparatively rich in small cavities, the regular prismatic shapes of which suggest their having been occupied by orthoclase phenocrysts.

Quarz is hardly ever observed as phenocryst, while biotite also plays a very minor part. When the latter is found it usually appears to have made part of a micaschist-inclusion.

Inclusions are abundant, their dimensions varying from minute fragments to some 5 cm. in diameter and still larger.

At its base, as well as at its top this lava is occasionally extremely rich in round amygdales, which sometimes reach a diameter of ½ cm. They are rendered conspicuous by their being filled by a white mass of soft zeolitic matter. Here the rock is mostly rather patchy in its colour, darker violet patches being irregularly dispersed within a pale grey or pink "groundmass". This facies of the rock can be observed on the military road Cugliate-Alpe Paci, some 40 m. above the village of Fabiasco, and 200 m. to the North of it, where the road bends inwards to cross a small brook. A second outcrop of the amygdaloid facies is found along the road from Mesenzana to the Mte. San Martino.

• Under the microscope the rock appears to have been a vitrophyre which has become crystalline by devitrification and consists of an allotriomorphic aggregate of quarz and orthoclase in which, very rarely, phenocrysts are found of:

Quarz in idiomorphic corroded crystals.

Orthoclase, usually fresh, sometimes partly wheathered.

Plagioclase, wholly decomposed, leaving a mass of zeolites, with the twinning partly preserved and including apatite in small needles.

Biotite, in the form of highly wheathered six-sided tablets and flakes.

Zircon in idiomorphic prismatic crystals.

The groundmass contains many grains of magnetite.

Crystallites abound: they consist of globulites, which are arranged into long strings, thus forming straight and bent hair-like margarites pointing in all possible directions, and showing no connection whatever with a possible flow structure. They are altered to limonite and when they abound, the rock takes on a greyish colour, which megascopically corresponds to the different shades of violet of the above mentioned streaks and bands.

The groundmass itself, when observed in ordinary light, is usually almost colourless, showing faintly yellow more or less parallel bands indicating flow structure. Sometimes such strains are accentuated by the presence of limonite, which was probably secreted during the devitrification, and finally, when megascopically the rock shows its darkest colour, and nothing betrays its structure, microscopically, the flow structure is to be observed at its best.

Between crossed nicols the texture most frequently met with is the felsitic, of which all degrees of coarseness are observed: from cryptofelsitic to micro-felsitic and micro-granitic. Besides the felsitic a spherulitic texture is frequently met with.

A base of cryptofelsite is seen almost everywhere. Within this base cumulitic masses of microfelsite are irregularly dispersed in the manner of phenocrysts. They consist of allotriomorphic grains of quarz and orthoclase and sometimes may be called granospherites, owing to a pseudospherulitic texture, which is occasionally vaguely hinted at. Their position is quite independent of the original flow structure, the strains of which run straight through these cumulitic masses. The number of grains of which they consist is variable; occasionally this number decreases to one round grain; in that case it is sometimes difficult to distinguish them from quarz-filled pores. When the flow structure is distinct and the streamlines are observed to run round the grains mentioned, their identity as gass pores is evident. If their position is independent of the streamlines such grains are the product of devitrification. When the texture becomes coarser grained this means that the granospherites increase in number, finally joining one another and showing an uninterrupted microgranitic mass consisting of an allotriomorphic aggregate of quarz and orthoclase. Locally this texture passes into a spherulitic, idiomorphic orthoclase showing a rough radial arrangement, while the quarz is found in between. This texture, in its turn, occasionally shows an inclination to become micrographic. Usually this coarse grained texture occupies large parts of the rock; at other times its extension is restricted only to some of the strained bands, the other bands bordering on them either showing a less coarse grained texture, or a well developed spherulitic one. The fine fibrous pseudospherulites occasionally pass, on their fringe, into a granophyric aggregate. This is especially liable to occur at such places, where the borders of three or more of the spherulitic aggregates come to meet, thus leaving a triangular or more irregularly shaped room, in which the texture is between the spherulitic and the granophyric.

Miarolitic cavities are frequently observed. Their size and number vary in proportion to the degree of coarseness of the grains. In the micro-granitic parts they are larger and sometimes visible with the naked eye, as has already been stated. Both the quarz and the orthoclase protrude into these cavities with freely developed crystal faces. The cavities are filled with fine grained zeolitic matter (low refraction index, weak double refraction). Sometimes they are coated with quarz; the difference between this quarz and that of the rock itself is that the latter has a dusty appearance, while the former is quite clear. With the decreasing coarseness of the grain the miarolitic cavities decrease in size and at the same time increase in number. They are sometimes scarsely to be detected, but when once the larger ones have been observed in the microgranite and their passing into smaller cavities when the rock becomes more fine grained, they can be traced and recognized as such within the above mentioned cumulitic masses or granospherites.

These miarolitic cavities are not to be confused with gass pores, which usually are also coated with quarz and filled with the same zeolites. But these have a sharply defined round border, without crystals protruding into them.

B. The Vitrophyre [1]).

This rock extends over a area that, although large, does not equal that of the felsophyre. Because of the thinness of this lava sheet its exposures are usually difficult to be found, even when one knows, were to expect them. The vitrophyre namely lies not far above the felsophyre, which, in itself, always forms a more or less prominent feature of the landscape. On the other hand fragments of this rock are frequently found, both on slopes and in the rivers as pebbles. The exposure mentioned by HARADA is the best developed and the easiest to be attained, as it lies not far from Grantola and Cunardo. It can be reached along the footpath which forks off from the road connecting both villages, opposite the limestone quarries of Camadrino. This path is followed till some 30 m. before the felsophyre is reached, where it is joined by a sidepath from the right which cuts through the vitrophyre.

The megascopical appearance on a fresh fracture of this rock resembles that of obsidian: it shows a lustrous black olour. With the naked eye it is difficult to detect the phenocrysts which it contains in large quantity. Only on closer investigation with the pocketlens many prismatic crystals of felspar are observed, which are so clear that the black groundmass is seen

[1]) Although the vitrophyre makes part of the quarzbearing porphyrite, I have deemed it advisable to describe it as a rock on itself.

through them. This fact accounts for their not showing off more clearly against the matrix. Their subparallel arrangement suggests a fluxion structure. Besides these other phenocrysts of a light green cotour with irregular rounded forms are discerned: these are olivines.

On the weathered surface the phenocrysts are clearly visible against their dark background, having assumed a dark yellow colour and having been prepared out of the slightly softer groundmass, thus rendering the surface of the rock somewhat rough. This weathered crust is apt to crumble under blows of the hammer, while the fresh vitrophyre shows a conchoidal fracture. The effect of the weathering does not reach deeper than 3 cm. into the rock.

At the outcrop mentioned by HARADA the lustrous appearance of the rock can be observed to disappear gradually, the more the inner part of the flow is reached. At last the rock has a dull black colour in which a tinge of green is observed. The felspars have lost some of their clearness and are now a transparent white. This is how the vitrophyre is usually found at other exposures: on the North slope of the Mti. di Castelvecchio, 50 m. to the South East of point 576, which consists of the felsophyre; directly below and to the South of the Colle della Nave; on the footpath Cugliate-Alpe Paci, 500 m. to the East of Derzaga. On the road from Mesenzana to the Mte. San Martino the lustrous type is found.

Both types deserve a special microscopic description.

a. The lustrous type. (Plate 33*a* and *b*).

The following minerals are found within a matrix of glass.

Plagioclase, olivine, augite (monoclinic and orthorhombic), hornblende, allanite, magnetite, apatite and zircon.

The plagioclase occurs in large prismatic phenocrysts, which occasionally reach a length of 3 mm. and more. It may be called microtine because of its exceptional clearness. Signs of corrosion are observed almost everywhere, but not of great intensity. The flowing movement caused mechanical destrutcion into smaller fragments and splinters, while occasionally bending of the prisms is observed. The plagioclase shows polysynthetic twinning and zoning with sub-zoning [1]). In the list on page 192 the twinning laws as well as the compositions of a number of plagioclases have been given, measured with the aid of the U-stage. The position of the prisms coincides with the direction of the flow. Some of the crystals show the wellknown sieve structure owing to more or less regularly arranged inclusions of brown glass. Many of the crystals show inclusions of apatite and magnetite, the latter in small idiomorphic grains, the former in short prisms, the orientation of which is frequently observed to be parallel with the zoning.

According to HARADA sanidine occurs in this rock. I have not been able to trace this mineral and am inclined to believe that HARADA must have confused some of the plagioclases without twinning with sanidine. In some cases it is obvious that the absence of twin-lamellae is due to the

[1]) CH. HARLOFF. — Zonal structure in Plagioclases. — Leidsche Geolog. Mededl. Dl. 2. V 1927. Pag. 99—114.

fact that plagioclases, originally in twinned position, were mechanically split up along their association-planes. In others the same effect may have been produced by the section running approximately parallel with the association-plane. In all cases the crystals showed the same optical properties (zoning etc.).

The olivine is an abundant constituent. Notwithstanding many sinuous gaps and inlets as signs of corrosion its original forms can be fairly well recognized. The olivine reaches a maximum size of 3 mm. in diameter. The cleavage is fairly distinct parallel to (010), less so in other directions.

This mineral is full of inclusions of apatite, occurring in long thin needles, magnetite and zircon. The replacement of olivine by serpentine can be observed not only in various stages of completeness, but also along different lines. As is usually the case the process begins from the cleavage-cracks, from which a pale green fibrous serpentine is observed, the position of the fibres being at right angles to the cracks. In a further stage the remaining parts of the olivine have been replaced by a non-fibrous mass of a dark green serpentine: antigorite. Occasionally a paramorph after olivine, consisting either wholly of the fibrous serpentine, or of antigorite is observed. In other cases a brown red fibrous serpentine, which is not pleochroic, forms homöoaxial paramorphs; of this mineral the non-fibrous variety also occurs. Both the green and the brown serpentine show a negative optical character. Parts of them, however, are apparently isotropic, while other patches show high interference-colours, with gradations to lower colours. These masses may only seem to be isotropic, in reality a superposition of differently orientated fibres occurring. In ordinary light not the least difference can be observed between the isotropic parts and those showing strong birefringence.

Within the serpentine a clear carbonate mineral is frequently found both in idiomorphic and irregularly shaped grains. Taking into consideration, that no carbonates are found as secondary minerals on cracks or elsewhere in the vitrophyre, its seems that this mineral must be regarded as a product of the alteration of the olivine itself, and is presumably magnesite.

No ferrous oxide or hydroxide has been secreted during the serpentinization. Thus it appears that no surplus of iron was present after the serpentine was formed, so that the composition of the olivine may have approached that of forsterite. In corroboration with this supposition are the results of ten measurements with the U-stage, according to which the optic-axial angle varies between 80° and 95°, while the optical character is positive.

Of pyroxene two varieties occur in the vitrophyre: a monoclinic one, namely diopside, and an orthorhombic one: enstatite. Both are fresh and occur in idiomorphic crystals as well as in fragments. To the enstatite the same discription applies as that given of this mineral for the enstatite-basaltite from Mesenzana. In some of the slides I found fragments of a browngreen hornblende. It is strongly pleochroic. The maximum extinction measured is 14°.

Allanite I found in three slides, namely in two from the exposure near

Grantola, and in one from a pebble in one of the many brooks on the South slope of the Mte. la Nave.

The first shows zoning which is most distinct when the mineral is placed in the position of maximum absorption. The pleochroism is strong:

n_α	n_β	n_γ
greenish-brown	dark brown	sepia-brown

The cleavage is not well developed. In the first individual a cleavage parallel to (100) is fairly distinct. The optic axial angle, measured on the U-stage by the application of Berek's method of the characteristic extinction is, for the first individual:

$$2\ V = 50°,$$

for the second: $2\ V = 51°.$

The result of these observations could not be checked by a direct measurement, the sections not favouring such a measurement.

Weinschenck gives an optic axial angle of 70°, while Iddings and Rosenbusch give a variable value of 2 V. In both individuals I found the bissectrix *n* to be inclined 29° to *c* in the acute angle of β [1]). This observation tallies with those of Brögger of allanite from Grefsenaas (Norway). The optical character is doubtfull, probably negative. The refraction is high. The double refraction is high in two of the individuals. The third one is altered; it has a dark brown, almost black colour and is partly isotropic, partly shows only a weak birefringence, while no pleochroism can be detected. It has a dull metallic lustre, when observed in reflected light.

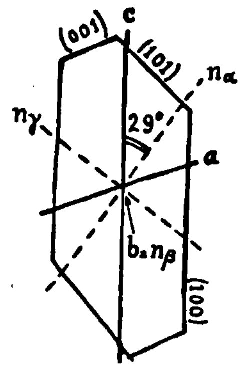


Fig. 31.

Position of the Index-ellipsoid with regard to the crystallographic planes of allanite in the vitrophyre from Grantola.

No epidote is found round or within the allanite.

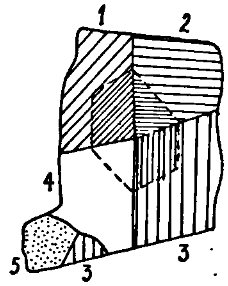
Of the accessory minerals mentioned above, magnetite and apatite occur as inclusions within the plagioclase; magnetite, apatite and zircon in the olivine and the diopside; the enstatite is free from inclusions; the hornblende encloses apatite, the allanite zircon. Magnetite also occurs as a phenocryst in the groundmass, while zircon and apatite are rarely to be observed as such.

The groundmass of the vitrophyre consists of glass, as the name indicates. There are two types to be discerned: a brown translucent glass, in which fluxion structure is not so well pronounced as in the second type, a pale brown, almost colourless, transparent glass, containing thousands of crystallites, and in which fluxion structure is excellently developed. Megascopically the two are not to be distinguished. There is no great difference to be observed in the flow structure in the sections taken parallel to the direction of the flow, whether in a vertical or a horizontal plane.

[1]) These measurements were made with the U-stage.

Vitrophyre Plagioclases.

Ind.	Lam.	Twinning Law	Percentage of Anorthite		Particulars
			centre	border	
I	1—2	Roc Tourné	45 %	38 %	
II	1—2	Albite	41 %	38 %	
III	—	—	41 %	37 %	cleavage plane (010)
IV	1—2	Carlsbad A	44 %	—	
V	1—2 1—3 2—3	Carlsbad A Albite Roc Tourné	39 %	34 %	
VI	1—2	Pericline	52 %	37 %	
VII	1—2 3—4 1—4 2—3 3—5	Scopi Scopi Esterel Esterel Baveno	43 % —	34 % 34 %	See fig. 31*a*
VIII	1—2 1—3 1—4 2—3 2—4 3—4 5—6	Albite Carlsbad A Roc Tourné Roc Tourné Carlsbad A Albite Acline A	39 % 38 % 40 % 39 % 39 % 39 % 39 %	—	
XI IX	1—2	Manebach	42 %	36 %	
X	1—2	Esterel	44 %	37 %	



Sketch of zonal Plagioclase from the Vitrophyre of Grantola. Nothe the remarkable combination of twinning laws.

Fig. 31*a*.

The brown glass is almost devoid of crystallites; it only contains irregularly dispersed globulites. Their immediate surroundings are less intensively coloured than the average brown of the glass. In the transparent type the flow structure is chiefly indicated by long strained bands, separated by dark lines, the nature of which is difficult to ascertain. Sometimes these borders are red-brown when the section is observed between crossed nicols, and when the direction of the strains is at right angles to that of the vibration plane of the analysator. This pseudo-anisotropic conduct is only observed, when the intersection of the regular planes, by which the strained bands are bordered, with the surface of the section is not at right angles. The more the first mentioned planes are inclined towards the plane of the slide, the more this phenomenon is distinct, from which circumstance it is clear, that the effect is due to reflexions of the light. The bands themselves are rich in crystallites. Globulites are found in cumulitic masses; their average diameter is ± 1 μ. A beadlike arrangement of globulites to margarites is frequently observed (fig. 32*a*). In these margarites either the constituent globulites are visible grain for grain, or their borders, where they touch on each-other, are indistinct, in which case a dark line running through the middle of the margarite is frequently, but not always, observed, dividing it in two halves (*b*). Occasionally several margarites eradiate from a common centre, which usually is a globulite (*c*). The margarites sometimes reach a length of 50 μ and more. The bulk of the crystallites are trichites. They are straigth as well as bent, while they show variety both in thickness and in length. The thickness varies between 0.2 μ and 1.5 μ; they reach a length of 15 μ at the least, of 40 μ at the most. As a rule the thickness remains constant; I only observed thinning out of comparatively thick individuals with a maximum diameter of 1.5 μ and an a average length of 15 μ (*d*). It is usually found that the thinner the trichites are the longer they are. Fig. *e* shows trichites which are wound in the manner of an irregular spiral. They occur separately as well as joined together in the fashion of the margarites represented in the figures *b* and *c*. Their thickness is 1.2 μ while they reach an average length of 20 μ. The arrangement of the crystallites within the strained bands indicating the flow structure is variable. Trichites usually are found within the narrow bands and stand more or less at right angles to their borders (fig. *f*). The margarites occur in broad and clear patches of the glass, in which also trichites are arranged in the manner indicated on fig. *g*, where they indicate a flow structure. These clear parts are inclusions of the same vitrophyre.

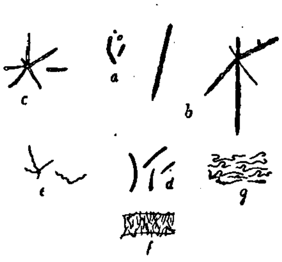


Fig. 32.

Different types of crystallites in the vitrophyre from Grantola.

In such inclusions I found two of the three individuals of allanite mentioned before and also numerous spherulitic aggregates of green serpentine. They are very small, reaching a diameter of 15 to 40 μ. Between crossed nicols the well known dark cross is clearly visible. Besides these, other inclusions of a dark brown colour, probably derived from the surface of the flow, are frequent. They are sometimes rich in gass pores, which contain either chlorite or chalcedony. The vitrophyre further contains homogeneous inclusions, in which the direction of the flow does not coincide with that of the including rock. Occasionally such inclusions occur in such a great number, that the rock may be called a microscopic flow-breccia.

Besides the vitrophyric inclusions, others, derived from underlying rocks, are found in great number, namely: micaschist, felsophyre, porphyrites of different kinds, and inclusions derived from layers of the lithic tuffs of the basal sandstone-tuff-series.

b. The dull type (fig. 33).

The vitrophyre showing the dull black colour differs from the lustrous type in that it represents the devitrified facies of the latter. With a more advanced stage of devitrification a more intensive alteration of the constituent minerals goes hand in hand. This means that the percolation of water in the glassbase, becomes more easy. As soon as this base becomes crystalline the solutions find their way through between the grains.

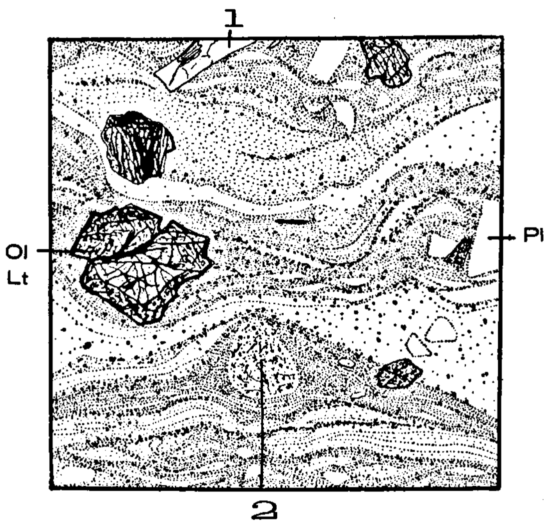


Fig. 33.
Vitrophyre showing fluxion structure indicated by strained bands with different amounts of limonite and different degrees of devitrification. 1: Inclusion of schist. 2: porphyrite inclusion. Pseudomorphs of limonite and zeolites after olivine. Ordinary light. 20 ×.

The vitrophyre found on the footpath Cugliate-Alpe Paci shows in ordinary light the same well developed flow structure. Between crossed nicols this structure disappears almost completely, the groundmass consisting of a crypto-crystalline mosaïc, the nature of which cannot be ascertained. The only indication of the flow-structure is furnished by lengthened out gass pores, containing quarz. The plagioclase has partly made place for zeolites, while the original presence of olivine is indicated by reticular masses of limonite, the interstices being filled by chalcedony or zeolites.

Some of the strained parts show spherulitic devitrification.

In a further advanced stage the groundmass is somewhat coarser grained and is partly altered into chlorite. Pseudomorphs after olivine consist of limonite, chlorite and zeolites. The plagioclase is completely altered into zeolites. Long stretched vesicles are filled with quarz, chlorite and calcite. The strained bands of the groundmass have almost disappeared, specially where chlorite abounds. In a still more altered rock from the exposure near Grantola the chloritization has reached a further stage. Large parts of the groundmass consist of worm-shaped individuals of chlorite. The original flow structure has completely disappeared. The plagioclase has been replaced by zeolites and calcite. The unaltered parts of the groundmass show a coarse felsitic texture, sometimes suggesting a graphic intergrowth of quarz and felspar. Miarolitic cavities are filled with quarz, while many idiomorphic individuals of orthoclase in rectangular prismatic crystals protrude into these cavities.

The vitrophyre of the Colle della Nave shows quite another kind of alteration. Here the rock is full of chalcedony deposited on cracks, varying in width from a few cm. to microscopic dimensions. The plagioclase has partly or wholly been replaced by this mineral; while the dark brown groundmass has not been affected at all. The olivine consists of the same reticular masses of limonite, the interstices being filled by chalcedony. In all the before-mentioned types the devitrification leads to the gradual destruction of the original flow structure. This type, however, shows, both in ordinary light and between crossed nicols, a well preserved fluxion structure, each of the strained bands being devitrified on itself in such a manner that it shows a weak birefringence as a whole, no granular texture being visible.

The rock from the North slope of the Mti. di Castelvecchio shows the same kind of devitrification in a still more advanced stage. Layers of stronger and weaker birefringence alternate. The dark brown vitrophyric inclusions, mentioned before as occurring in the lustrous type have undergone a different devitrification. They consist of a dense mass of innumerable small spherulites of remarkably equal dimensions (average diameter 30 μ). The gass pores in these inclusions are coated by zeolites and filled with chlorite.

The augite of the vitrophyre must presumably be slightly titaniferous, for in the devitrified vitrophyre the augite is invariably replaced by a mass of serpentine and zeolites, while in the serpentine numerous small grains of a brown titaniferous mineral occur, probably of rutile (strong refraction, high double refraction).

On the South slope of the Mte. la Nave I found fragments of vitrophyre, apparently belonging to the lustrous type. Under the microscope, however, it appeared to be highly devitrified. In ordinary light the flow structure is distinct, but disappears completely between crossed nicols. The groundmass shows a relatively coarse-grained felsitic texture with a weak double refraction. Inclusions consisting of the already mentioned clear vitrophyre with trichites show a coarser grain with stronger birefringence. Other inclusions derived from the surface of the flow show strained gass pores containing baryte.

The olivine is completely replaced by a mass of calcite and spherulitic chalcedony, or by a mass of fine grained zeolites, coloured a pale yellow by limonite, with or without calcite.

C. Quarz-bearing Porphyrite.

The occurrence of this rock has been given in the first chapter. An outcrop of it is found at ten meters distance from the Grantola vitrophyre, where a small quarry has been made to use it as a bottom layer in the limekiln of Camadrino, on which the limestone is burned. Megascopically the rock shows a grey groundmass in which white zeolitized felspars abound. Their subparallel arrangement together with the presence of strained gass vesicles filled with pink chalcedony, renders a fluxion structure very distinct.

Under the microscope the rock appears to have very much in common with the quarz-bearing porphyrite, of which pebbles occur in the red clays, and of which the description has been given on page 172.

The rock contains as phenocrysts: plagioclase, an altered mafic mineral, probably a pyroxene, and as accessory constituents: apatite and magnetite.

The plagioclase is partly altered into zeolites. Parts of the twin-lamellae have been preserved, on which measurements were made with the U-stage.

Individuals	Lamellae	Twinning law	Percent. of An.
I	1—2 1—3 1—4 2—3 2—4 3—4	Carlsbad A Roc Tourné Albite Albite Roc Tourné Carlsbad A	48 %
II	1—2	Carlsbad A	48 %
III	1—2	Carlsbad A	48 %
IV	1—2	Albite	52 %

The form of the mafic mineral suggests the original presence of augite, which has been completely altered into limonite and irregular aggregates of dark green fibres of serpentine. Occasionally such fibres are restricted to the original cleavage cracks of the augite, the interstices being filled either with zeolitic matter, or with a pale green serpentine. These pseudomorphs enclose much apatite.

The groundmass contains the same constituents and quarz.

The plagioclase occurs in prismatic laths.

The same mafic mineral occurs in between the plagioclase laths and has been altered just as the phenocrysts. The remaining interstices are occupied by quarz, the presence of which renders the flow structure somewhat indistinct. It is the last crystallized constituent and does not occur as phenocryst.

D. Hypersthene-basaltite. (fig. 34).

This rock is found on top of the felsophyre on the footpath Cugliate-Alpe Paci. It consists of two layers, in between which the vitrophyre is found. The rock is greyish black and shows phenocrysts of plagioclase and a mafic mineral.

Under the microscope the following is observed:

Plagioclase, hypersthene and a few pseudomorphs of chlorite and calcite after another mafic mineral, possibly a monoclinic pyroxene occur as phenocrysts. The groundmass consists of the same minerals. An accessory constituent is magnetite. The plagioclase phenocrysts reach a length of more than two mm. They occur both in prismatic and in tabular forms. Sometimes they form small clusters. Most of them show a distinct border zone, which is considerably more sodic than the centre. No sub-zoning is observed. The U-stage gave the following results.

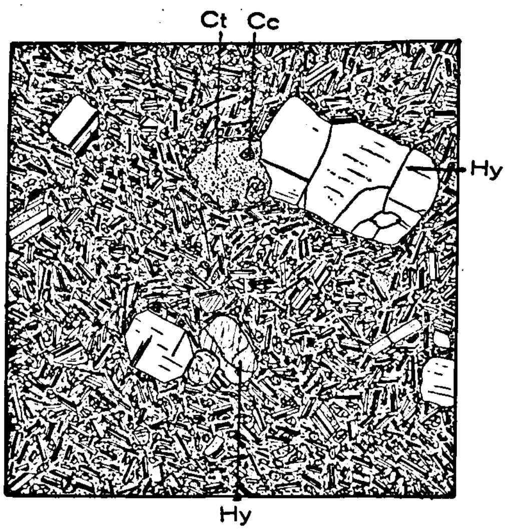


Fig. 34.

Hypersthene Basaltite.
Nicols +. 20 ×.

Ind.	Lamellae	Twinning law	Percent. of An. centre	Percent. of An. border	Particulars.
I	1—2 3—4 6—7 1—8	Pericline Albite Roc Tourné Albite	89 % 91 % 90 % 90 %	— — — —	The combination of 1 with the other lamellae does not give a twinning law, except for 1—2 and 1—8. 5 is quite independant of the others.
II	1—2	Pericline	90 %	60 %	
III	1—2	Carlsbad A	91 %	58 %	
IV	1—2	Pericline	89 %	59 %	
V	1	—	85 %	59 %	Measured with regard to (010) and (001).

The plagioclases in the groundmass reach a length of 0.5 mm. at the utmost and are lath-shaped. Notwithstanding their small size the greater number show polysynthetic twinning. With the U-stage the following twinning laws and compositions were obtained.

Ind.	Lamellae	Twinning law	Percent. of An.
I	1—2	Albite	57 %
I	2—3	Roc Tourné	56 %
	1—3	Carlsbad A	56 %
II	1—2	Roc Tourné	58 %
III	1—2	Roc Tourné	59 %
IV	1—2	Roc Tourné	59 %
V	1—2	Carlsbad A	58 %

The result shows that the composition of the border zone of the phenocrysts is the same of that of the groundmass plagioclases. From this we may conclude that the border zone and the groundmass plagioclases are contemporaneous products of the effusive phase.

THE QUARZ-PORPHYRY-SERIES.

A. The Quarz-porphyries. (fig. 35).

The microscopic examination of sixteen slides prepared from different exposures of the quarz-porphyries, combined with observations made in the field, permits the statement that the eruptions which produced these acid lava's occurred during one uninterrupted period of volcanic activity. Though the outward appearance of the quarz-porphyries shows differences in colour and in the manner of weathering, we are sufficiently certain of their belonging to one and the same period of effusion, because of the many points which they have in common. It is nevertheless certain too, that they did not come to the surface as one sheet, in the same manner as was probably the case with the granophyre in the Southern parts. Several lavaflows must have come

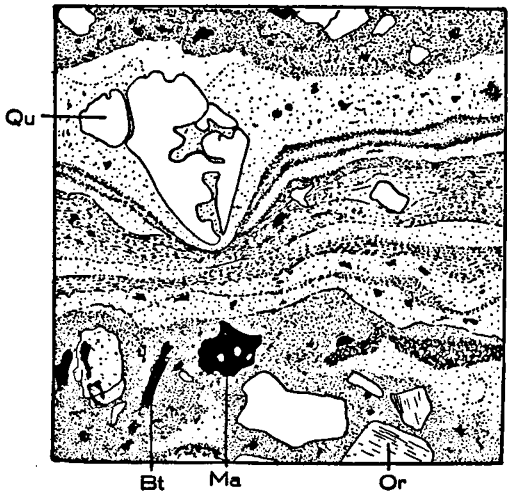


Fig. 35.

Quarzporphyry.
Fluxion structure.
Ordinary light. 20 ×.

to the surface at different localities, while the effusive phase occasionally made place for an explosive activity, as can be derived from the presence of vitric tuffs in between the layers of quarz-porphyry. Although I did not succeed in tracing the exact borders of the different flows in the field, so much I could gather from my observations, that the flows occur the one beside the other, as well as the one on top of the other, each sheet thus occupying a more or less confined part of the whole area.

So as not to loose one self in the description of minor differences en details, it will be better to describe the quarz-porphyries as a whole, although they may vary even in different exposures of one and the same flow.

Together with the already described felsophyre, the quarz-porphyries represent an excellent example on which felsitic texture can be studied in all its varieties, beginning from the very first initiations of devitrification, which pass in various manners into coarse crystalline textures. It is but rarely that each of these stages in the process of devitrification occurs on itself. Usually coarse- and finegrained textures are found together, while many times a cryptocrystalline mesostasis is found in between, part of which still seems to be glass. In some cases it is difficult to ascertain wether the felsitic groundmass is a result of direct crystallization or of devitrification, especially when miarolitic cavities occur, which are alway confined to strained broad bands indicating flow structure. It seems to me to be almost inconceivable that these should be the result of glass becoming crystalline.

The following minerals are found in these rocks as phenocrysts.

Quarz in corroded crystals reaching a diameter of 3 mm. It contains inclusions filled with fluid.

The orthoclase has the same dimensions as the quarz and is observed both in angular fragments and corroded. It shows a distinct cleavage // (001), less so // (010). Twinning is frequently observed following the law of Carlsbad.

Brown biotite is found to abound in some of the flows only; in others it plays a minor part, while some of the biotite found in this rock is evidently derived from the micaschists, of which rock numerous small inclusions occur. The biotite of the schists is usually bleached to an almost colourless mica, while that which belongs to the quarz-porphyry itself is idiomorphic and more fresh, being only partly altered into limonite.

Zircon is only found sporadically within the biotite, while magnetite occurs in variable quantities. Some of the flows are almost free from ore, while others are very rich, especially those quarz-porphyries which are rich in biotite.

Of apatite I did not find one individual in all the slides.

The groundmass shows, as has already been stated, considerable varieties.

In a pink coloured quarz-porphyry from the South-Western slope of the Mte. la Nave, which is nearly free from biotite and magnetite, the following was observed.

The structure is slightly fluxional, more as a result of the arrangement of the phenocrysts, than because of the structure of the groundmass itself. The latter is very clear in ordinary light. Between crossed nicols a felsitic texture is observed, showing a great number of minute angular crystalline grains, probably of quarz, lying within a "groundmass" showing very feeble double refraction. Occasionally the texture of this mesostasis shows a tendency to the spherulitic. Some strained parts show this texture more distinctly. The borders of the spherulites are set off with larger, irregularly shaped individuals, chiefly of orthoclase, judging from their dusty appearance. A further stage of devitrification is observed in a sample of the same rock where the numerous angular crystals begin to touch eachother, the mesostasis of weakly birefringent "glass" playing a far more subordinate part. In another example the groundmass appears to consist chiefly of quarz-orthoclase pseudo-spherulites, interspersed with comparatively large round grains of orthoclase and quarz.

In a quarz-porphyry from the Mt. di Castelvecchio (fig. 35) the fluxion structure is much better developed. In this rock bands rich in limonite alternate with others showing only a brown transparent colour. The former have been devitrified to a finegrained mass of quarz and orthoclase; the latter show a coarse crystalline texture of well developed pseudospherulites: along the borders of these bands the pseudospherulites pass into eachother, an uninterrupted fibrous borderzone being the result. When the strained band is narrow the two borderzones touch eachother; when it broadens the remaining room is occupied by pseudospherulites of quarz and orthoclase. Occasionally these strained bands contain miarolitic cavities in between the pseudospherulites, in which the thin prisms of orthoclase protrude with well defined crystal planes, the cavities themselves being occupied by one or more grains of quarz, or with zeolites.

In a slide prepared from another exposure of the same rock I observed the same coarse grained strains showing a microgranitic texture. In a quarz-porphyry from the neighbourhood of Grantola (tunnel of the ralroad Cunardo-Grantola) the texture of the rock is wholly microgranitic with a tendency to become granophyric. The orthoclase shows idiomorphic long prismatic crystal forms, the interstices being occupied by quarz.

Other quarz-porphyries show a wholly spherulitic texture; the pseudospherulites occurring either independantly within the groundmass, or forming a border round the phenocrysts.

Vitric quarz-porphyry-tuff. San Paolo, North of Cugliate.

This rock is of a brown red colour and contains „phenocrysts" of orthoclase, quarz and biotite. Under the microscope the „groundmass" appears to consist of crystal fragments of the above mentioned minerals and of volcanic ashes showing spherulitic devitrification, whereby limonite has been secreted.

Amongst the inclusions those derived from the micaschists abound, while porphyritic fragments are not altogether rare.

Vitric tuff from Mesenzana (fig. 36).

This rock has the same colour as the one mentioned before, but only contains a few small "phenocrysts" of quarz and a zeolitised felspar. It consists wholly of well bedded vitric material which, because of its form and shape being different from the typical ash structure, could also be called pumice. Within some of the larger fragments idiomorphic individuals of a fresh green biotite occur, enclosing apatite and zircon. All the vitric material has been devitrified showing an even-grained microfelsite, the chief constituent of which may be quarz. The mass in between is limonite, while calcite is found in small quantity. Inclusions of micaschist and porphyrite occur, but are not abundant.

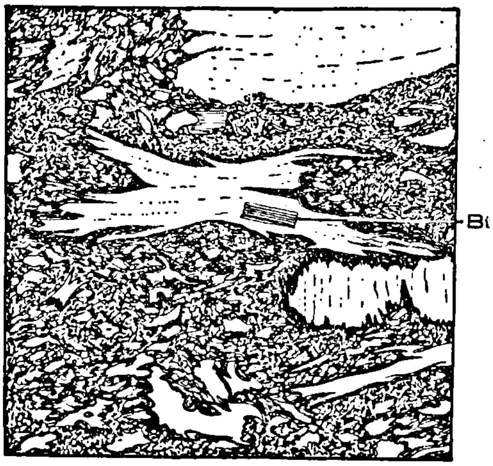


Fig. 36.
Vitric tuff.
Ordinary light. 20 ×.

The inclusions occurring in the quarz-porphyries and their tuffs are derived from the following rocks: micaschists, porphyrites, felsophyre and vitrophyre. These inclusions, especially those of the micaschists, reach dimensions as large as a fist, while those of the other rocks are usually only recognised under the microscope.

B. THE BASIC ROCKS OF THE QUARZPORPHYRY-SERIES.

Augite-porphyrite. Cavoiasca (immediately underneath the Werfenian)..

Megascopically the rock is greenish-grey in colour, showing greyish-white phenocrysts of felspar in an aphanitic groundmass.

Under the microscope the following minerals are observed as phenocrysts.

Plagioclase, showing polysynthetic twinning. It is partly wheathered to zeolites. A measurement with the U-stage of five individuals gave an average of 53 % of An.

Pseudomorphs after a mafic mineral, most probably augite, are found. This mineral has been altered to villarsite, serpentine, zeolites and calcite. The villarsite protrudes from the borders and from the original cleavage-cracks of the augite, the remaining space being occupied by one or more of the other secondary minerals mentioned.

Grains of rutile are visible in the villarsite.

The groundmass consists of a devitrified glass, partly changed to limonite, wherein minute plagioclase laths and small crystals of the same altered augite show off clearly.

No accessory constituents are observed in this rock.

Augite-porphyrite. Derzaga.

Megascopically this rock is greenish-grey and does not show any phenocrysts.

Under the microscope it appears that the rock as a whole has undergone an intensive zeolitization, as far as the felspar constituents are concerned. The plagioclase occurring as phenocrysts and those of the groundmass are altered with preservation of the original twinning.

A dark mineral, probably augite, has made place for a mass of light green serpentine and calcite. The same mineral is observed in the groundmass, the texture of which is slightly fluxional.

Augite-porphyrite. Near Casa Chini; SW. slope of the Mte. la Nave.

The same that has been said for the rock just mentioned applies also to this rock, only that no serpentinization of the augite took place, but an intensive chloritization. Chlorite is found throughout the whole rock showing well developed minute spherulites. This rock also contains amygdales filled with zeolites and chlorite.

VI. THE EQUIVALENTS OF THE QUARZPORPHYRY-SERIES IN THE TRESA VALLEY.

In the Tresa-valley no trace of the quarzporphyries and their tuffs is found.

Another complex, consisting of basic eruptiva, is found taking its place.

These rocks are found on top of the felsophyre and consist of alternating lavasheets and tuffs, the latter prevailing more and more in the higher horizons and resembling the older red tuffs very much, but for the small amount of mica that is found in them.

At the base of this complex a thick sheet is found of a porphyritic lava which is full of gass-pores reaching diameters of two centimeters and more, filled usually with a chloritic mineral and chalcedony. I have called this rock an Amygdaloid.

Amygdaloid. Tresa-valley, to the South of the Dogana Fornasette Svizzera (fig. 37).

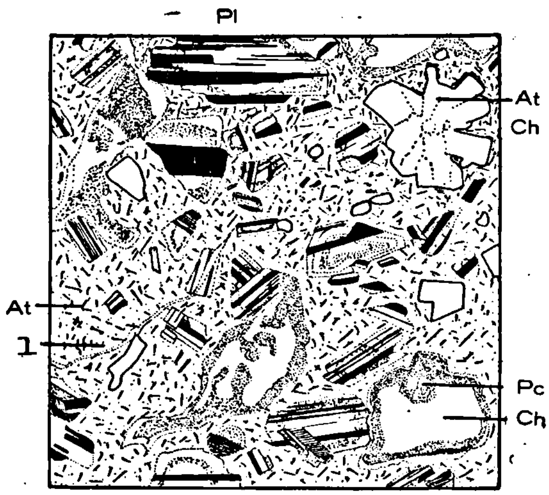


Fig. 37.
Amygdaloïd from the Tresa-valley.
1 = devitrified glass base.
Nicols + for the Plagioclase. 20 ×.

The constituent minerals are plagioclase and augite.

The plagioclase phenocrysts are partly altered to zeolites. Some of them show intensive sub-zoning; no mainzones are observed [1]). Measurements with the U-stage gave the following results.

[1]) CH. HARLOFF. Zonal structure in Plagioclases. Leidsche Geolog. Mededl. Dl. 2; V, 1927, Pag. 99—114.

Ind.	Lam.	Twinning law	Percent. of An.
I	1—2	Albite	63 %
II	1—2 1—3 1—4 2—3 2—4 3—4	Ala A. Manebach Scopi Scopi Manebach Manebach-Ala A.	63 % 64 % 64 % 63 % 64 % 63 %
III	1—2	Carlsbad A.	65 %
IV	1—2	Albite-Esterel	67 %
V	1—2	Albite	65 %
VI	1—2	Carlsbad A.	65 %

The augite has wholly disappeared and has been replaced by chalcedony. It shows off clearly against the grey groundmass because of a sharply defined border of limonite.

The groundmass consists of a devitrified glass, wherein numerous

Fig. 38.

Amygdaloïd from the Tresa-valley. Amygdales coated with limonite. Pseudomorphs of serpentine after Augite. Nicols + for the Plagioclase. 20 ×.

microlites of felspar and augite are found, the latter also replaced by chalcedony.

Within this groundmass large amygdales are found (Plate 34*a* and *b*, Plate 35*a*). They show irregular forms and are filled up with chalcedony and a dark green variety of prochlorite showing the wellknown wormlike strings of six-sided tablets.

In some of these vesicles I found chlorite, zeolites, occasionally also calcite and quarz.

Higher up however the same rock is found without the large amygdales, only small vesicles are still visible.

Here the gass pores were coated with hematite which was subsequently altered to limonite; the remaining room was filled with a little chalcedony and much chlorite.

In this rock the augite is not replaced by chalcedony but by a brown green serpentine (fig. 38).

Augite-porphyrite.

This rock resembles the one described from Cavoiasca.

Phenocrysts of plagioclase and augite are observed in a groundmass consisting of microlites of the same minerals. The plagioclase has an average composition of 54 % of An.

There are two kinds of augite: an orthorhombic, namely hypersthene, and a monoclinic.

The orthorhombic pyroxene has undergone a remarkable alteration, namely to brown, occasionally to green biotite.

This mineral has replaced the pyroxene in such a way that each crystal is altered to one individual of biotite. in which remnants of the original occupant are observed in the shape of smaller and larger grains. The pleochroism of these grains is from colourless to a pale pink, the extinction is symmetric, which points to this pyroxene being hypersthene.

The monoclinic pyroxene, namely diopside, is rarely observed as a phenocryst, but it occurs in great number within the groundmass in minute crystals, together with plagioclase and magnetite.

Vitrophyre.

This rock has a grey-black colour and contains large amygdales filled with chalcedony and agate. It is especially the latter that fills many cracks in the rock, and, where these cracks widen, beautiful pieces of this agate can be collected, reaching dimensions of one dm. in diameter. Under the microscope it appears. that more room is occupied by the gass pores than by the intervening glass base which has become devitrified and subsequently partly chloritisized.

A few phenocrysts of plagioclase are found with a composition of ± 44 % of An. No mafic constituents are present.

The microscopic gass pores are drawn out, thus causing a well developed fluxion structure. They are either coated with a dark green chlorite, or by hematite which is altered to limonite.

Inclusions of garnet, probably derived from the fundamental schists, are not rare.

Vitrophyre (fig. 39).

This rock is darkbrown in colour showing parallel light brown bands each of ± 5 mm. in width.

Fig. 39.

Amygdaloïd Vitrophyre.
Bands rich on limonite with gass pores.
Fluxion structure.
Ordinary light. 20 ×.

Under the microscope the dark brown bands appear to consist of limonite with numerous irregular gass vesicles, filled either with chalcedony or zeolites.

The intervening transparent glass shows a microfelsitic devitrification and contains a few small phenocrysts of felspar. Apatite is found occasionally.

The red tuffs.

These rocks alternate with the brown vitrophyric lava just described. They are of a red brown colour.

Under the microscope the rock appears to be a lithic tuff.

The bulk is occupied by dark brown inclusions of vitrophyric lavas and porphyrites, together with such derived from the schists.

Quarz and zeolitised felspar are found in between these fragments.

The matrix consists of undefineable limonitic matter.

Vitrophyric tuff.

In the first chapter I made mention of this rock occurring in large boulders in a little tributary of the Tresa, to the South of the Dogana Fornasette Svizzera.

This rock is of a dull black colour and shows many plagioclase phenocrysts.

Under the microscope the following constituents are observed.

Fragments of a devitrified vitrophyre, containing phenocrysts of plagioclase, apatite and zircon.

Fragments of crystals of plagioclase, brown biotite, apatite, magnetite and zircon. Corroded quarz is only occasionally observed.

The groundmass consists of devitrified volcanic ashes and minute splinters of the minerals mentioned.

On the bank of the Tresa I found boulders of rocks which I was not able to find *in situ* among the lavas and tuffs just mentioned. They cannot have been transported from elsewhere by the Tresa, because no eruptiva occur more to the East. They are porphyritic rocks. Judging from the spot where they were found as boulders, they probably repose on top of the augite-porphyrites.

Augite(?)-porphyrite (fig. 40).

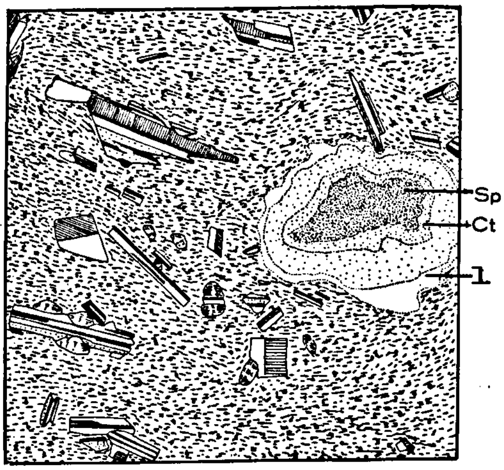


Fig. 40.

Porphyrite boulder in the Tresa-valley. 1: Chalcedony.
Nicols + for the Plagioclase. 20 ×.

This rock has a light grey colour and shows phenocrysts of felspar. It contains amygdales filled with a pale green mineral.

Under the microscope the following constituents are observed as phenocrysts.

Plagioclase in large polysynthetic individuals with an average composition of 67 % of An.

A mafic mineral altered to serpentine, probably an augite.

Accessory constituents are apatite and magnetite.

The groundmass consists of the same constituents with a subparallel arrangement, thus showing flow structure.

The gass pores are filled with chalcedony, a mixture of chalcedony and chlorite, chlorite and serpentine.

Porphyrite (fig. 41).

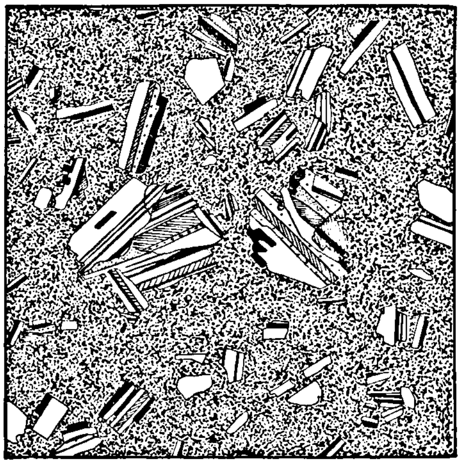


Fig. 41.
Porphyrite. Boulder in the Tresa-valley.
Nicols +. 20 ×.

This rock only contains phenocrysts of plagioclase lying within a groundmass consisting of plagioclase laths and a dark mineral which has been replaced by chlorite and calcite.

The average composition of the plagioclase is 68 % of An.

Accessory minerals are apatite, magnetite and zircon.

CHAPTER IV.

TECTONIC GEOLOGY.

The tectonic geology of the regions investigated may well be called complicated. The geological map and the sections show that these complications are caused by numerous faults, especially in the valley of the Grantorella and in the Tresa-valley. In the latter matters were so complicated, that I deemed it advisable to add a special set of sections together with two block diagrams, to render my interpretation of the map more clear. Considered as a whole, these regions form a syncline in the South-East with an anticline to the North-West, the axes of both stretching in a direction NE—SW.

The syncline is divided into three parts by faults which must have come into existence during a rather early phase of the folding process, as each of the parts shows a structure which is more or less independant of that of the others.

The first of these parts consists of the complex of the Mte. la Nave. It is separated from the next one, that of the Mti. di Castelvecchio, by the fault running through the valley of the Lisascora, along which fault the downward vertical displacement of the Northern part with regard to the Southern one increases towards the North-West. This fault can be traced along the Piana river, bending slightly towards the East, crossing the Grantorella at right angles, and probably running in the schists near Bosco.

The fault of the Valtravaglia separates the last mentioned part from the syncline of the Mte. San Martino.

Of the three parts mentioned the Northernmost is bounded on the North-West by a fault, running along the valley of the Rio Campiago, crossing the saddle of the Collo della Nave and bending towards the North, to run parallel with the Rio Vallone.

This probably means that this fault is slightly inclined towards the North, as shown in the sections I and II. (Table 29).

The part consisting of the Mti. di Castelvecchio is bounded on the North partly by a system of faults between Grantola and Bosco, partly by the stratigraphical boundary between the schists and the Sandstone-tuff series near Castendallo and Roverpiano.

The third mentioned part, near Mesenzana, shows no intervening fault between the syncline and the anticline; the axis of the latter may be roughly drawn to connect the Mte. Pian Nave and the Mte. Sette Termini (Bedeloni).

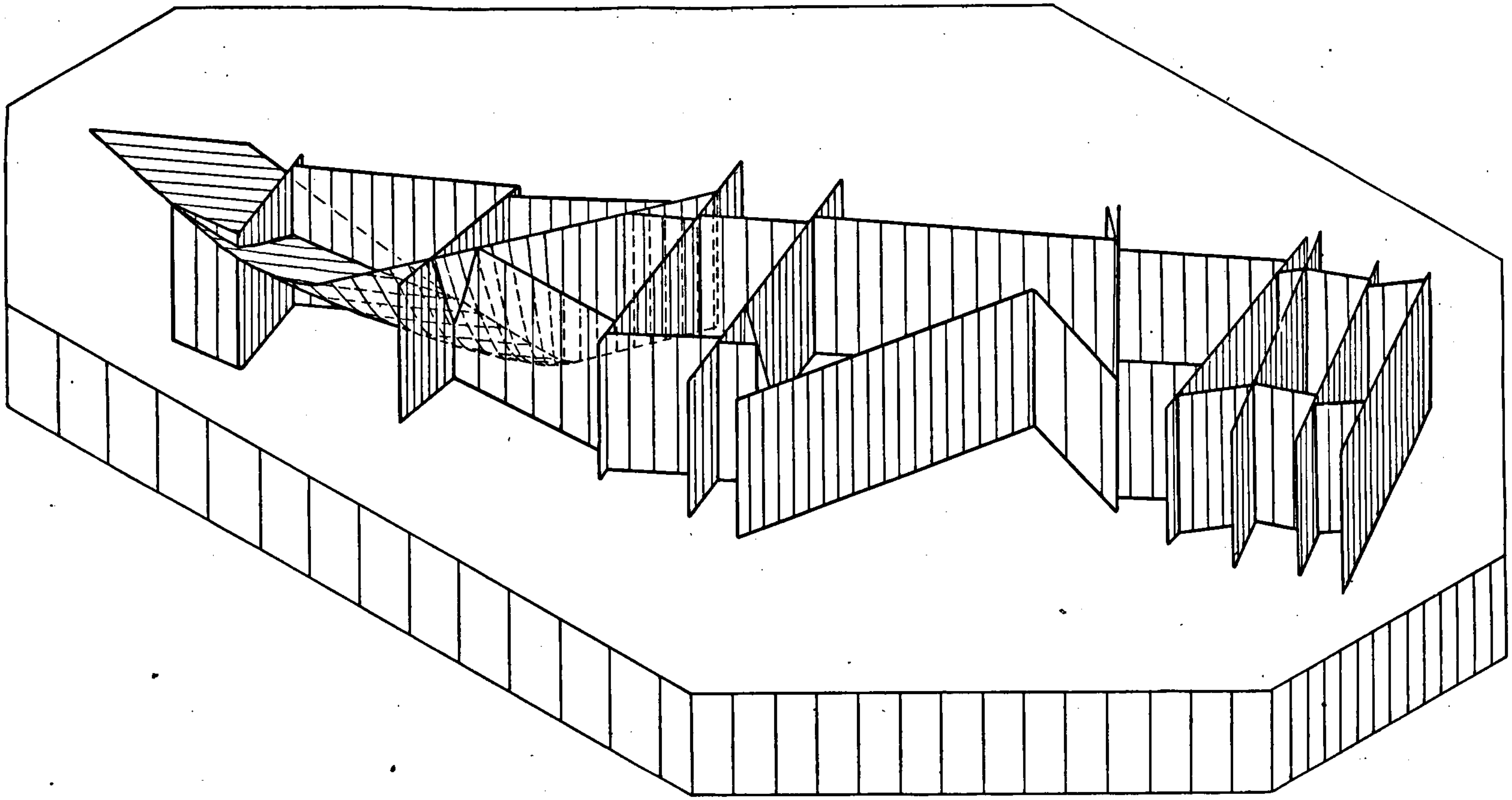


Fig 42.

Scheme showing the complex of faults in the Tresavalley, seen from the North-West.
Scale 1: 25.000.

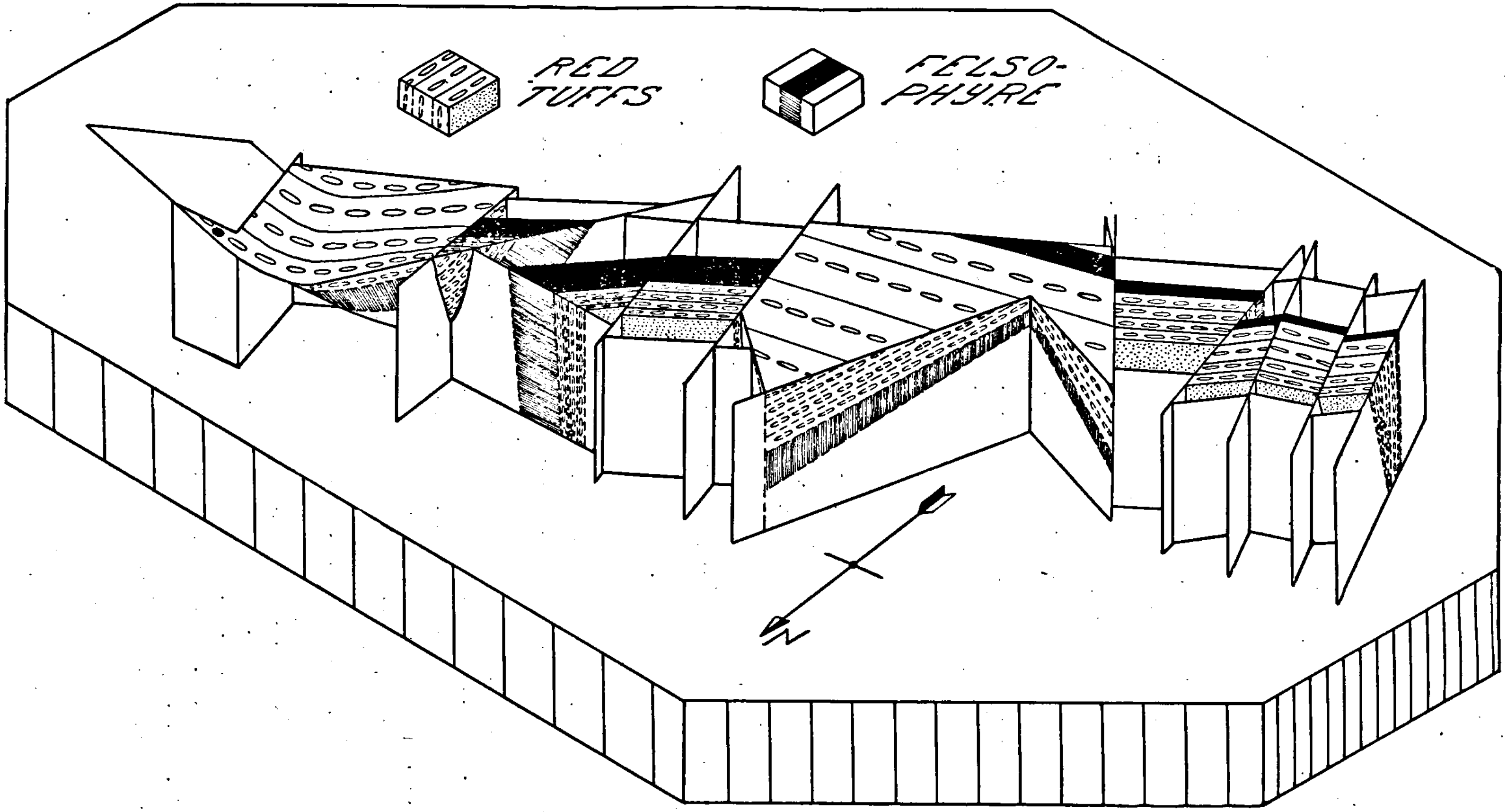


Fig. 43.

Scheme showing the complex of faults with two of the formations: the (older) red tuffs and the superseding felsophyre.
Note the reverse position of these formations in some parts of the valley.
Scale 1: 25.000.

That this part of the country, consisting of the micaschists, must be regarded as an anticline can be derived in the first place from the fact that, in the West, between Roggiano and Brissago, a distinct anticline is observed in the Triadic dolomites, secondly from the circumstance that the Mte. Sette Termini is free of Permian sediments and volcanic rocks. These rocks, originally lying at a high level, because of their being folded into an anticline, were long ago removed by erosion.

That the covering of Permian and Triadic sediments of the Mte. Pian Nave was spared by the erosion is due to the fact that these parts are separated from the more Eastern block by a fault, which runs almost parallel with that of the Valtravaglia. Along this fault the Pian Nave part was sunk, probably over some 100 m. or more, relative to the adjoining part of Mesenzana, without horizontal displacement. Remnants of the Permian sediments, consisting of the red tuffs with conglomerates, are found wedged in between the dolomites and the schists near Roggiano, at Casa Ferrini. This fault may, very probably, be traced further towards the North, running along the valley of the Torrente San Giovanni in the direction of Germignaga.

Further to the North the Permian and Triadic rocks reappear once more. They form a long and narrow tract from the shore of the Lago Maggiore (near Bedero Valtravaglia) to the village of Cremenaga in the valley of the Tresa, the whole reaching a length of about 7.5 km. with an average breadth of some 400 m.

According to STAUB (26) this part forms the boundary between the *Alpides* and the *Dinarides*. From here this boundary bends towards the South along the Lago Maggiore, reaching the other shore near Meina in the South. To the East this boundary is traced by STAUB over Manno, where the wellknown conglomerates of carboniferous age are wedged in between the schists.

This may possibly be true, but I must add that from my own observations in these regions there are no definite conclusions to be drawn that are either in favour of, or against STAUB's supposition.

The micaschists to the North of the complex of sediments in the Tresa valley do not show any difference with those to the South.

Nevertheless it seems to me that STAUB is justified in his opinion, having traced this boundary in analogy with the more Eastern parts of the Southern Alps, where the Dinarides show a better development and where higher parts (in a tectonic sense) are exposed at the surface.

In my opinion the Tresa-complex must be regarded as the lowermost part of a zone of wedged in sediments and volcanic rocks. The two enclosing faults should then diverge slightly in the now disappeared higher regions, finally to become less and less pronounced and to disappear wholly, the sediments of that higher zone being normally folded. It seems to me namely that here, where we find ourselves in that part of the Alps where the Dinarides begin to appear as a separate element, we must not expect to find the boundary of the Alpine arc to be pronounced, especially not in the higher parts.

The main tectonic features of the Tresa-valley can be described as follows, A series, consisting of the fundamental schists and Permian and Triadic rocks, has been placed in an upright position between two large vertical faults: a Northern and a Southern fault. As a result of tangential pressure this complex was at the same time cut into a number of blocks by secondary faults, crossing the first mentioned more or less at right angles, with the result that each of these portions was displaced horizontally, at the same time undergoing alterations as to its upright position, according to the direction and to the force in which, locally, the tangential pressure resulted.

Possibly vertical movements along the faults occurred afterwards as a result of the settling down of the blocks after the relaxing of the pressing forces. In how far such movements actually occurred I have not been able to ascertain, but I believe that the complete overturning of the complex of rocks in some parts of the Tresa-valley (near Ponte Cremenaga, the Dogana Fornasette and Biviglione) must be due, at least partly, to such movements.

I wish to state here that the interpretation of the geological map in the series of sections given on Table 30 and on the two block diagrams on pages 187 and 188 cannot but be subjective, the depth of the exposures not being sufficient to remove doubt. Furthermore the accuracy of the field work was highly influenced by difficulties of the following nature.

In the first place the cover of morainic deposits rendered the mapping of the geological boundaries difficult, at some places even impossible.

Secondly measurements of strike and dip of stratified rocks, as the red tuffs, were not at all reliable. Although good outcrops were available, the presence of numerous slickensides and minor faults, and the fact that sometimes no bedding was visible, owing to their being turned into a mass of red mud by the rains, rendered measurements with the geological compass impossible. The strike and dip given in the sections, have thus been drawn in according to the general directions which I believed to observe in the field.

The overturning of the complex of sediments near Cremenaga (sections 1 and 2) (Table 30) has not actually been observed. The small outcrop of the felsophyre gives in the field the impression that this rock underlies the red tuffs, instead of being an erosion remnant reposing on top of them. The construction of sections in this part of the Tresa-valley, showing the series upside down, has been chiefly based on analogy with the conditions as I found them to the South of the Dogana Fornasette, where I actually observed the felsophyre lying on top of the younger porphyrites and porphyritic tuffs (sections 3 and 4). More to the West the whole complex is observed in vertical position (sections 4 and 5), while near Biviglione the reversed position is once more seen in the sections 6, 7 and 8, although in the field there is no actual evidence of this supposition being right.

Still more to the West good outcrops become more numerous and to the South of Creva and Voldomino the whole complex can be observed to stand vertically (sections 9, 10 and 11). To the East of Creva a large fault separates the schists from the red tuffs. How far this fault can be followed to the South, and whether it must be connected with one of the faults that occur to the South of Creva, or whether it is independant from the other faults, I could not ascertain. Before this fault crosses the Tresa river an isolated fragment of the schists is found alongside of it. This fragment must be considered as having detached itself from the schists nearby, as frequently is the case in a fractured zone.

To the South of Creva the Triadic dolomites, which are absent in the West, begin to become a more and more important constituent.

On the Western side of the Valtravaglia these dolomites are seen in an almost upright position in a large quarry. To the North and to the South this fragment of dolomite is separated from the schists by faults. In the North a small remnant of the red tuffs is found wedged in between the dolomite and the schists.

The hill of la Canonica near Bedero Valtravaglia consists wholly of the Triadic dolomites, also enclosed by faults, while the strike of the vertical layers does not differ from that in the afore mentioned quarry, namely about N—80°—E. [1])

The fault forming the Southern boundary of the whole complex can be traced fairly well in the field. The Northern fault. however runs partly within the schists and could not be followed everywhere, so that its trace on the map is partly hypothetical.

From the fact that, following this tract of sediments from West to East, we find that the dolomites gradually disappear in that direction, that the red tuffs and the felsophyre, on the other hand, begin to appear more and more, we may derive the following.

First, that both the faults intersect the line of the general trend of the rocks concerned at a more or less acute angle, so that in the West the sediments underlying the dolomites. must be supposed to be still present in the deeper parts. The same can be said of the dolomites in the East, where they possibly may be found at still greater depths.

Secondly we may venture the suggestion that another element added its effect, namely that the sinking in between the two faults occurred in such a manner that in the West the sediments must have sunk deeper than in the East, so that we could imagine an axis lying parallel to the trend of the sediments concerned, and in one special horizon (no matter which), to protrude out of the valley of the Tresa, for instance near the Dogana Fornasette, while the other end of this axis should intersect the landsurface far under the level of the Lago Maggiore.

Of the tectonic features of the remaining parts I have already mentioned their being separated into three parts by faults, the trend of which is approximately NW—SE.

The Mte. la Nave part is divided into two halves by a N—S fault along which the Western half underwent a downward movement with regard to the Eastern. On the Southern slope of this mountain several minor vertical dislocations occurred, almost always with the same sense of movement.

In the Mti. di Castelvecchio, where the succession of the constituent rocks can be studied at its best, a fault can be observed running from

[1]) For particulars concerning these parts I refer to the publication of J. VAN HOUTEN, which shortly will appear.

the station of Grantola in a WNW. direction. Here also the evidence points to a subsidence of the Southern part with regard to the Northern.

A small fault, which could not be traced further in the Triadic dolomites, divides this part into two halves, the Western half having sunk slightly relative to the Eastern.

In the South-Eastern part of these hills, to the South of Fabiasco, the felsophyre is exposed over a comparatively long distance. This is a slight secondary anticline in the syncline, which rapidly flattens out to the South. Beyond the intervening Lisascora fault, on the other side of the valley, this small culmination is not to be found, which shows that the folding of each of the parts mentioned must have occurred independantly, so that the Lisascora fault must have come into existence during an early stage of the folding.

The same can be said of the Valtravaglia fault, for the fault of Grantola cannot be traced on the other side of the Valtravaglia: no repetition of the occurrence of the schists and the red tuffs can be observed there.

In the valley of the Grantorella, in the bed of one of its tributaries, the Rio Campiagno, near Casa Righini, the schists are exposed over a distance of some 350 m. A lack of outcrops round this exposure renders uncertain whether we have to deal with a separate occurrence or whether it stands in some connection with other parts of the schists. The interpretation of the occurrence of these schists in section no. III (Table 29) is far from satisfactory, but no field evidence was obtained pointing to some other solution of the problem.

That still many more faults occur in the schists is almost certain but, although I found many zones of crush in this rock, I was not able to trace them over larger distances, chiefly owing to the presence of the morainic cover, but also to the fact that in this case schists are lying against schists.

In the first chapter (page 133) I made mention of exposures of the Permian rocks and the Triadic dolomites along the Western slopes of the Mte. Pian Nave, which could be mistaken as occurring *in situ*. These exposures are the following three and their presence must be explained in another way.

In a river that has its source at Casa Profare, 1,5 km. to the East of Muceno, where it is crossed by the road from that village to San Michele, the whole series of Permian rocks is observed in a reversed order, nearly upside down.

Along the same road, near Casa Collo, the same complex is observed together with part of the dolomites over a distance of about 70 m.

At about the same level, in the river coming down from Casa Profare, exposures of the same rocks are found, but here the red tuffs are seen to be mixed with fragments of felsophyre and dolomite.

Judging from the fact that these three occurrences in the volcanic rocks are always more or less mixed with morainic material, we may conclude that large portions came sliding down from the neighbouring slopes, so that, at first sight, they might be mistaken for blocks separated from the surrounding schists by faults.

This sliding down occurred during interglacial times, as morainic material is also lying on top of them. The eroding force of the Ticino-glacier had a stronger effect upon the soft red tuffs than upon the overlying harder rocks, the result being that, when the ice retreated to the North, large portions of the latter, lacking a sufficient base, slid down over the moraine-covered slopes.

Afterwards the reappearing ice carried some of this material towards the South, together with its own moraine, which accounts for the fact that large fragments of quarz-porphyry are found in the bed of the Torrente Froda, where this rock does not occur on top of the felsophyre.

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(A more complete bibliography, in which the older literature is also included, may be found in LEUZINGER's work).

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Fig. 28. Crystal tuff. Pebble in the conglomerate of Germignaga.

Fig. 29. *a.* Crystallites of monoclinic pyroxene with globulites in groundmass of glass. Enstatite-basaltite.

b. Arrangement of globulites and augite-crystallites in the groundmass of Enstatite-basaltite.

Fig. 30. Basaltite from Casa Demenech, Tresa valley.

Fig. 31. Position of the Index-ellipsoid with regard to the crystallographic elements of allanite in the vitrophyre from Grantola.

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Fig. 34. Hypersthene basaltite.

Fig. 35. Quarzporphyry. Fluxion structure.

Fig. 36. Vitric tuff.

Fig. 37. Amygdaloid from the Tresa valley.

Fig. 38. Amygdaloid from the Tresa valley. Amygdales coated with limonite. Pseudomorphs of serpentine after augite.

Fig. 39. Amygdaloid vitrophyre. Bands rich in limonite and gass pores. Fluxion structure.

Fig. 40. Porphyritic boulder in the Tresa valley.

Fig. 41. Porphyrite. Boulder in the Tresa valley.

Fig. 42. Scheme showing the complex of faults in the Tresa valley, seen from the North-West.

Fig. 43. Scheme showing the complex of faults with two of the formations: the (older) red tuffs and the superseding felsophyre. Note the reverse position of these formations in some parts of the valley.

LIST OF PLATES.

LIST OF ABBREVIATIONS USED IN THE SLIDE DRAWINGS.

At. = Augite.
Bt. = Biotite.
Cc. = Calcite.
Ch. = Chalcedony.
Ct. = Chlorite.
Ho. = Amphibole.
Hy. = Hypersthene.
Lt. = Limonite.
Ma. = Magnetite.
Mu. = Muscovite.
Ol. = Olivine.
Or. = Orthoclase.
Pc. = Prochlorite.
Pl. = Plagioclase.
Qu. = Quarz.
Sp. = Serpentine.

LIST OF ABBREVIATIONS USED ON THE MAP (PLATE 28).

A. P. = Alpe Paci.
B. = Bosco.
Br. = Brissago.
Bv. = Biviglione.
CdN. = Colle della Nave.
Cl. = Cugliate.
Cm. = Cremenaga.
Cn. = Cunardo.
Cr. = Creva.
Dg. = Dogana Fornasette Svizzera.
F. = Fabiasco.
G. = Grantola.
L. = Luino.
L. Mg. = Lago Maggiore.
M. = Mesenzana.
Mte. B. = Monte Bedeloni.
Mti. C. = Monti di Castelvecchio.
Mte. l. N. = Monte la Nave.
Mg. = Montegrino.
R. = Roggiano.
S. P. = Church of San Paolo.
Vd. = Voldomino.
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1—9 Sections of Plate 30.