THE PORPHYRY DISTRICT OF LUGANO WEST OF THE VALGANNA

BY

PH. H. KUENEN.

With the plates 12—15.

CONTENTS.

I. INTRODUCTION.

During an excursion to the South of Switserland, Professor ESCHER suggested my mapping out the south-western corner of the porphyry district of Lugano. I gladly agreed, for his detailed examination of the Morcote-peninsula had already shown that many interesting facts had escaped unobserved during the small-scale mapping forty years ago; and it was, therefore, highly probable that the projected work would prove fruitful.

The necessary field-work was carried out in the spring of the years 1924 and 1925. The collected material I examined in the geological museum of Leiden, where it will remain in future.

As comprehensive treatments of the history of investigation in these parts can be found elsewhere (bibl. 2, 15) I will not enter into a detailed recapitulation, but only mention the most important facts.

Thus it was on observations made in the porphyry district of Lugano that L. VON BUCH, in the beginning of the last century, founded his well-known theory of the upheaval of mountain-chains, and the dolomitisation of limestone under the influence of igneous intrusions.

Afterwards a controversy ensued as to which of the two types of porphyry, the "red" or the "black", was the older; but although many geologists of name: L. VON BUCH, A. ESCHER VON DER LINTH, B. STUDER and others gave their opinion, it was only after a long time and by slow degrees that the "red" or "quartz" porphyry was recognised as the younger.

The first good map published, on which the porphyry district of Lugano appears, was Sheet XXIV of the Swiss DUFOUR-atlas 1:100.000 by NEGRI, SPREAFICO and STOPPANI in 1876 with a descriptive text in 1880 by TARAMELLI.

By far the most important contribution, however, was given by HARADA in the eighties, a pupil of ROSENBUSCH. It was not his mapping that added much to the knowledge already obtained for he spent only one month in the entire district. But his microscopic investigations, almost the first ever made upon these rocks, were excellent.

At this period the following facts had been ascertained. The igneous rocks are of Permian age as proved by the absence of porphyry or tuff pebbles in the Carboniferous conglomerate of Manno. They have been exposed over an area of more than 100 square kilometers around and to the west of the lake of Lugano, where they had been denuded of their Mesosoic covering. Their base is formed by crystalline schists of unknown age. Deepest lies a composite sheet of porphyrite that is covered by a great flow of quartz-porphyry, fed by a number of dykes. In the north-western parts a different kind of quartz-porphyry and a quartz-phorphyritic tuff occur. The largest mass is bounded on the north by a great vertical fault; to the south the Permian rocks dip away under the Mesosoic sediments.

So exhaustive were HARADA's investigations that nothing of importance concerning the porphyries was discovered for the next thirty years. In 1910, however, ESCHER showed that a revision had at last become desirable, especially as excellent small-scale topographic maps were now available. This will be readily admitted on perusing his provisional note (bibl. 14) which, short as it is, contains many new observations. Of great importance was the proof that a large part of HARADA's "porphyrite" is in reality tuff and that the nature of the quartz-porphyry-dykes is different from what HARADA imagined.

In the meantime RIVA gave a petrographic description of the crystalline schists and their contact-metamorphism adding a few remarks on the porphyries.

A recent publication of importance to our subject is that of KELTERBORN on the Malcantone, a tract of country west of Lugano (bibl. 20). It is occupied mainly by the ancient crystalline schists but some dykes and important outliers of the Luganese Permian rocks are also exposed together with the Carboniferous conglomerate of Manno.

In the sequel reference will be made to the work of KAECH (bibl. 9) on the Permian igneous rocks of the Lago Maggiore that may be looked upon as part of the same volcanic tract, as may also the porphyries near Bozen (bibl. 11).

The topographic basis for my field-work was formed by the tavolette Arcisate, Gavirate, and Germignaga of the Foglio 31 of the Carta d'Italia, scale 1:25.000, (to be procured from: Instituto geografico militare, Ufficio smercio, Firenze). On the whole these are excellent, although the rock-drawing and a few minor details are less carefully treated and the new military roads are not yet drawn in. All names and heights referred to in the text are to be found on these maps.

The part of the porphyry-district that forms the subject of my investigations is of triangular shape. The northern boundary is formed by the great fault already mentioned, running from Cabiaglio over Bédero to Ghirla and thence on to the Lago di Lugano. The second boundary runs from Cabiaglio along the northern slopes of the Campo dei Fiori to Rasa and then over the M. Chiusarella to the eastern Olona in the southern continuation of the Valganna. The latter large valley forms the third side of the triangle, running southwards past Ganna from Ghirla.

The sedimentary terrains along the northern and most of the southern border are being examined by P. LEUZINGER of Bale University; while those eastward of the western Olona have already been dealt with by Dr. A. SENN, another pupil of BUXTORF; and by A. FRAUENFELDER of Zürich. The Permian rocks that join on directly to the east form the subject of the dissertation of my fellow-student L. U. DE SITTER, that is appearing in the same number of "Leidsche Geologische Mededeelingen"; while CH. HARLOFF, also of Leiden, has begun an examination of the porphyries and tuffs of the M. la Nave and the valley of the Tresa, further north. Our constant interchange of thought makes it impossible to unravel mutual plagiarisms.

The block-diagram was constructed from the topographic map, using the contours in the manner described by A. K. LOBECK ("Block diagrams" 1924, p. 140). The vertical and horizontal scales are both 1:20.000. Of the parts lying outside the field of investigation, as for instance the Valcuvia in the foreground, the general outlines are given as far as indicated by the map. In the parts I visited, details have been drawn in from field sketches and memory. The dolomite ridges on the Campo dei Fiori are somewhat exaggerated.

The drawings of slides were made on rough outline sketches, obtained by using a micro-projection apparatus.

To CH. HARLOFF I am endebted for the excellent micro-photographs.

II. GEOMORPHOLOGY AND SOME REMARKS CONCERNING GLACIAL GEOLOGY.

(See block diagram).

The igneous rocks under consideration form the deeper core of the great Campo dei Fiori anticline where it has been laid bare by erosion. The contrast between the round inexpressive forms of the volcanic material and the sharp, craggy shapes that the calcareous and dolomitic sediments have assumed is in general very marked, especially along the southern side. Consequently the position of large parts of the latter may be seen from a distance while the former generally have to be chipped with the hammer before certainty as to their nature at any given point can be obtained. Thus the hard sandstone of the Werfénian and the Triassic dolomites form continuous ridges along the northern slopes of the M. Chiusarella and the M. Campo dei Fiori, but of the alternations of pyroxene-porphyrite, tuffs and dykes lower down nothing can be seen from a distance. Only where the slopes are bare and steep the red colour of the granophyre affords an indication, and some of the dykes stand out in relief.

As the topographic conditions are due to the enormous glacial erosion we will begin with a description of its effects. The most striking feature of the landscape is the peculiarity of its valley system. Instead of finding trunk-valleys branching off into smaller and smaller tributaries becoming steeper as they diminish in size, which would be the case if they had matured under the influence of running water, we meet with the deep open trough-valleys typical of ice-erosion. The flat horizontal bottoms are covered by fluviatile drift with marshes and a small trickle of water; the walls by screes with alluvial fans in between, Another abnormal feature is the occurence of watersheds in the valleys. These, however, are so slightly marked that they cannot be located when looked at from above.

The most important valley in these parts is the Valcuvia. It starts on the Lago Maggiore at Luino as a branch of the great Ticino valley of which the lake forms a part, and running south sweeps round the foot of the M. San Martino to join the Lago Maggiore again at Laveno. The bottom of this broad trough is about 250 m. above sea level, so that its glacier was small in comparison to the main trunk, that reached down below sea level (300 m. thicker).

Three tongues of the Valcuvia-glacier entered the region under consideration. The most northern one branched off at Ferrera and flowing round the M. Scerre and M. Mondonico passed by Ghirla into the Valganna and thence further south, to Varese. South of the M. Minisfreddo a small branch was sent off in the direction of Arcisate, and during the stronger glaciation another over the pass north of the Poncione di Ganna. The next tongue occupied the valley south of the M. Mondonico and met the first at Ganna. The third came over the ridge to the north-west of Cabiaglio and passing along the northern slopes of the M. Campo dei Fiori bent round between the M. Legnone and M. Chiusarella to join the Valganna-glacier some distance further south. The bottoms of these diffluent valleys hang from 200 to 250 m. above that of their feeder, the Valcuvia.

It seems likely that ice came also from the western parts of the Lago di Lugano, following the valley of the Tresa to the Valcuvia, and the low ground in front of the M. Piambello, to flow off through the Valganna and perhaps even the Valcuvia. The amount would be difficult to estimate, for it too was Ticino ice, from Bellinzona (bibl. 12, p. 781) and therefore transported the same erratics.

During the height of glaciation, however, most ice-sheds were submerged and only a few ridges formed nunataks above the enormous waste of flowing ice. The M. Mondonico and M. Legnone were entirely covered; the only parts found to be free of moraine are the summit of the M. Campo dei Fiori and the ridges from the M. Martica to the Chiusarella with a branch in the direction of the C. della Miniera and from the M. Piambello to the Sasso del Corno, interrupted north of the Poncione di Ganna, where they reach higher than 900 m. above sea level.

From data given by KELTERBORN (bibl. 20, p. 134), SENN (bibl. 21, p. 610) and FRAUENFELDER (bibl. 17, p. 340) concerning the maximum height to which the ice reached in adjoining parts, it would seem that the slope ran exclusively from north to south. This renders the origin of some valleys with an east-west trend, as that of the Tresa, even more obscure. From M. Torri in the Malcantone to the M. Martica the gradient was 1.2 % and from thence to the terminal moraines at Varese 5—6 % (for southern border of ice see bibl. 18, map opposite page 214), so that the glacier's surface at the lower end was convex, thus conforming to the rule. PENCK and BRÜCKNER (bibl. 12, p. 783) give the average gradient in these parts as 2—2.5 %.

Now that the ice has disappeared the watershed in the Valganna is formed by the very flat delta of the Valle Castellera, the water of the stream draining off in both directions principally underground. Just opposite this delta branching off in the direction of Arcisate is a fine U-shaped diffluent valley, the ground-moraine of which is marked on SENN's map, hanging about 200 m. above the main truck[1]).

Just south of the Casa della Miniera a frontal moraine has

[1]) Compare DAVIS' drawing p. 445 of "Die erklärende Beschreibung der Landformen" (1912) of the hanging valley of the M. Cenere south of Bellinzona.

been left, and at the southern end of the L. di Ghirla also, while around Ganna the remains of a larger one may be seen, covering the bottom of the valley over a length of almost one kilometer. Probably owing to water erosion during the final stages of its development the top is practically flat and horizontal. There is a low ridge between the stream coming from Pralugano at the point where it is being forced to the north by the delta's at the foot of the M. Martica on one side, and on the other the Margorabbia running northwards with a wide sweep out of the Lago di Ganna. It may either be a separate terminal moraine, or an erosion remnant belonging to the fluvioglacial drift in front of the moraine of Ganna, but in any case the present steep inside of this sickle shaped tongue is due to erosion of the Margorabbia.

Obviously these Valganna-moraines belong to the last manifestations of glacial conditions, when the receding glacier halted or even readvanced a little before drawing away altogether. Later these structures have been seriously attacked by the little rivers that drain away the water to the north and south.

Of the two small lakes, L. di Ganna and L. di Ghirla, which were looked upon at the end of the eighteenth century as craterlakes (bibl. 1, p. 2), the former, no more than a slight depression in the valley bottom, is shallow and is rapidly being filled up by the growth of vegetable matter, whereas the latter, a deep basin behind the terminal moraine just mentioned, is only being slowly encroached upon by the growth of a few delta's.

The valley of Pralugano must formerly have contained a lake, but it is now occupied by a large, boggy basin of peat. Towards its western end it is somewhat higher and a small terminal moraine has been preserved (point 473). Along the southern wall a trough shoulder may be traced, that shows up most clearly while the sun is setting. Starting opposite the moraine, just mentioned, at about 500 m. it rises slowly to nearly 600 m. above the L. di Ganna where it becomes indistinct.

Although the third glacial valley has been greatly altered, northwest of Brinzio, by postglacial erosion the original flat bottom can be traced as far north as Mlo. dei Gaggioli where it met at right angles a slight depression behind the ridge that separates it from the Valcuvia. A sudden downward bend in the spur between the Vle. Gallina and the Vle. Buragona north of the M. Chiusarella marks the position of a former shoulder at an altitude of approximately 700 m., where it is also indicated by the contours of the map.

On the eastern slope of the M. Legnone a ridge occurs starting at pt. 701 and running some small distance to the south. By the position of the rocks, especially the Werfénian, it was possible to prove that the whole mass, roughly estimated at ½ million m^3., has slid from the gap in the dolomite crag 100 m. above it. Undoubtedly the glacial overdeepening of the valley is the cause of this small land slip.

The mountains themselves have the shape of large "roches moutonnées", the M. Mondonico presenting the best example; and along the north-western boundary of the volcanic rocks runs a strip of land bearing small specimens generally quite steep, only a few meters high and from 20—200 m. apart. The hollows in between are often filled with boggy material. The finest examples may be seen between pt. 631 and pt. 633 west of Roccolo, and the country directly south of the road Ganna-Bédero opposite pt. 473.

According to FRAUENFELDER (bibl. 17, p. 342) the glaciers had practically no influence in modeling the present contours of the country round Lugano; but when the geomorphological evidence is taken into consideration I find it impossible to accept this view.

As no detailed study of the moraine material was made a few remarks must suffice. Most common is a typical boulderclay, consisting of a yellow clayey quartz sand, in which are embedded the erratics varying in size from minute fragments to blocks of many cubic meters. Most of the larger blocks, however, were carried along on the back of the glacier, for they are little rounded although almost without exception belonging to Alpine gneisses coming from a distance of 100 k.m. or more; and many lie as perched rocks on top of the ground-moraine. The latter on the other hand seems for the greater part to be built up of local material, taken up, ground down and deposited again within quite a short distance. Thus the moraine contains a great many granophyre blocks where it lies on the granophyre, but on passing onto darker rocks they begin to disappear almost directly and soon become scarce. The same is seen in relation to the calcareous sediments; these can however be traced further as constituting part of the matrix. Here and there it can be observed how the local material is less rounded off than the matter transported from further away.

FRAUENFELDER (bibl. 8, p. 339), KELTERBORN (bibl. 2, p. 135) and SENN (bibl. 3, p. 612), describe the moraine as fluvio-glacial, but I am inclined to attach less importance to the action of running water in my field of investigation. I did not find local terraces and bedding as observed by them, and although the stones in general are not striated the dolomite and limestone blocks usually are. This softer material would have lost its striation during aqueous transport. Gneiss and porphyry bear no glacial markings because they are far less susceptible material, being coarse-grained and not changing colour where they are scratched as the dark sedimentary rocks do.

SENN was able to distinguish two moraines of different age, the younger being less weathered and containing striated chalk boulders, and being deposited only east of the Valganna. I have observed no such devision, for deposits that can be proved to be the youngest (terminal moraines for example) contain totally weathered gneiss blocks, and the older (on the higher slopes) blocks only little altered. In this way the difference in durability of the various types of rock makes it exceedingly difficult to form an opinion on their relative age; and I venture to suggest that SENN's devision is not one of age but of contents: one with, and one without calcareous matter. This may have had a conserving influence on the inclusions by hindering the percolation of water. To me it seems more likely that the difference in their composition is due to their positions, and not as SENN believes to the difference of their age.

The glacial deposits cover about half of the total area. Generally they are not more than a couple of meters thick, although in some depressions they attain to 10 m. and more. On the rounded ridges running north they are frequently quite thin, the bare rock showing through everywhere (south of Cabiaglio, east of the Mlo dei Gaggioli). In the lee of the mountains they do not reach nearly as high as on the north sides, and where the slopes are too steep, as for instance along the Valganna, they have been washed down immediately. In the Valle Castellera no erratic material is to be found, and the shapes are entirely those of running water erosion. This may be understood on considering that the ice coming round the lower end of the spur that devided the valley from the Valganna, must have entered it at the mouth, but being stagnant could not erode nor deposite.

In the Valle Fredda the total absence of boulder-clay needs another explanation. The spur namely that separates the valley from the Valganna is too low to have been responsible for keeping out the ice: it is no higher than the bottom of the diffluent valley of Arcisate just opposite. I imagine the valley was too steep and narrow for the ice to move in it, so that it was filled up with stagnating ice over the top of which flowed the glacier.

The post-glacial erosion must now be considered. In the smaller shapes it is all important, having cut countless narrow steep clefts in the mountain slopes and valley bottoms. While the glacial valleys seem to bear no connection with faults, excepting perhaps the Valganna, these smaller furrows are often found to correspond to lines of disturbance. On both sides of the M. Mondonico for instance the great northern fault has been traced by a small narrow gorge. Also the little stream at K. 11 along the road Brinzio-Bédero follows a fault.

The bed of the little river coming from the M. Martica to Brinzio and running thence to Rancio in the Valcuvia is of complex origin. It starts in a slight basin-shaped depression south of C. Valicci, into which it has carved a narrow deep gorge down to Brinzio, where it enters the broad glacial trough valley down to the depths of which it has cut itself. Just after the confluence with the Brivola and Riazzo it drops down a waterfall of some 15 m. and then follows a sinuous course in another deep incision right down to Mlo. dei Gaggioli. At two points, namely 458 and 431, this cleft is broader though retaining its steep sides. Contrary to what might be expected in a young incision in a glacial valley we find at these points primary ummoved ground-moraine, right down to the level of the river. The parts in between show steep rocky sides. Without doubt a narrow V-shaped valley, that must have been formed during the last interglacial period and then filled up by the glacier, existed to the west of the present course. The winding river on the bottom of the glacial trough then cut down, forming a narrow gorge in the hard rocks and carrying away a large quantity of material where it was eroding the soft boulder clay. Below pt. 431 the present river has worked down deeper than the interglacial one, and no moraine has been left.

The same applies to the tributary coming from Cabiaglio, only the valley must have been deeper as the cutting down into the untouched rock has only just begun. The remains of the two glacial throughs are seen to join at one level, about 50 m. above the present waterline. Again in the last part, the T. Rancina down to Rancio, the postglacial erosion, working quickly from the low erosion basis of the Valcuvia has erased all signs of glacial and interglacial forms. In a like manner interglacial furrows are indicated on the slopes of the M. Campo dei Fiori.

As the larger features of the landscape are so entirely those of ice erosion, these V-shaped valleys cannot be older than one of the last interglacial periods; and their having been preserved proves that the last covering cannot have worn down the country to any marked degree.

Another fact that points to the same conclusion is the comparatively slight deepening of the Valle Castellera and the Valle Fredda by the postglacial erosion (gullies).

A small example of stream-piracy may be seen on the southern side of the former valley, where a postglacial gully has beheaded the left tributary of the Valle Fredda.

III. GEOLOGY.

The structural problems presented by a region occupied by volcanic rocks cannot be solved in such a satisfactory manner as those of a region with sediments, even when the number and quality of the exposures are alike for both. In the former, complications may arise not only from tectonic features but also from irregularities in the distribution of the rocks over short distances; and strike and dip can very seldom be measured[1]). The consequence is that a newly discovered exposure or single new observation may change the conception on any detail or even major feature of the structure. The interpretation I offer in the sequel is therefore not intended as a final conclusion, but only as what seems to me the most likely explanation of my field observations.

On my maps and sections no attempt has been made to subdivide the sediments or give their exact structure as this matter is fully dealt with in SENN's essay on those to the east, and that of P. LEUZINGER, on the remainder of the surrounding dolomites and limestones, which may shortly be expected.

A. Succession and distribution of the rocks. *(See folding out reference page).*

In the first chapter may be found the main facts ascertained by HARADA and his predecessors concerning the structure of the porphyry district, and as no more recent investigations of the western parts have been published HARADA's essay formed the basis of my observations.

That the region round L u g a n o was greatly effected by the Hercynian orogenetic movements is certain, but difference of opinion exists as to the exact period at which these took place. ESCHER (bibl. 13, p. 174) considered that the Upper Carboniferous conglomerates ("Ottweilerstufe") of M a n n o were folded concordently with the underlying crystalline schists but that the younger, and therefore Permian eruptive rocks were later than these older movements. KELTERBORN (bibl. 20, p. 161), however, believes he is able to disprove ESCHER's statement about the M a n n o rocks and asserts that the unconformity is older than the Carboniferous strata. In this case the orogenetic period must have come to an end, not after but during the Upper Carboniferous age.

[1]) For the same reason two sets of sections at right angles were required to render the structure clear.

On this point I obtained no further evidence and I can only state that when the volcanic period commenced the country was occupied by a tract of foliated crystalline schists and gneisses which still retained a *considerable relief,* although lying above the sea level and profoundly denuded.

Besides dynamo-metamorphism these ancient rocks bear evidence of regional metamorphism and also of contact metamorphism, which is less pronounced, however, than in the rocks round Marcote and in the Malcantone. In the latter area the Hercynian granite that was the cause of contact-metamorphism is exposed, but further south I imagine it lies deeper and to the west of the Valganna.

After a period of orogenetic quiescence following the Carboniferous crustal movements, during part or the whole of which period the volcanic activity manifested itself, a slow epigenetic subsidence set in and lasted until the Alpine folding commenced. The sandstone and conglomerates of the Werfénian (Servino) transgressed from the south (bibl. 21, p. 558) and east (they wedge out west of the valley of Rasa); but, during the Virglorian, marine sediments became universal.

The Tertiary movements which resulted in the formation of the Campo dei Fiori anticline and the numerous faults, were in their turn followed by a period of sub-aerial denudation which continues up to the present, and in which glacial erosion played a prominent part.

The shallow Pliocene transgression which covered the southern fringe of the Alps only attaining to 280 m. higher than the present sea level (bibl. 17, p. 341) did not reach the porphyry district.

We will now consider more especially the Permian rocks. Volcanic activity first manifested itself in the formation of *lithic biotite-quartz-porphyry-tuffites and-tuffs,* but before they came into existance *detrital conglomerates* consisting of gneisses and vein quartz derived from the fundamental crystalline schists were being formed in the lower-lying parts of the country but had nowhere attained to any considerable thickness. As purely sedimentary layers occur interstratified with the tuffites it is evident that a gradual transition took place from the one formation to the other, (north of the M. Martica and on the M. Legnone). It was therefore not found practicable to separate out a non-pyroclastic basal conglomerate to correspond with the Carboniferous deposits found elswhere (bibl. 20, p. 159), and I have combined all the products lying at the base of the igneous rocks on the fundamental formations under the heading of "*basal tuffite series.*" Their greatest thickness is about 75 m. (Section C or 4).

Immediately on top of these clastic rocks follows a lava flow of *quartz-biotite-porphyrite.* Although it is locally very thick it tapers away rapidly so that it was evidently comparatively viscous. (Maximum thickness 200 m., section D).

In its turn the quartz-biotite-porphyrite is overlain by the thick series of *pyroxene-porphyrite* with its *lithic tuffs.* The relative positions of the latter two are not quite clear but we may confidently assume that the tuff is in part interstratified with the porphyrite without however forming a continuous horizon throughout. Petrological evidence tends to prove that the tuffs originated in a magma that was slightly different to that of the porphyrite and also richer in gas. The igneous material was deposited in the shape of bombs and crystal ash on the slopes, and here and there washed down these as "lahars" (see p. 158). The greatest thickness of the tuff appears to be 90 m. (section E); of the whole series 450 m. (section F). By then the whole basal tuffite series was covered by either the one or the other kind of porphyrite.

After the pyroxene-porphyrites came a *quartz-porphyry* series. The groundmass of these rocks is devitrified and most of the small lava flows that were formed show *fluxion structure. Lithic tuffs* were also generated in between, but their mode of formation is not quite certain. Probably they represent detrital waste of older lava flows intermingled with pyroclastic material. This series though 150 m. thick (section D) is not spread over a large area so that the individual flows besides being thin were also short.

Finally came the extrusion of the enormous sheet of quartz-porphyry that flooded most of the country several hundred meters deep with one massive "Decke" of *granophyre.* No tuffs, sediment or indications of old surfaces having been found anywhere in this rock, either west of the Valganna or elsewhere in the Luganese district, there can be little doubt that the whole mass was poured out at once. The mode of occurence suggests (section 1) that the lava was viscous and did not spread out very flat.

An exposure of crystalline schists south-east of Bédero covered directly by Triassic sediments[1]) proves that the higher summits of the pre-Permian relief still maintained themselves, even at the close of the Permian age after several hundred meters of granophyre had been deposited on the lower-lying parts immediately surrounding them. This is also proved by the preponderence in the Werfénian sandstones of pebbles of veinquartz, from the crystalline schists, that have not been much rounded off.

In the neighbourhood of Brinzio *dykes* several dozen meters thick may be seen passing through the gneiss and feeding the flow. Thinner apophyses of a few meters down to only millimeters crowd the immediate surroundings. Although the rock of these dykes is not always exactly that of the flow it constantly shows a strong tendency to graphic intergrowth of the groundmass constituents and miarolitic cavities and is evidently a different facies of the same magma. Harada describes these dykes as forming a network in the crystalline gneiss along the road from Brinzio to Casa Valicci just outside the village. Other good exposures are met with further east in the Valmolina south of the Casa Valicci.

A different rock with phenocrysts larger than in the granophyre is contained in other dykes that abound all over the district but as they generally break through the flow they must be somewhat younger. Apart

[1]) P. Leuzinger of Bale drew my attention to this fact. Probably they are the schists represented by Harada on his first section but on the wrong side of the northern fault.

from a few exceptions they all seem to thrust up vertically (Valle Castellera), and striking north-east do not change their direction over their whole length. The average width is some ten meters, but some much narrower and others a good deal broader were found.

Where the termination is exposed laterally they end quite abruptly [1]). Whether any lava was poured out on the surface I cannot say.

Narrow pegmatite veins in the gneiss and schists of the Valmolina and veins of barite and fluorite with argentiferous galena and pyrite bear evidence of late and post-volcanic activity. SENN (bibl. 21, p. 555) showed on the San Gorgio peninsula that though some of the barite veins were cut off sharply by the transgression of the Werfénian sandstone others passed up into these rocks. Also at point 893 north-east of the M. Chiusarella small barite veins penetrate into the Triassic sandstone.

The question must now be considered what *type of eruption* these rocks had. At an early date it was recognised that the granophyre flow was produced by a fissure eruption and the same was then supposed to be the case with the porphyrites. As we have already seen the more recent investigations have confirmed this surmise concerning the granophyre, but direct evidence was not forthcoming for the older rocks west of the Valganna as no eruptive channel, either central or fissural, has been found. ESCHER on the other hand believes that a mass of porphyrite exposed near Morcote and already observed by HARADA, forms a dyke feeding the porphyrite flow (bibl. 14, section). For the porphyrites on my map and sections, however, an inference can be drawn from the following facts.

A *marked difference* exists between the *granophyre on the one hand and all older rocks on the other.* While the former gradually welled up and spread out in one thick sheet the latter show at least four tuff horizons and many separate, often small, lava flows of varying constitution side by side or on top of eachother. De Sitter found an even more complicated alternation of lava flows and tuffs on the Piambello lying regularly one on top of the other with the same strike and dip. He supposes this series is part of a *volcanic cone* built up round a central eruption. But west of the Valganna no such regularity is met with and, even when the irregularities of the surface on to which the lava poured are taken into account, it is not possible to point out one focus from which all the flows and layers of ejectamenta could have come into their present position, either from the "*Piambello volcano*" or any other point. This is a matter which must be considered in detail.

The distribution of the basal tuffites seems to have been principally influenced by the primary relief of the country and affords no indication as to where it came from. The quartz-biotite-porphyrite exposed west of Brinzio may have come from a point of emission west of Cabiaglio but there is no space in section 4 to connect this

[1]) One dyke with a very irregularly shaped margin is exposed in a bend of the road Ganna-Mondonico.

stream with the great mass of the same rock lying on the M. Martica. If my conception of the tectonic build of this mountain is correct this mass is almost entirely surrounded by crystalline schists that the biotite-porphyrite did not cover. The vent through which it issued must therefore lie buried somewhere below the summit of the mountain under the porphyrites. The pyroxene-porphyrite with its clastic rocks may have come from any point, series of points or fissure south of the line connecting Cabiaglio with Brinzio and Ganna. The quartz-porphyry with fluxion structure evidently flowed from west of Cabiaglio perhaps from the same vent as the quartz-biotite-porphyrite found there, and the exposure half-way between this village and Bédero may be connected with the principal mass by a flow following the present stream down to Rancio. The presence of this rock in the exposure on the M. Legnone can hardly be accounted for by the same eruptive centre.

Thus it is clear that we are forced to assume the existence of vents at various places either in or round the present exposure of volcanic rocks.

As it does not seem quite so likely that these vents were fissures or parts of a fissure giving different magmas and fragmental material at different points and times we are brought to the conclusion that in all probability there were *several small central eruptions which delivered themselves of all rocks older than the granophyre without, however, building up regular cones.*

B. Tectonic Geology.

In Harada's time the existence of the great Campo dei Fiori-anticline, with a vertical fault in the northern limb, was already known, and also the existence of a fault along the Valganna.

No complications occur along the *southern border*, where the volcanic rocks dip away at an angle of some 30° to 40° under the sediments. To the west a well developed *pitch* is the cause of the disappearance of the Permian rocks below the Triassic dolomites. Exactly where and how this pitch and the *fault in the northern limb* of the anticline pass into each other could not be ascertained in the volcanic rocks, but we may look forward to P. Leuzinger's publication for better information on this matter.

Only in two exposures can the actual contact between the porphyry and the dolomite along the fault be studied. The first occurs in the bed of the T. Rancina 250 m. east of Casa Colètti, where a small area of fluxional quartz-porphyry with narrow veins of barite and fluorite crops out. The fault extends to a belt, one meter broad, of sliding planes with slickensides and a jumbel of crushed dolomite and porphyry, partly changed into a clayey substance.

Somewhere between here and the stream coming down past K 12 on the big road the fault-plane is carried about 75 m. to the south-east. Probably a transverse fault with horizontal displacement is the cause of this deviation; but it may be that a slight incorrectness in-the topographic map is responsible for it; as also for the dent by the Valle C e r b o r a.

The second exposure of the fault-plane may be seen south-east of the road from B é d e r o to M o n d o n i c o. As the topographic map is wrong here I have given (fig. 1) a rough sketch of this part. A large quartz-porphyry dyke running close to, and parallel with the fault forms the eastern side of the little gorge through which the stream flows; but along the fault-plane itself a narrow strip of the normal granophyre is generally intercalated. Some 250 m. from the road Bédero-Ganna, and about 75 m. further, the actual contact is laid bare. At the lower of these points (fig. 1, section) a soft greyish-blue clay containing hard inclusions of the fundamental crystalline schists is pressed between the rough irregular dolomite and granophyre that are 0.7 m. apart. Another vein of the same material, 10 c.m. broad, occurs 1,4 m. away in the granophyre. Sometimes the clay is pressed, and divided by slickensides into thin papery sheets, or reduced to only a few c.m. Probably it represents a decomposed mass of the underlying rocks and sides of the fault, squeezed out like paint from its tube. In the higher exposure the porphyry and dolomite touch each other along a straight line.

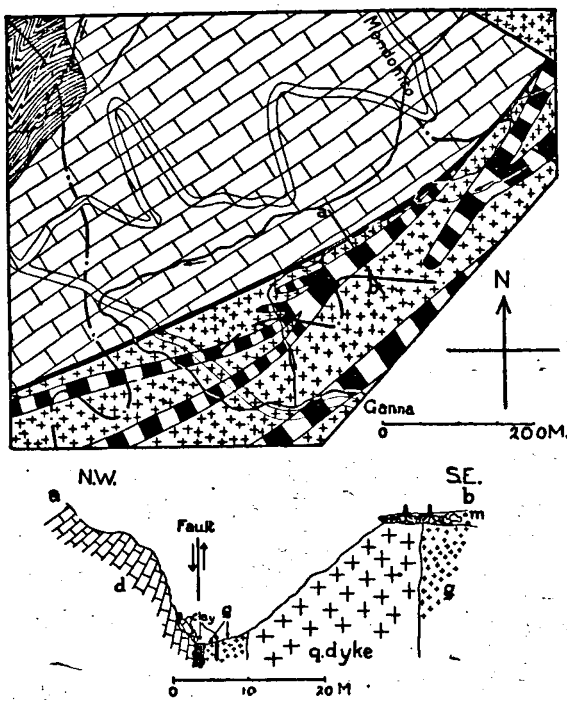

Fig. 1.

Map and section of the region east of B é d e r o.

Between here and the stream from Casa R o m b e l l o to the Lago di G h i r l a, that also runs along the fault-plane on the northern side of the M. M o n d o n i c o the fault is diverted some 150 m. to the north-east, and again 200 m. in the same direction in the Lago di G h i r l a.

Some 500 m. to the south a small fault parallel to the large fault has been traced by another little torrent on the northern side of the M. M o n d o n i c o. By its movement, that was probably in part horizontal, it has cut off a dyke sharply and the continuation must lie some distance to the south-west, starting under the moraine. Slight disturbances along the plane of movement are to be seen in the bed of the stream.

As the great northern fault hardly changes its direction when passing across a mountain, or valley it is evidently approximately vertical. The minimum throw is on the average about 300 m., but the exact amount cannot be ascertained, as the original thickness of the granophyre is not known.

The transverse faults with horizontal displacement are evidently younger than the northern fault itself, but both were probably late in developing as compared with the anticline, of which they are only a minor feature. Had the fault been formed before the anticline was hunched up, its original shape and position would not have been maintained throughout the later stages of folding.

SENN, from whom I here borrow (bibl. 21), has most recently dealt with the structural problems offered in the south of the Valganna. A great vertical fault, the *Valganna-fault* runs along the eastern slopes of the valley, placing the granophyre directly opposite the Triassic dolomites. To the south the fault gradually dies away in the sediments, and according to DE SITTER the same happens in the volcanic rocks to the north of the Poncione di Ganna.

Only on the subject of the origin of the Valganna-fault do I disagree with SENN. According to SENN the fault was caused by the turning off of the strike east of the Valganna as compared to that west of the valley. The fault however with a throw of some 5—600 m. (bibl. 21, p. 616)) is so large that if the corresponding formations on both sides were again placed in juxtaposition (fig. 5), this change of strike would disappear almost entirely and the strike run from east to west from the Poncione to Cabiaglio. The divergence is only a consequence of the movements along the fault slightly augmented by dragging up along the eastern side, and the pitching of the anticline towards the west. The two small anticlines and synclines, found by SENN on the eastern side, are minor folds due to the general disturbance of which the fault is the principle feature.

At an *early stage* in the folding of the Campo dei Fiori-anticline the Valganna-fault was formed, possibly in consequence of disturbances in the underlying rocks; and thence forward the strata on opposite sides reacted differently to the tangential stress. To the west one broad flat anticline was thrust up; to the east a narrower and steeper fold with its axis further north came into existence, its southern limb being slightly crumpled (the small anticlines and synclines) and lifted along the fault. Thus the dying out the fault to the north and south with a maximum throw about opposite the M. Munisfreddo becomes comprehensible.

Having now considerd the boundary with the sediments we will turn to the tectonic problems in the *interior*, starting at the western end.

The *complications met with around Cabiaglio* must for the greater part be explained by primary irregularities in the distribution of the lavas and tuffs. In the southern limb of the pitching anticline the fluxional quartz-porphyry wedges out to the east below the Triassic dolomites. Where the boundary with the pyroxene-porphyrite and its tuffs crosses the C a p r e r a and runs up the little righthand tributary it is formed by a slight vertical fault (section 7). On the north side the quartz-porphyry also wedges out; here between the pyroxene-porphyrite-tuff and the granophyre. Originally the latter spread somewhat further south than at present, for a small knob of this rock sticks out of the moraine just north of the big road. The quartz-biotite-porphyrite east of C a b i a g l i o however remained uncovered until Triassic sediments closed over it. Section 7 and 6 show that we must assume a slight doubling of the anticline with a small syncline in between.

Further to the east the granophyre on the north and the older formations on the south meet along a *fault* (fig. 2), that can best be

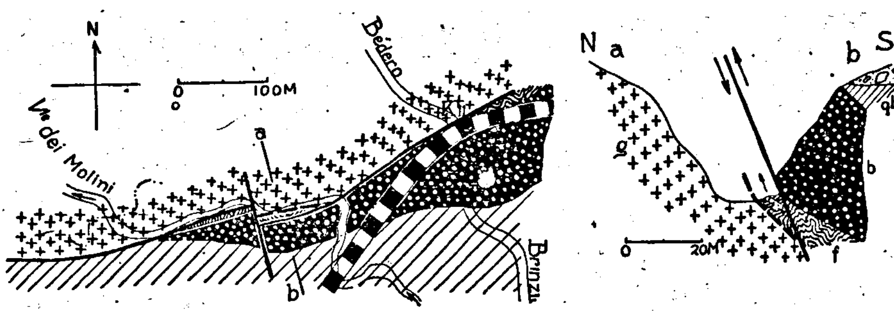

Fig. 2.

Map and section of the fault crossing the Valle dei M o l i n i below K. 11 on the road Brinzio-Bédero.

studied in the stream crossing under the road B r i n z i o - B é d e r o at K 11 and the part of the Valle dei M o l i n i that forms its continuation. A slight complication is caused by a quartz-porphyry dyke on the south side that just comes up to the fault at the level of the road, bending away from it higher up and lower down the slope [1]).

The peculiarity of this fault is that as far as it is exposed the contact is always between the granophyre on the north and the fundamental schists, or the coarse conglomerate at the base of the basal-tuffites on the south, that run as a narrow strip, not more than a few meters broad, along the fault; and this while the lowest point exposed lies 150 m. lower than the highest. It makes the impression of a dragging having occured along the plane of movement; but this cannot in reality be the cause as the upwards dragged strip should appear along the area relatively sunk, the opposite to what we actually encounter.

[1]) HARADA, not knowing the existence of the fault, naturally thought that this dyke was the selvage of the granophyre and that the basal-tuffites were a porphyrite rich in quartz.

I have therefore assumed that an irregularity existed in the relief of the ancient landsurface before the volcanic rocks were laid down; and that the fault-plane, with a southerly dip of some 75°, now cuts through the ancient southward slope. Although it is unlikely, it is not impossible that a small steep secondary anticline, and not a feature of the pre-Permian land surface causes the older formations to rise up where they were cut by the fault.

Down in the valley a small transverse fault displaces the larger fault for some 10 m. to the north on the western side (fig. 2) and a small strip of crystalline schists with granophyre-dykes appears on the northern side of the fault. From a mechanical point of view it is difficult to account for its position here, lifted relatively to the rocks on both sides, and overhung on the south by a dipping fault (see section fig. 2).

In the Valle dei Molini, just above the high waterfall half a k.m. west of Brinzio, the quartz-biotite-porphyrite and the basal-tuffite series crop out. The latter consists of the normal fine grained type on the eastern, but of a coarse conglomerate on the western side where it touches the porphyrite. Two explanations are possible: there is no fault and the rocks lie normally on top of each other, the conglomerate must then be younger than the fine grained tuffite (fig. 3 A); the other possibility is that it is older, and a fault separates it from the porphyrite (fig. 3 B). I have adopted the former of these two explanations as being the most probable one.

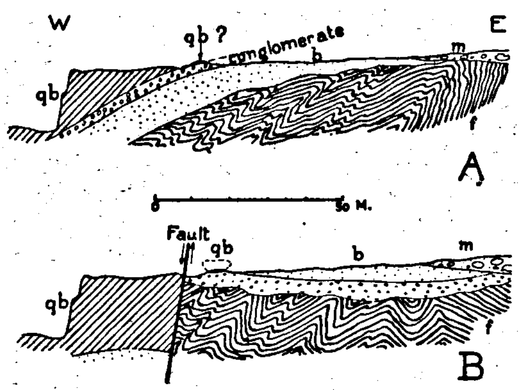

Fig. 3.

Two alternative sections of the Valle dei Molini 500 M. west of Brinzio.

In the immediate surroundings of Brinzio the granophyre sheet and its feeders are exposed. The granophyre may be traced without a break from the north right along the little stream behind Brinzio close up to the point where it is crossed by the road to Bédero. The exposure of this tongue is about 250 m. long and 100 m. wide between the gneiss. That it is a dyke is beyond doubt; the northern contact can be studied on the righthand side of the road from Brinzio to Casa Valicci just beyond where it crosses the stream. Though showing no contact-metamorphism it is certainly an eruptive contact. The southern edge may be seen in the bend of the Valmolina 100 m. east of Brinzio. Here the gneiss lies on top of the granophyre on a slickenside surface, that dips southwards at an angle of 40° (section fig. 4).

At the eastern extremity of the Valmolina another dyke, the thickness of which is at least 40 m., is exposed. It appears from under the crystalline schists, is evidently curved and has a small dip (20°—30°) to the south-west.

The relative position of the basal tuffites and the schists around Fonte del Cerro suggests that a very slight syncline runs in the direction of the Valle d'Intrino. The impression may however be due only to inaccuracies in the mapping.

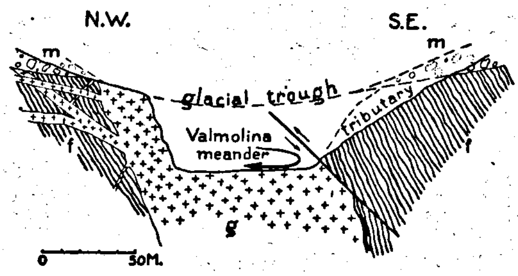

Fig. 4.

Section across the Valmolina east of Brinzio.

The tectonic features of the M. Martica now remain to be discussed. The top of this mountain consists of the older formations, that join on to those of Brinzio. They abut abruptly against the younger granophyre on the north, the east, and the south. The junction appears to be vertical as far as any indications as to its position are afforded [1]), so that we must assume a *heaved block,* around which vertical faults occur, the throw of which gradually diminishes towards the south-west (maximum 500 m. sections D and 2). Here again, however, we meet with the same difficulty as with the fault dealt with on page 145, namely that for the greater part a narrow strip of gneiss and schists, not more than a few meters thick, follows the fault plane; and again not on the side of the down throw so that dragging cannot be taken as the cause of this peculiarity. If this matter is to be explained by relief in the substratum, as in the former case, the reconstruction given in the sections is arrived at. An ancient valley appears to have run in the direction Ganna-M. Legnone in which the basal tuffites and the quartz-biotite-porphyrite were deposited, the higher slopes remaining bare until the pyroxene-porphyrite flowed over them.

North of the M. Legnone the fundamental crystalline formations with their covering of basal tuffites are slightly lifted. As they abut against the pyroxene-porphyrite just along a dry water course we may assume a small vertical fault here, and connect the whole with the heaved block of the M. Martica.

While in the area taken up by igneous rocks *folding does not seem*

[1]) The lead-mine in the Valle Castellera has, while still working in the granophyre, approached, 250 m. below the surface, to within some 100 m. of the vertical projection of the junction.

to play a very important part, more or less vertical faults, mostly with a vertical movement, are frequent. Moreover everywhere, almost all joints are at the same time planes of movement showing slickensided surfaces, often in two, three or more planes in one and the same exposure. The dolomites and calcareous sediments surrounding, and those formerly overlying, the volcanic rocks evidently reacted much more strongly and in quite a different manner to the orogenetic stresses, as they are much folded and plicated.

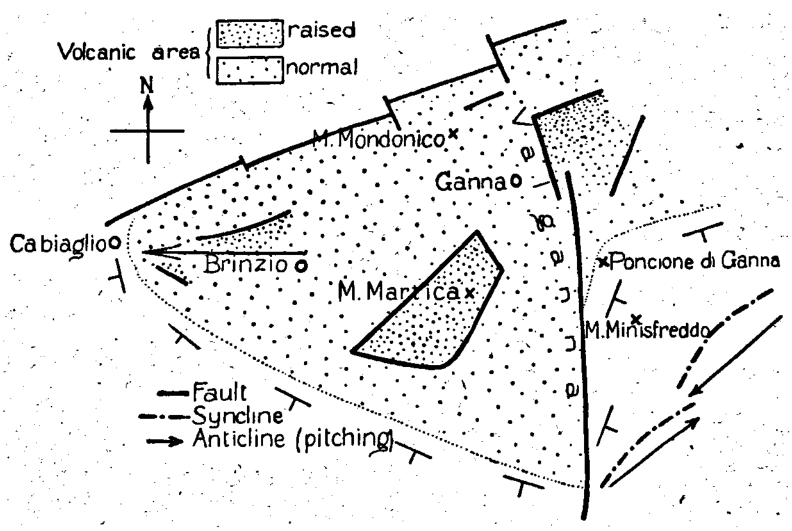

Fig. 5.

Structural map 1: 100.000.

IV. PETROGRAPHY.

The first comprehensive treatment of the petrography of the L u g a n e s e-porphyries we owe to HARADA (bibl. 2). This forms an excellent basis for further investigation, but much must be added to it. For this reason I give an entire petrographic description of the rocks, that I have not burdened with acknowledgment of every seperate observation taken from HARADA, as these are too numerous to be expressly pointed out.

Of several rocks HARADA published analyses made by FELLENBERGER, SCHWAGER and others:

Analysis III p. 17 applies to the pyroxene-porphyrite of the M. L e g n o n e; N⁰. V, p. 42 to the granophyre north of B r i n z i o.

In all likelyhood Swiss petrologists will shortly make new analyses but as yet this important part of the investigations has not been carried out.

For the sake of conformity with other writers on the volcanic rocks of the district of L u g a n o I have retained the somewhat antiquated names of quartz-porphyry and porphyrite for pre-Tertiary rhyolites and andesites; but I have used the terms „texture'' and „structure'' in the same sense as English and American petrologists do; which unfortunately is the opposite to the way in which continental writers employ them.

A. Fundamental crystalline formations.

Two fairly distinct types of crystalline rocks, a *gneiss* and a *mica-schist* crop out in the investigated area. They are not marked separately on the map; their distribution is as follows; the gneiss: east of B r i n z i o, east of the M. M a r t i c a, part of the masses on the M. L e g n o n e, at F. del C e r r o, and at K. 11 on the road B r i n z i o-B é d e r o; the mica-schist: north of the M. M a r t i c a, B é d e r o, here and there in the V a l m o l i n a, and north of the M. C h i u s a r e l l a.

The *gneisses* are hard, fine and evenly grained rocks, rich in quartz. They are light grey or pink, with a weathered surface that is mostly dark grey. No foliation or crumpling occur, but quite frequently they show a slight bedding and sometimes cleave along these planes (B r i n z i o). At other localities quartz has been injected along these (F. del C e r r o). In a less fine grained type (K. 11) the pink felspar and the clear quartz can be distinguished with the naked eye.

Under the *microscope* the small *quartz* grains that constitute the principal mass of the rock are seen to show strain shadows and often to be rich in inclusions. The *biotite* and the *felspar* that form the remainder are much altered, the former being bleached, the latter (mostly plagioclase) sericitized. While the relative quantity of the quartz varies considerably the grain remains on the whole quite small. The grains of the quartz injection are larger, with strong strain-shadows. In small number we find colourless *andalusite* in irregularly bounded, fairly large crystals. Greenish *tourmaline* I only observed once; in the basal tuffites it is a frequent inclusion however. Round, colourless *zircon* occurs abundantly, *rutile* and *magnetite* are less common.

The *mica-schists* form a variable group. They contain hardly any primary *quartz*. At Bédero occurs a schist with *muscovite* and *biotite* sometimes with a great number of minute, dark red *garnets*. In the schist north of the M. Martica the muscovite is absent. In the Valmolina the garnet is missing also.

They are all dark foliated rocks, badly weathered and often intensely crumpled. Generally a *quartz-felspar injection* has taken place.

In the slide we see that nearly the whole mass is formed by *sericite*, probably the decomposition product of *felspar*. *Biotite* has given rise to the formation of *chlorite*, sometimes with *sagenite*. Most likely the little brown pleochroic *biotite* flakes, that occur in some slides, are of secondary contact metamorphic origin. *Muscovite* when present occurs in large colourless crystals, the *garnet* is light pink; along its margin and the cracks it is decomposed leaving chlorite. *Zircon* and *magnetite* are rare. The injection veins show quartz with interlocking outlines and strain shadows, and many inclusions often in rows. Other veins contain a large amount of biotite, bleached and chloritized and of dusty felspar, principally plagioclase, with polysynthetic albite-twinning. In one section a large quantity of dark brown *rutile* crystals occured together with biotite in these veins.

Inclusions of the fundamental rocks are frequent in the porphyries and tuffs. One contained feathery aggregates of *sillimanite*. In another a large amount of green *spinel* and a mineral that is probably sillimanite were found. These occured either alone or together, and sometimes with magnetite also, in irregularly bounded, oblong masses orientated more or less parallel. The maximum size of these rods was 0.35 by 0.05 m.m.

Evidently the fundamental formations represent *metamorphic sediments*. ESCHER following RIVA and SALOMON termed the schists of the San Salvatore peninsula "*contact gneiss, sometimes with andalusite*" (bibl. 14, p. 724). West of the Valganna the evidence of contact is somewhat less pronounced (less tourmaline and cryptocrystalline biotite). The andalusite is, as we saw, restricted to the gneiss type.

B. Basal tuffite series.

(This group corresponds to DE SITTER's "tuf acide").

Under this heading I have united all the products lying at the base of the igneous rocks on the fundamental crystalline formations. It was not found practicable to separate from them a non-pyroclastic conglomerate to correspond with the Carboniferous deposits recognised by KELTERBORN (bibl. 20, p. 159), for although purely sedimentary layers do occur, they are partly interstratified with the tuffs and tuffites (for instance north of the M. M a r t i c a, and the stream on the north-easterly slope of the M. L e g n o n e), and evidently a gradual transition took place from erosive to volcanic products. It does not seem impossible however that this series is of the same age as the Carboniferous conglomerates of M a n n o.

Megascopically these rocks show a great diversity of types (bibl. 16). Between coarse conglomerates and very fine grained rocks all intervening stages are met with, and the colour though generally distinctly grey often shows brown and blue-green tints. The most typical variety (Valle dei M o l i n i ½ k.m. west of B r i n z i o) can hardly be distinguished from a quartz-porphyry, for it is an evenly grained rock with an aphanitic ground-mass in which appear quartz grains of a m.m., that sometimes stand out in relief on the weathered surface. Quite large stray quartz or felspar crystals or mica flakes are of common occurrence. Some types are uncommonly rich in quartz while others are very poor but contain a high percentage of mica (at the foot of the M. L e g n o n e). The coarser conglomerates are built up out of more or less rounded inclusions of crystalline schists, gneisses and vein-quartz that are firmly held together by a fine matrix.

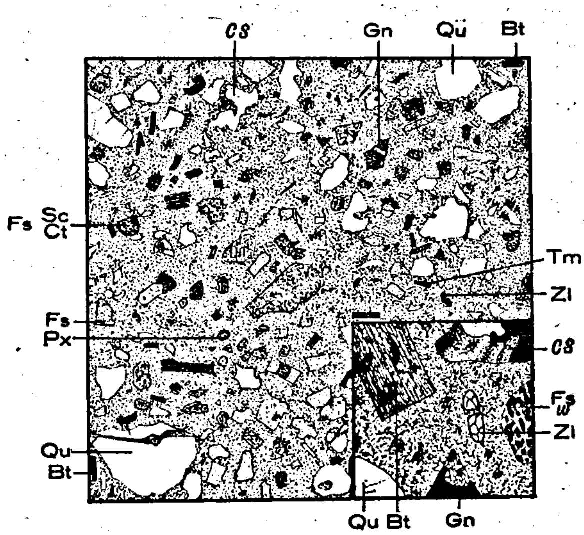

Fig. 6.

Basal tuffite, 10 ×. Inset: nicols +, 32 ×.

The *microscopic* observations (fig. 6) are in accordance with the macroscopic character of the material as lithic-tuffites. In a ground-mass consisting of *sericite* and *quartz*, probably originating in a volcanic ash, countless inclusions lie embedded. These are of volcanic and of non-volcanic (older) origin, but it is only of the quartzes that this can be proved directly. For besides fragments of sometimes sixcornered quartzes almost without strainshadows, that bear more or less pronounced signs of magmatic corrosion, interlocking quartzes from the substratum occur with undulatory extinction. The size of both is subject to large variations. Not infrequently they are cracked and the matrix has penetrated between the loose bits. The latter kind moreover is from time to time intergrown with *muscovite*, and fairly large weathered crystals of *orthoclase* (with micro-perthite) and even more often with *plagioclase.*

In a few cases even *tourmaline* is added. Loose tourmaline and *garnet* are no doubt of the same origin. How many of the loose felspars and biotites are magmatic I found no way of ascertaining. The felspar is sericitized or calcitized and principally plagioclase; the biotite ie either bleached or changed into *chlorite* while *titaniferous magnetite* was separated out.

Zircon in thick rounded crystals or thin sharp needles; apatite, sometimes in the biotite; *pyrite* in small cubes, and titaniferous magnetite are usually represented but always in small quantities.

Although *no vitro-clastic structures,* and only in rare instances a slight bedding can be distinguished the tuffaceous nature cannot well be doubted, for the absence of any regularity either in the shape, size or distribution of the inclusions is proof enough. The parent magma must have been an *acid biotite-quartz-porphyry.*

The differences in megascopic appearence are caused by the degree of weathering and by the changes in number and nature of the inclusions. They form either more, or less than half the total mass, and sometimes the felspar, sometimes the quartz, either magmatic or from the substratum, predominates.

The mica in the micaceous type to be found 250 m. west of Fonte del Cerro south of Brinzio is split open at the ends and it gives the rock a structure rather resembling fluxion. As all quartzes show strainshadows there are probably no volcanic products in this layer. East of the Fonte this same layer contains also quartz and gneiss inclusions of the size of a walnut.

A quite different rock occurs among the diversified group exposed on the road Brinzio-Bédero, some 100 m. south of K. 11. It is a very fine and evenly grained slightly bedded crystal tuff, containing no material evidently other than pyroclastic, but only fragments of crystals in a very fine matrix. All along the course of the stream passing down into the Valle dei Molini at K. 11, and close above the waterfall half a k.m. west of Brinzio, the best examples of the coarser type are exposed.

C. The porphyrites and their tuffs.

The rocks contained in this group were included in the "schwarzen Porphyre" of Harada and his predecessors. Escher was able to show that a large part of the black porphyries of the Morcote peninsula were tuffs and the same holds good for those west of the Valganna. In his slides Harada observed porphyrite inclusions in porphyrite and mentions the summit of the M. Martica as one of the places of occurrence (p. 16). Without doubt the rock examined was a tuff for nearly the whole of the top of this mountain consists of them.

Further Harada distinguishes more or less tentatively between a "quartz-porphyrite" and a "felsophyrite"; the groundmass of the former containing hardly any interstitial glass and many quartzes with double pyramides and orthoclase; that of the latter being rich in interstitial microfelsite between oligoclase laths, and with fewer phenocrysts of quartz and orthoclase. Although he believes there to be a gradual transition from the one type to the other this writer is nevertheless of the opinion that they belong to different lava-flows. The first mentioned type he found round Brinzio, the other higher up the M. Martica (p. 16). With this devision I fully agree, but did not find any transitional types. On the contrary, the difference is even more pronounced as the "quartz-porphyrite" contains biotite as dark phenocryst; whereas the "felsophyrite" is characterized by a pyroxene.

Although agreeing with RIVA that the plagioclase phenocrysts are not oligoclase but labradorite, I do not believe there to be any olivine or amphibole phenocrysts in the porphyrites west of the Valganna; so that I cannot adopt his subdivision of those around Porto Ceresio, that is based on the above mentioned minerals.

1. *Quartz-biotite-porphyrite.*

The best samples of these porphyrites may be collected just above the waterfall in the Vle dei Molini half a kilometer west of Brinzio and on the slope 200 m. south of K. 11 on the road Brinzio-Bédero where the bare rock shows through the grass slope.

This rock is the oldest of the porphyrite group. It is fine and evenly grained with countless small phenocrysts of brown *biotite* and colourless *felspar,* both of about one m.m. lying in a dark greenish grey aphanitic matrix. The more weathered the rock is the lighter green it becomes, and the more clearly the felspars, from which a few rare *quartzes* can then readily be distinguished, show up as white spots. The biotite on the other hand becomes increasingly difficult to identify. Besides this green colour of the whole rock, a dark carmin red colouring also occurs at some exposures.

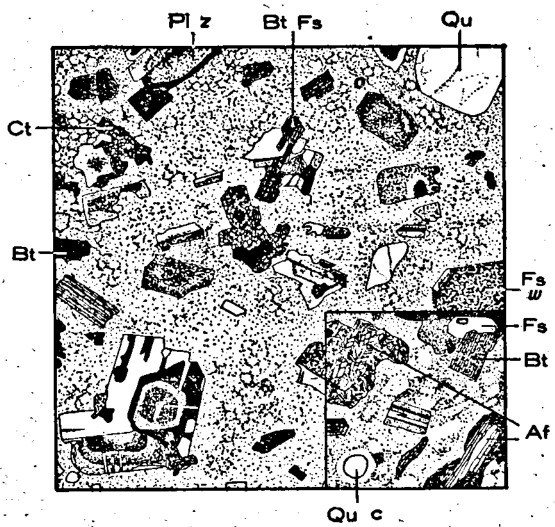

Fig. 7.

Quartz-biotite-porphyrite, plagioclase with nicols +, 20 × & 53 ×.

The *microscope* reveals (fig. 7) that the felspar is *plagioclase only,* with marked zoning, equidimensional forms and of small but varying sizes. It is an andesine-labradorite, in which Carlsbad- is often combined with the albite-twinning (see next chapter). The decomposition into sericite and calcite begins in the centre. HARADA mentions orthoclase, but this mineral is not present. The *biotites* are thin hexagonal tablets with pleochroism from black brown to light yellow. Decomposing, they become green or lose their colour altogether while *leucoxene* and titaniferous *magnetite* are formed, and in a few cases *sagenite.* The size and number of the biotites vary considerably, but usually this mineral is abundant. It occurs as inclusion in the other phenocrysts and must therefore have started separating at an early stage. Only a *pseudomorph* of chlorite, calcite, ilmenite and quartz remains after an other constituent, not always occuring, and never in large quantities. Judging by the shape I should say that it was a *pyroxene,* not amphibole as HARADA thought.

The *quartz* though not abundant is all the same an essential constituant. Besides a few normally sized strongly corroded crystals, a larger number of very small rounded or bipyramidal pieces may be seen. HARADA considered these part of the matrix, which seems to me improbable on account of a thin primary reaction-rim (corona) in the groundmass that is never absent (see fig. 7).

In a few sections lie irregular patches of green bleached biotites. In one case they contained also small parallel prisms of hornblende with an extinction angle of 16° and pleochroism pale green to very pale green. I imagine the whole to be of secondary origin. Not to be confused with these are amygdales of sizes comparable to those of the phenocrysts that are now filled with chlorite, sericite, calcite and sometimes zeoliths too.

The *matrix* is pilotaxitic or devitrified, consisting of lath shaped on rounded felspar crystals. Although the felspar shows no twinning, so that HARADA thought it was orthoclase, it is probably *plagioclase* as it is decidedly zonal. Its refractive index being lower than of the labradorite phenocrysts it must be less calcic than these (probably oligoclase). Decomposition has produced *sericite.* A high percentage of *chlorite* in the groundmass, generally surrounding the grains of felspar is probably derived from a dark constituent (biotite) formerly part of the matrix. The accessory constituents are *zircon* in rounded grains or with sharp pyramides (pleochroic halos in the biotite); *magnetite* and *apatite* with dark inclusions in the centre and in planes parallel to the c-axis under angles of 60° (bibl. 2, p. 12).

Inclusions of schists in a remarkably good state of preservation are by no means scarce.

The differences with the "biotite-porphyrite" of DE SITTER are manifold. The rock I have just described contains quartz, the felspar and biotite phenocrysts are of a different shape and more numerous, while the groundmass is somewhat coarser. There can be no doubt as to their belonging to different eruptions.

2. *Pyroxene-porphyrite.*

(= "porphyrite à pyroxène of DE SITTER).

"Pyroxene porphyrite" I find a more appropriate name for the rock that HARADA calls "felsophyrite rich in oligoclase". It is practically identical with the "porphyrites" described by KAECH, especially the hyalopilitic type (bibl. 9, p. 64). It may be obtained in good specimens from many places, amongst others the new military road to the top of the M. Martica and south of Brinzio, south-east of Fonte del Cerro.

Without the aid of the microscope we can distinguish an abundance of small phenocrysts of glittering felspar and occasionally of quartz in an aphanitic groundmass, the fracture of which is rough, often somewhat conchoidal, the colour greenish black. Locally, probably at the surfaces of different flows irregularly shaped amygdales are to be found now filled up with a green chlorite, or pink and white quartz. Some however of the green spots visible with the pocket-lens must be the chloritized dark constituent.

On weathering the colour either becomes lighter green or reddish purple, and the felspars either become indistinct, or they show up very conspicuously as white or orange spots. Other weathered types again might well be taken for tuffs as quite small, yellow, green, brown and black spots closely packed without sharp margins give the rock an irregular clastic appearance (Campo dei Fiori-slope at ± 600 m. south of pt. 492 on the road Brinzio-Cabiaglio). Also a few localities yield a dark porphyrite which dimly shows a flow structure (Valle Riazzo above the tuff).

In the *slide* (fig. 8), besides the phenocrysts of *plagioclase* those of a dark constituent are seen to play an important part in the building up of the rock. In all respects the former are the same as the felspars of the biotite-porphyrite. On the whole they appear to be somewhat more calcic and variable, and are a medium labradorite (see next chapter). In some slides many felspars show a zone with glass inclusions, now devitrified to a brown mass. In cases where these are very small they might easily be taken for decomposition. As in the quartz-biotite-porphyrite orthoclase is absent. Weathering has sometimes produced pale green epidote, generally in the felspars, rarely in microscopic veins.

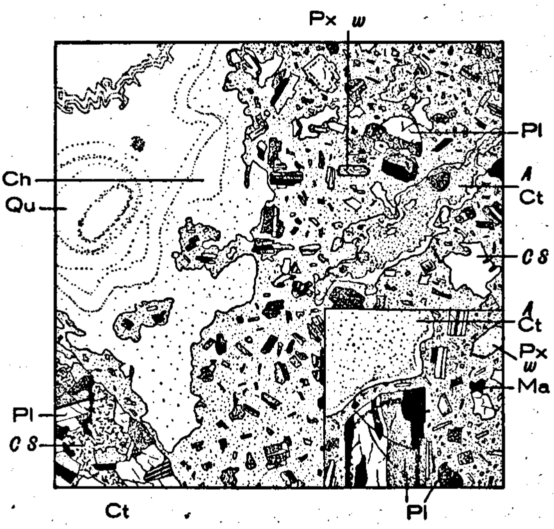

Fig. 8.

Pyroxene-porphyrite, plagioclase with nicols +, 12 × & 20 ×.

The phenocrysts of the dark constituent are entirely decomposed, only a pseudomorph of green chlorite with blue and brown interference colours remains, often with titaniferous magnetite or limonite along the margins or former cleavage and cracks; while epidote, calcite and quartz also occur. The shape is that of *pyroxene*, so that I do not agree with HARADA that the dark constituent was amphibole. Only in one case a sericitized *biotite* was observed; corroded *quartzes* are not rare. Small amygdales with chlorite and quartz contents are of frequent occurrence, in some slides they are even more abundant than the phenocrysts (C a p r e r a just south of the road). *Zircon* is quite rare, *apatite* and *magnetite* are common accessories.

The groundmass is hyalopilitic with a considerable but changing amount of devitrified brown glass containing *magnetite* and *leucoxene* grains. The lath shaped *felspars* are generally of varying size, and often show albite- and Carlsbad-twinning, not infrequently with repetition. They contain 50 % An (extinction of albite twinning lamellae).

Besides the type depicted in fig. 8 another with far smaller and flatter plagioclases exhibiting a marked flow-structure has been developed. A case in which the two alternated in irregular bands in one and the same section proves that it would not be right to distinguish separate rocks on account of this difference (south of the road in the stream parallel and to the east of the C a p r e r a).

Inclusions of crystalline schists in a good state of preservation and porphyrite are by no means of exceptional occurrence. Cracks filled with calcite or pale yellow epidote occur here and there.

The difference between these porphyrites and those of the former group lies partly in their missing the biotite and the smaller quartz-phenocrysts, and partly in the hyalopilitic instead of the holocrystalline groundmass.

3. *Porphyrite-tuffs.*

By far the finest exposures of these clastic rocks may be studied along the new military road to the top of the M. M a r t i c a. The

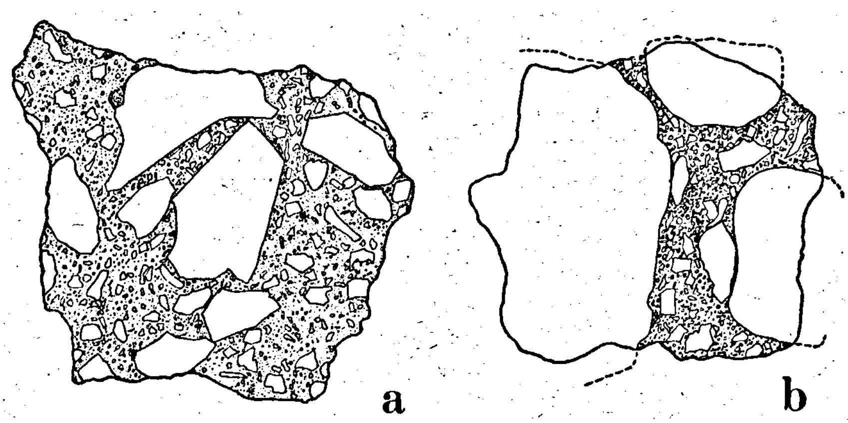

Fig. 9.

Pyroxene-porphyrite tuffs, *a* brecciatic, *b* conglomeratic. $^2/_3$ ×.

porphyritic tuffs and brecci as found by KAECH (bibl. 9, p. 81) show great affinity with the rocks I am about to describe.

In the porphyrite tuffs dark to light colours, generally purplish red but also green and greenish black prevail. Very often the inclusions are green and brown and red, the matrix red, white or green and in cases where these are contrasted the clastic nature of the rock is beautifully clear. As a rule the fracture on the other hand passes through groundmass and inclusions without being differently influenced by the one or the other.

The coarseness varies within wide bounds, but at any given spot there is generally a rough regularity in the size of the inclusions, that is to say a fairly constant maximum size, which may vary from that of a hazelnut to that of a cocoanut. In the coarser varieties occasionally blocks, up to several cubic feet lie embedded here and there. Between the larger bits smaller fragments down to microscopic dimensions are packed in a aphanitic groundmass. The shape is on the whole angular with rounded edges (fig. 9, *b*) but regular conglomeratic and brecciatic tuffs (fig. 9, *a*) also occur. Roughly speaking the smaller the size of an inclusion is, the less rounded is its shape. More commonly the macroscopic inclusions form by far the larger part of the mass of the rock, but in some cases the groundmass may predominate.

Weathering either makes the rock soft and crumbly throughout or only the matrix; and in this case the surface of the rock becomes very rough and shows up the inclusions in relief. This may even go so far that they roll out whole.

Apart from a few stray ones of mica-schists all inclusions appear to be closely allied to the porphyrite. Megascopically the only difference is that they often have a bright red colour, and frequently show fluxion-structure.

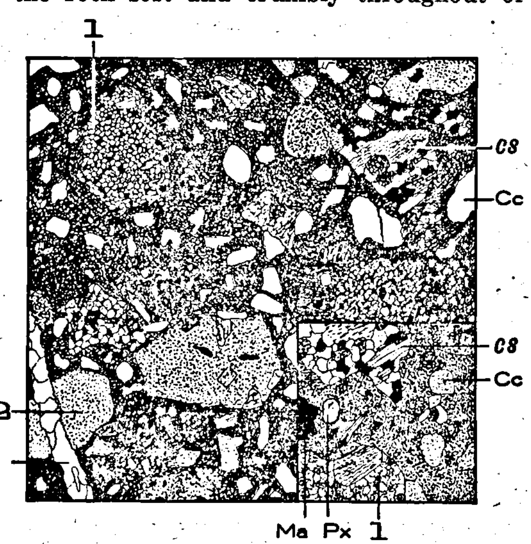

Fig. 10.

Pyroxene-porphyrite-tuff, nicols +, 9 × & 34 ×.
1 = inclusion of a biotite-porphyrite.
2 = inclusion of a pyroxene-porphyrite.

If the inclusions lie embedded in a groundmass of the same colour and amount of weathering it may become very hard or even quite impossible to distinguish such rocks from the normal porphyrites. The consequence is that part of the rocks marked on the map as pyroxene-porphyrite might, on microscopic investigation turn out to belong to this group.

Under the *microscope* (fig. 10) the contrast between the matrix and the inclusions is nearly always clearly to be seen. The clastic character of the former when viewed by itself is not always apparent. The chief difference with the groundmass of the pyroxene-porphyrite is the absence of a marked contrast between phenocrysts and groundmass-felspars, as a gradual transition occurs from small crystals to minute particles and the indeterminable dust in which they lie embedded. On the whole the crystals are unbroken, probably on account of their small size. In some slides they are roughly arranged so as to simulate a fluxion structure.

The chief constituent is *plagioclase* in laths, beside which lie stray magmatic quartzes. In varying amount a green pseudomorph of chlorite after *pyroxene* is found. Products of decomposition are *calcite, sericite, epidote* and part of the abundant *ilmenite*. The whole groundmass of a specimen collected in the Valle P a r d o m o consisted of sericite and chlorite without any visible crystals.

Although it is older the normal quartz-biotite-porphyrite is not represented in the inclusions. Neither is the porphyrite of the normally developed type, for the plagioclase phenocrysts are smaller and more equidimentional and frequently show magmatic corrosion [1]). Of yet another kind the groundmass is developed more coarsely than that of the normal pyroxene-porphyrite.

Thus pre-existing rocks do not seem to play a part in constituting these tuffs, so that the bulk of the material must be of magmatically-clastic origin. The chief difference between the parent-magma of the tuffs and that of the pyroxene-porphyrite must have been a higher percentage of gas in the former. To account for the rounding off of the inclusions it seems most likely to suppose the loose material was washed down the existing slopes, probably in the shape of "lahars" [2]) as known from J a v a. In this way the absence of any stratification could still be understood.

D. Fluxional quartz-porphyries.

(= The upper of the two "quartz porphyres fluidaux" of DE SITTER).

The rocks belonging to this series were looked upon by HARADA as a marginal facies of the granophyre; but on detailed investigation they have turned out to be a sharply definable, absolutely separate group with no transitional types between them and the granophyre. The best exposures are presented in the watercourse south of C a b i a g l i o and in the C a p r e r a south and north of the road.

In the comparatively small area occupied by these quartz-porphyries a number of fairly divergent rocks are disclosed, that probably belonged

[1]) It was in a slide belonging to one of the porphyrite inclusions that the interesting combination of plagioclase phenocrysts described in the next chapter occurred.

[2]) = Murgänge or cold mud flows (see "Leidsche Geologische Mededeelingen" p. 19).

to separate lava-flows. They are always, often badly, weathered. On the whole they show light colours: pink, green, brown and orange with purple; but a blueish-black and a dark carmin red are also met with. Most members have flow-structure shown up by fine layers with different colours, or by elongated pores now filled in with green chlorite (in the stream 450 m. south of the church of Cabiaglio).

The not very abundant phenocrysts of clear *quartz* and glittering or dull pink rectangular *felspar* are not more than a few m.m. across; the aphanitic ground-mass if not too much weathered has a somewhat conchoidal fracture.

The *microscopic* analysis of these rocks shows that the variability is no less pronounced in the slide than megascopically, but it is seen to be of small general importance only affecting the structure of the ground-mass.

The phenocrysts are: quartz, felspar and biotite. Apart from magmatic corrosion many of the *quartz*-bipyramides are intact, while others with strain-shadows have been broken and scattered in the direction of flow. The cracks may be filled either with ground-mass material or secondary quartz; and in a few cases a tail of small irregularly shaped quartz grains joins on to one end of a phenocryst (bibl. 9, p. 99).

The decomposition of the corroded *felspars* into zoisite or sericite renders it difficult to distinguish between ortho- and plagioclase, which are both present. Plagioclase could sometimes be proved by the presence of calcite; where the albite twinning-lamellae could still be recognised their extinction pointed to a low percentage of An.

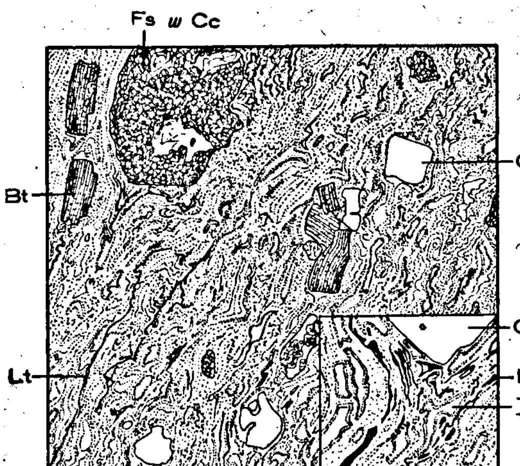

Fig. 11.

Fluxional quartz-porphyry, 10× & 40×.
1 = groundmass resembling vitroclastic textures.

The brown *biotite* occurs in thick six-cornered tablets that have often been bent during the flowing. It has been chloritised or bleached while irregular quartz grains, ilmenite, and leucoxene were separated out.

The accessory constituents are *zircon, apatite,* and *ilmenite.* The first occurs in colourless, rounded grains or short prisms with two pyramides lying in the biotite or felspar. Slender or thick six-cornered apatite prisms are to be found in the biotite; large irregular bits in the ground-mass.

The *ground-mass* is devitrified to an allotriomophic aggregate of quartz, weathered felspar and colourless mica, derived from biotite or felspar. The flow-lines in this mass are drawn either by limonite pigment in waving lines, that can be followed right through the grains of the matrix, or by streaks of quartz with a serecite edge that have been drawn out in bent lines between the rest of the ground-mass, rather reminding one of vitroclastic structures (fig. 11). Their presence is probably due to differentiation before consolidation.

KAECH describes how he was able to prove the former existence of spherulites by the radial and concentric disposition of limonite grains; sometimes they showed an edge of radiating sericite flakes (bibl. 9, p. 97). I found precisely similar phenomena (fig. 16, 2). One rock I examined showed perlitic structure, a thin seam of sericite following along both sides of the cracks. Where these gaped they had been filled up by a quartz mosaic. Amygdales drawn out during the flowing and now filled up with quartz and colourless mica are typical of the hard, dark red quartz-porphyry exposed in the stream 1 k.m. south of Cabiaglio.

In amongst these quartz-porphyries *lithic tuffs* occur in two localities along the Caprera, one just north, the other 600 m. south of the road. At the former the tuff is only a few meters thick and is a dark, purplish red rock with hazelnut sized, vague inclusions and many clear quartz grains. Under the microscope we see that the rounded inclusions are partly of the quartz-porphyry with fluxion-structure, partly of pyroxene-porphyrite; but by far the greater number are too small and too badly weathered to allow determination. Further there are a great many corroded and broken quartz and felspar phenocrysts of all sizes and shapes; while a few undulose quartzes probably represent fragments of the substratum. The not very abundant matrix is full of limonite, sericite and calcite showing no structure typical of a tuff, or otherwise. Part of the tuffs lying further south greatly resemble the porphyrite conglomerate tuffs megascopically, only that they are rich in quartz; the rest are the same as the tuff just described. Of the coarser varieties the colours are various tints of green; and the inclusions, about the size of apples, may be seen quite clearly. In the slide they are seen to consist of quartz-porphyry, pyroxene-porphyry, and crystalline schists. The magmatic quartzes are more scarce than in the other kind of tuff.

E. The granophyre.

The granophyre that covers a large part of the older rocks in a thick sheet, HARADA described under the name of "die rothen Porphyre", and he distinguished several types, the "Granitit" forming the core merging into a rock with "porphyrartige Ausbildung" nearer the margins, while the "Quartzporphyr" is to be found at the very edges, and "die braunen Porphyre" further north at the M. *la Nave.* It has turned out however that the rock actually forming the "Decke" is far less variable than HARADA thought, as neither the "quartzporphyr", that is the rock just described, nor the "braunen Porphyre" are facies of the granophyre, but separate rocks. Careful examination has further shown that the

"Granitit" (= biotite-granite) *is porphyritically* developed so that no essential difference exists between this rock and that with the "porphyrartige Ausbildung". Besides this, the variations in coarseness are abrupt and stand in no relation to their position with regard to the selvage of the sheet. For these reasons I will not describe the types separately.

Megascopically the granophyre is a quartz-porphyry with a carmine-pink colour and apparently granitic texture, that is of medium, rather irregular, grain. In many places however part of one of the minerals betrays its phenocrystic character by greater size. In a few cases the rock has an aphanitic appearance (but the microscope proves that the indistinctness of the quartz and felspar grains is not due to smallness of size, but to their having both taken on the same aspect, while being graphically intergrown).

Streaks or irregularly shaped masses with much coarser or finer grain and sharp margins appear almost everywhere (for instance north of the Valle Castellera), so that types forming extremes may be got in the same hand specimen. Weathering sometimes makes the colour lighter, sometimes greenish, and as may be seen under the Werfénian sandstones of the M. Chiusarella the Triassic weathering has rendered it dark crimson.

The *orthoclase* is red, the *plagioclase* white or transparent, the *quartz* transparent and the *biotite* greenish black. *Miarolitic* cavities are very characteristic of the granophyre. In some places they are scarce and small, in others (quarry above the road Brinzio-Bédero opposite pt. 508) they are abundant and up to 1 c.m³. and more in size. Besides the freely developed ends of the normal constituents, *fluorite* in clear colourless cubes and in rare instances black *tourmaline* with striped prisms form the walls. The coarser development of the grain around these cavities is often most striking, quartz crystals up to 5 c.m. occurring.

In the thin *section* the granophyre constantly shows porphyritic texture. The ground-mass is hypidiomorphically granular, and generally in part also micro-graphic.

Both Haradà and Riva state that in the central parts of the flow a granitoid texture has developed by the slow cooling of the mass. Examination of a large number of slides has shown however, that the texture is *always porphyritic;* but the grains of the ground-mass are often found to be so coarse as to equal the phenocrysts in dimensions, so that these can no longer be recognised by their greater size. The difficulty of identifying the phenocrysts as such is even augmented when the micrographic crystalline matter of the effusive period has attached itself directly to that of the intratelluric period, growing outwards from the phenocrysts in crystalline continuity and without any visible margin, thus merging the porphyritic crystals into the general picture.

On the other hand this circumstance may lead to the detection of a phenocryst by its forming the centre of a graphic part of the ground-mass; and in other cases the shape or the unmistakable magmatic corrosion of a crystal proves its intratelluric origin.

As phenocrysts we encounter the minerals: quartz, plagioclase, orthoclase, and biotite. Both the number and relative proportions vary considerably, but their size is subject only to small changes that stand in no relation to the coarseness of the ground-mass. The ground-mass consists of the same minerals. The accessory constituents are: magnetite (mostly titaniferous), zircon and now and then apatite; while fluorite and pyrite belong to the post volcanic periods. The products of decomposition are calcite, sericite, kaolin (?), limonite, leucoxene, and chlorite.

As the ground-mass consists of the same minerals, in most respects with the same properties, in dealing with the phenocrysts I will only mention the characteristics of these as porphyritic crystals.

The colourless bipyramidal *quartzes* have been attacked by magmatic corrosion.

The *orthoclases* show more or less distinct crystallographic outlines, but generally they are rounded or have no characteristic form whatever. Their dimensions are more variable than those of the quartzes, but have the same average size. Twinning in accordance with the Carlsbad law is common, and is sometimes combined with the Baveno law.

The phenocrysts of *plagioclase* are on the whole more bounded by crystal planes than those of orthoclase. With Fedorov's method I found albite twinning and 37 % anorthite (average andesine).

Of the *biotite* the greater part was without doubt formed in a late stage of development of the ground-mass. Generally it fills the space between more idiomorphic felspar- and quartz-crystals belonging to the effusive period, sometimes nearly enveloping these (fig. 12). On the other hand it is also found in the quartz phenocrysts, and a few of the biotite crystals have phenocryst habitude, so that it is highly probable that part of the biotite substance was already present before the eruption took place. A fact that points in the same direction is the marked tendency of the zircon crystals to be concentrated in the biotite; a fact that can only be explained by assuming that this was already the case before the ground-mass had crystallized to any great extent. Most of these phenocrysts must have continued their growth

Fig. 12.

Granophyre with bent biotite and hypidiomorphic felspar and quartz 30 ×.

until nearly the whole of the ground-mass was crystallized, thus greatly increasing the resemblance of the texture to that of a granite.

In exceptional cases the biotite is slightly bent (fig. 12) probably in consequence of the Tertiary crustal movements, for the mass could not have gone on flowing after the crystallization of the biotite and therefore also of most of the ground-mass.

The ground-mass is for a large part *hypidiomorphically granular*, as we saw, but it is never quite free from *graphic* texture, and some sections are entirely micrographic. When a combination of the graphic and the granitic textures occurs, the former seems to consist of smaller particles, but an entire individual of felspar or quartz is larger than the separate pieces in the granitic parts. The granophyric matter, that is in cristalline continuity with the phenocrysts that it surrounds, contains besides *quartz* both *orthoclase* and *plagioclase* [1]). Although the amount of the latter varies considerably, the former always predominates. The plagioclase contains on an average 35 % anorthite (andesine).

The remarks here following on the ground-mass constituents apply to the corresponding phenocrysts as well.

The *quartz* shows slight strain shadows between crossed nicols; only once I observed a distinct cleavage parallel to the rhomboeder.

In the *orthoclase* decomposition has either produced a fine dust of reddish limonite throughout the whole crystal, or it has resulted in the formation of kaolin (?), which renders the crystal opaque. The kaolin is generally concentrated in streaks, that are white in reflected light. Frequently they are not distributed evenly thoughout the whole crystal but are concentrated in the centre or at the margin. Now and again they are seen to run parallel to the cleavage and somewhat resemble microperthite. But the streaks remain dark under crossed nicols, and do not show a higher indices of refraction than the remainder of the crystal. Occasionally the decomposition has produced small but distinct crystals of sericite.

A rim of orthoclase that I observed surrounding a plagioclase phenocryst probably belonged to the ground-mass and the examples that HARADA mentions must be explained in the same manner. A common phenomenon is the formation of microperthite, and in the next chapter we shall see that the orthoclase is evidently always rich in plagioclase substance.

The *plagioclase* is on the whole more decomposed than the orthoclase. As a rule sericite in flakes has replaced nearly the whole of the felspar substance, so that the twinning can no longer be detected, or at least is not pronounced. Neither in the fresh felspatic substance nor in the decomposed material could any indications as to zonal structure be detected.

The *biotite* is never quite fresh, the colour always being green. Generally the pleochroism is still strong: pale yellow often with a greenish tint to dark green often brownish or nearly black. Where the

[1]) A few general remarks concerning the nature of graphic intergrowth of quartz and felspar will be found in the next chapter.

decomposition has gone further the biotite has been bleached and granular leucoxene and limonite formed. The colourless mica thus formed has not infrequently taken on a radiate arrangement, sometimes forming complete spherulites. In other slides we find that the biotite has been chloritized, or that secondary quartz has been deposited in lenses parallel to the cleavage.

Of the accessory constituents *zircon* in colourless or light yellow grains or sharp little crystals is the most common. It generally occurs in the biotite with pleochroic halos or in the magnetite. The much rarer needles of *apatite* occur in the same way. The ilmenite is characterized by a thin covering of leucoxene, and is often changed, giving limonite; it seldom shows crystals planes.

Irregular patches of colourless or light purple *fluorite*, the larger with a distinct cleavage, occur in a number of slides sometimes in the ground-mass, but mostly in cavities in the biotite.

F. Dykes of quartz-porphyry.

The dykes of quartz-porphyry are too numerous to be all marked on the map. Only the larger ones have been drawn in, approximately to scale; and a more or less arbitrary selection was made for microscopic analysis.

This group of rocks can be subdivided as follows:

1. Granophyre-dykes.
   I. Sheet-feeders.
   II. Dykes formed after the granophyre sheet.
2. Quartz-porphyry dykes (all younger than the sheet).
   I. With biotite phenocrysts.
   II. Without biotite phenocrysts.

1. The granophyre-dykes.

I. *Dykes feeding the sheet.* Of two of the broader dykes belonging to this group it may actually be seen that they feed the flow (Brinzio). They contain a rock that is undistinguishable from finer varieties of the granophyre flow. A number of the smaller dykes are apophyses of these larger ducts, and contain a slightly differentiated rock. Nearly all the dykes of Brinzio and the Valmolina belong to this type and so do those in the crystalline schists north of the M. Martica and in the Valle dei Molini 150 m. east of the mill at point 431.

Amongst other slides I examined three from dykes crossing the road Brinzio-Casa Valicci just before the road branches off to point 591. One of these contains a rock megascopically light pink with a sub-conchoidal fracture and aphanitic ground-mass in which the fairly thin, shiny felspars and clear quartzes, that are both small, hardly show up. Under the microscope it can be seen that these phenocrysts are not numerous; those of the former kind are brownish, with limonite and lie together in balls, those of the latter are corroded. The matrix is a fine granophyre with pseudo-spherulitic texture here and there.

The other two dykes differ from the normal granophyre only by the fineness of their texture. In one especially the graphic intergrowth of the quartz and felspar is elegant to a high degree, shooting out from the phenocrysts at right angles to the crystal faces in feathery aggregates of parallel shreds.

One of the dykes of only a few c.m. broad that cut through the schists north of the M. M a r t i c a; and of which I had a slide made, has no phenocrysts and is richer in plagioclase than the rock of the flow. It shows only very slight tendencies to graphic intergrowth.

II. *Dykes formed after the flow.* About one kilometer along the road from B r i n z i o to C a s a V a l i c c i a narrow dyke is exposed, that was microscopically examined. It contains a carmin-pink fine grained rock in which glittering quartzes and felspars and chloritized biotite are to be seen. It also shows small miarolitic cavities. Parallel to its borders and close to one of these it contains a narrow secondary dyke that is greyish brown with an aphanitic ground-mass in which are held numerous small quartzes of varying size, and also a few indistinct felspars.

In the former dyke the microscope does not disclose any phenocrysts; but we do see a few patches of quartz and felspar in graphic intergrowth floating like phenocrysts in the much finer grained ground-mass. The matrix is hypidiomorphically granular and also graphic, often as pseudo-spherulites. In cases where these pseudo-spherulites show an optical character it is negative. The graphic intergrowth is older than the granular development, for it envelopes the graphic phenocrysts as a thin rind. At the contact with the schists the granophyre is absent and the grain is somewhat larger. The plagioclase contains about 30 % An (extinction of the albite twinning lamellae) (= oligoclase-andesine).

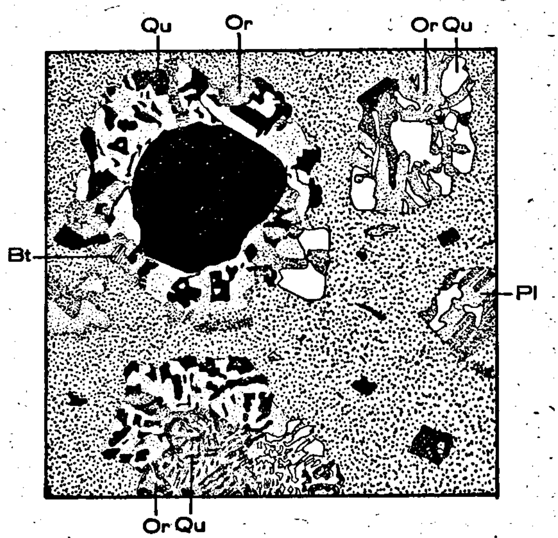

Fig. 13.

Quartz-porphyry with graphic border round quartz phenocrysts, and graphic phenocrysts. Nicols +. 40 ×.

The smaller secondary dyke is characterized by the large number of beautifully developed graphic phenocrysts (fig. 13). Besides these it contains quartz and plagioclase phenocrysts, the former always, the latter generally in the centre of the graphic patches. The number of these patches however is so large that they cannot all have a normal phenocryst as centre, which would have lain outside the plane of the slide. Roughly speaking they are of spherical shape and the quartz and felspar may have more than one orientation. The felspar is both orthoclase and plagioclase. The groundmass contains some biotite in a quartz-sericite mass.

Yet another kind of dyke belonging to this group I observed twice; once in the cleft opposite S. Gémolo in the M. Martica at about 700 m., the second time on the ridge from the M. Martica north of the Valle Castellera, to the west of point 921. They were 15 c.m. broad and could be traced for a few meters only. Although their colour is that of the granophyre they were fairly conspicuous, as they stood out in relief. They consist of the same minerals as the rock in which they occur, but the texture is much finer.

Microscopically they are seen to contain no real phenocrysts only a few patches of the coarser graphic intergrowth as described above. The remainder of the rock is allotriomorphically granular with here and there graphic intergrowth. Besides orthoclase, microperthite is met with, in which the orthoclase is clouded, the plagioclase clear. The plagioclase of the groundmass contains 30 % An (extinction of albite-twinning-lamellae).

There are several rocks that may be classified with the foregoing group, but of which it is not certain whether they occur in dykes. They were found in the granophyre flow and might possibly represent differentiations of this rock.

One was found north of the Valle Castellera at 750 m. due east of the Miniera. It is light brownish pink with a smooth fracture along joints, on which small quartz and felspar phenocrysts appear indistinctly, and along which it breaks up into geometrical forms. Under the microscope the groundmass is seen to be a very fine aggregate of allotriomorphic grains of quartz and felspar. The phenocrysts of quartz, orthoclase and plagioclase are numerous and small and nearly always bear a thick crust of comparatively coarse granophyre (plate II, fig. 1) shows a section through such a graphic border with a peculiar regularity in its growth).

Another of these questionable dykes occurs north of the Valle Fredda due south of the Miniera at about 700 m. Megascopically it resembles a fine variety of the normal granophyre, but under the microscope it shows more affinity to the dykes. The phenocrysts of quartz, plagioclase and orthoclase are small and surrounded by a thick bolster of graphic matter; a thin rim of crypto-graphic matter envelopes these with a sharp margin. The quartz and felspar of the latter are in crystalline continuity with that corresponding part of the graphic phenocryst onto which they have joined; this may be seen best with the gypsum slide. The remainder of the groundmass, that is the larger part, consists of pseudo-spherulites that gradually merge into micrographic growth towards the outer edge (plate I, fig. 2). The negative character of the pseudo-spherulites is less pronounced than their subdivision into area's with the same extinction throughout (on pseudo-spherulites see bibl. 10 and 19).

The interstices of the pseudo-spherulites are filled with quartz and felspar grains. The former are crowded with minute hairlike needles too small to allow determination. If biotite was ever present it can not have been abundant, and is now entirely decomposed.

North east of the Miniera di Vassera at about 800 m. a rock, also in all likelyhood occuring in a dyke, greatly resembles the normal granophyre. Both the quartz and the felspar are undulose however, there are no phenocrysts and the biotite is less altered. The plagioclase contains approximately 30 % An (see next chapter).

Narrow little aphanitic, chocolate coloured dykes may be found on the eastern slopes of the M. Mondonico. In the slide they are seen to be without phenocrysts and to be built up of small allotriomorphic grains of quartz, orthoclase, plagioclase and biotite. The quartz and felspar are graphically intergrown on a minute scale, the quartz presenting rounded forms.

2. Quartz-porphyry dykes.

I. *The quartz-porphyry dykes with biotite phenocrysts* have a pink aphanitic groundmass in which large phenocrysts are enclosed. Those of *quartz* vary in size from about 1—5 m.m.; originally they were bipyramidal with a short prism, but they are nearly always corroded to irregular shapes. In many dykes they are surrounded by a thin shell, a *corona*, belonging to, but darker than the groundmass, from which the quartzes let go, leaving a smooth surface. The *felspars* are somewhat larger, up to nearly a c.m. and only slightly corroded; they are decomposed and yellow, white or red in colour. The small tabular *biotite* phenocrysts are changed into chlorite.

From the weathered surface the quartzes stick out, often with part of the corona still clinging to them, while the felspars become crumbly and may have entirely disappeared leaving a sharp impression in the matrix. It also occurs that these cavities are now occupied by a spongy mass of limonite. At a few localities brown felspars may be collected where the whole rock has become crumbly and where they roll out whole, (showing the following faces (110) (130) (010) (021) (001) ($\bar{2}01$) ($\bar{1}11$) often as Carlsbad twins).

Many of the dykes have a greenish colour that makes them conspicuous amongst the red granophyre. While some of them have large phenocrysts, for instance the middle one of the three in the Valle Castellera with quartzes of 12 m.m. and felspars up to 5 × 5 × 25 m.m., others as the dyke north west of the M. Chiusarella have smaller and fewer phenocrysts.

Only three dykes were examined microscopically; namely: **a** the most western of the dykes in the M. Mondonico at the junction with the sediments, **b** the dyke at K. 11 on the road Brinzio-Bédero, **c** the middle one of the three dykes crossing the Valle Castellera.

In the *slide* the corrosion of the *quartz* phenocrysts is very striking, in c the larger are attacked most. The *felspars* are badly changed, so that it is not certain whether those that do not show polysynthetic twinning are not plagioclase also. It does seem likely however that there should be some orthoclase. The decomposition products are principally sericite scales and calcite also. A common phenomenon is that the felspars are united in balls of several individuals. They are not zonal, and are only slightly rounded off by corrosion. The *biotite* occurs as phenocrysts in thick hexagonal plates, that may be slightly bent. It is bleached or changed into chlorite and leucoxene. It encloses a large number of *zircons* and in **a** and **b** of *apatite* needles as well.

These rocks exhibit a considerable variety of texture. No evidence of flow has been preserved, but that devitrified glass is the chief constituent is fairly probable.

In **a** (fig. 14) the matrix is partly spherulitic and the corona round the quartzes has great affinity with spherulites. In exceptional cases spherulites have joined onto the felspar phenocrysts (fig. 14). Although some of the spherulites show a dark cross with a weak negative character, between crossed nicols, most of them become alternately light and dark on rotating the table. This makes it likely that they are cryptographic *pseudo-spherulites.* The corona's show the same colour with the gypsum slide as the quartzes to which they belong. They contain many small calcite tufts.

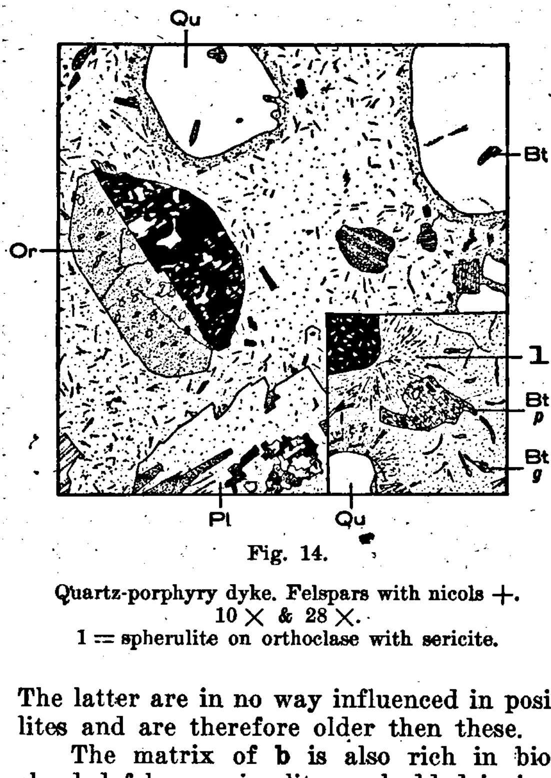

Fig. 14.

Quartz-porphyry dyke. Felspars with nicols +. 10 × & 28 ×.
1 = spherulite on orthoclase with sericite.

Besides these graphic formations quartz and felspar in allotriomorphic grains and small bleached biotite scales form the groundmass. The latter are in no way influenced in position or shape by the spherulites and are therefore older then these.

The matrix of **b** is also rich in biotite and consists of brown clouded felspar microlites embedded in irregular quartz grains. Apart from coronas round the quartz phenocrysts loose pseudo-spherulites occur as darker spots. They are older than the grains of the groundmass, as their edges are not influenced by these grains and run straight through them. At a different point in the same dyke the felspar of the groundmass forms larger and irregular crystals. Along the edge of the dyke countless minute irregularly shaped veins, consisting of quartz with undulose extinction, and with a small amount of orthoclase have afterwards been injected.

II. *The quartz-porphyry dykes without biotite phenocrysts* are only of exceptional occurrence, the four dykes on the Campo dei Fiori being the only examples.

Macroscopically they greatly resemble the former group; but the quartz and felspar phenocrysts are considerably smaller.

The dyke north of point 701 on the M. Legnone contains a great number of phenocrysts. Those of quartz are undulose and corroded, those of orthoclase and plagioclase (34 % An, extinction of albite-twinning lamellae) corroded and decomposed. The matrix, a fine grained mass of quartz and felspar with a large amount of leucoxene from decomposed titaniferous biotite, was probably formed by devitrification.

The dyke cropping out west of the Valle Riazzo has very few felspar phenocrysts, but a large number of quartzes. The groundmass is rich in pseudo-spherulites, often surrounded by an irregular rim of quartz; the remainder is a granular mass of quartz, felspar and decomposed biotite.

The dyke south of Fonte del Cerro is in all respects the same, apart from its missing the pseudo-spherulites.

G. Products of post-volcanic activity.

The evidences of post-volcanic activity are met with especially in the granophyre. The *fluorite* and *tourmaline* in the miarolitic cavities of the granophyre and part of the *pyrite* that occurs in most rocks in cubes or on cracks are probably of pneumatolitic-hydrothermal origin, while the veins of *barite, quartz* and other minerals are more likely of hydrothermal origin [1]). In the Valle dei Molini close to Mo. dei Gaggioli *dark strips* occur along the *joints* of the granophyre. In the slide it may be seen that the felspar is entirely replaced by spherically orientated greenish sericite. This alteration must be due to post volcanic exhalations along the joints.

In the Valmolina, especially at the eastern end, a large number of small *pegmatite veins* occurs in the crystalline schists. The quartzes and felspars are up to several c.m. in size. In the section only quartz with strain shadows and plagioclase were observable, together with a small amount of sericite and chlorite as alteration products of the felspar and perhaps biotite.

Some remarks concerning the age of the *barite-fluorite* veins may be found in chapter III. In the small veins, that consist of barite only, this mineral is arranged more or less completely in rosettes.

In the Valle Fredda a vein occurs running from east to west in the

[1]) Calcite veins are numerous in the rocks on the Campo dei Fiori and just below the waterfall in the Valle dei Molini; they are probably Tertiary infiltrations from the overlying calcareous sediments.

granophyre in the neighbourhood of the bend near Alpe Cuseglio [1]. Its exact shape was not to be seen, but it was at least a few meters broad and a hundred long. Its border, where it could be studied, showed a gradual transition from granophyre to a *brecciatic vein.* First the granophyre contains a few narrow branching injections along its joints. These become more and more numerous until, about one meter further, the granophyre occurs as angular fragments in a groundmass of vein material. This material is dark brown and consists principally of barite and limonite, but also contains galena and some manganese mineral.

The great vein, on which the Miniera di Vassera in the Valle Castellèra is working, hardly shows itself at all at the surface. Hand-specimens from the mine show that it is also a brecciatic vein. The polished surface of one (fig. 15) showed the following sequence

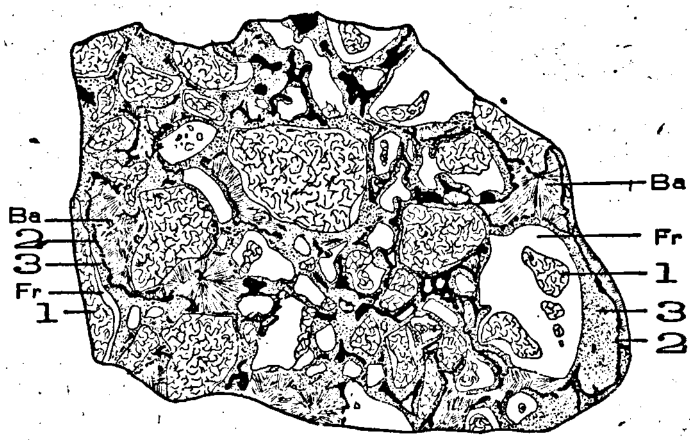

Fig. 15.

Barite-fluorite vein $^2/_3$ ×.
1 = granophyre, 2 = galena, 3 = quartz etc.

for the depositing of minerals: Granophyre fragments with a crust of colourless fluorite, light brown rim consisting microscopically of quartz, barite, some galena and calcite; then comes a border of small galena crystals with here and there a minute pyrite crystal, and finally the interstices filled with rosettes of light pink barite. In other pieces the galena occurs in larger masses of several c.m. across.

Information I obtained at the mine: "The galena is argentiferous. The ore is chiefly concentrated in vertical pillars in the centre of the vein, slightly richer in ore towards the top. The whole vein may be up to 8 m. broad, but varies much in size and shape. It is more or

[1]) An abandoned lead mine has been worked on this lode.

less vertical and at right angles to the general trend of the quartz-porphyry dykes."

The vein is a "Zusammengesetzter Gang im Sinne Kruschs"[1]) in which the matter occurs as "Kokarden- oder Ringelerze".

In fig. 16 a slide from a barite fluorite vein occurring in fluxional

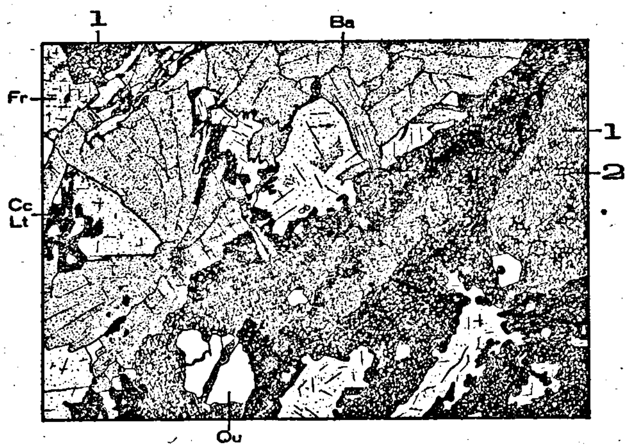

Fig. 16.

Barite-fluorite vein 10 ×.
1 = fluxional quartz-porphyry.
2 = remains of spherulites.

quartz-porphyry is represented. The fluorite is younger than the limonite-calcite mass, the barite youngest of all. In some small veins (as for instance one crossing the stream flowing from Casa Valicci northwards, near the valley of Pralugano) pyrite is even more abundant than the galena.

[1]) Beyschlag-Krusch-Vogt: Die Lagerstätten der nutzbaren Mineralien und Gesteinen, Bd. I, p. 37 and 104.

V. THE APPLICATION OF THE METHOD OF FEDOROV.

As FEDOROV's method for the examination of minerals by means of the theodolite- or universal-microscope ("Universaldrehtisch") is as yet comparatively little known, I unite the results obtained in this way in one chapter. This is more convenient for those already acquainted with the method; and those to whom it is still unknown may find their interest in this highly "elegant" mode of investigation awakened. With a view to the latter aim I will point out the results obtained, that could not have been arrived at by the old methods.

While the plagioclases of the granophyre consist practically of albite and anorthite only, those of the porphyrites contain a considerable amount of orthoclase; and the orthoclase of the granophyre is rich in lime-soda felspar. The laws of twinning could now be established beyond doubt, and the composition of the zones in the zonal plagioclases measured. All crystals, not too much decomposed, in one slide could be examined as to their composition and twinning, so that a more complete insight into the possible variations in a rock was obtainable. The difference in composition of the various individuals forming one twinned crystal could be ascertained with a certain amount of precision. Further a conclusive proof was found that in the graphic intergrowth of quartz and felspar there is no regularity in the orientation of the two minerals with regard to each other.

It must be admitted that the considerable amount of time required for one determination (several hours for complicated crystals) is a drawback. But the excellent results, that are obtained, through an interesting series of mutually corroborating and completing data, well repay the time and trouble expended, and are invaluable for checking those obtained by the old, quicker methods.

By use of the following two works the method can be mastered;

L. DUPARC et M. REINHARD: La détermination des plagioclases dans les coupes minces. Mémoires de la Société de physique et d'histoire naturelle de Génève (1924).

M. BEREK: Mikroskopische Mineralbestimmung mit Hilfe der Universaldrehtischmethoden, Gebr. BORNTRAEGER (1924).

The former deals more fully with the plagioclases and explains the use of the highly important control-projections. It also gives a comprehensive treatment of all other methods for the determination of lime-soda-felspars. The latter gives some new applications of the theodolite microscope, and important technical details.

I will begin with a treatment of the *graphic intergrowth* of quartz and felspar.

By means of the theodolite-microscope the position of the optic axis of a number of quartzes with relation to the ellipsoid-axes of the orthoclases, with which they were micrographically intergrown, was determined. The same was done in a slide from a graphic granite, and the results were brought together in fig. 17 in which ng, nm and np represent the ellipsoid axes of the orthoclase. Evidently there is *no regularity whatever,* and the quartz may have all manner of position with relation to the orthoclase. It goes without saying that the same must be the case with plagioclase. It was already known that if any rule existed it must be complex, as quartzes with different positions are found enclosed in one and the same felspar. It was not known however whether one position might not be privileged above others [1]. According to VAN DER VEEN [2]) for instance, the crystallographic c-axes of the two minerals would generally be more or less parallel; but as this is not the case, his hypothesis about the cause of graphic intergrowth cannot be right.

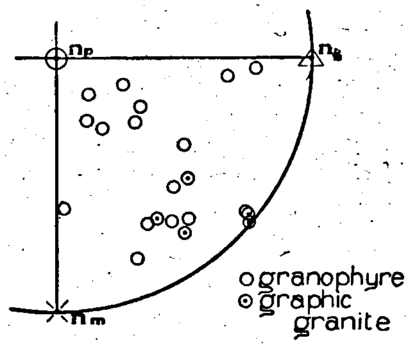

Fig. 17.

Orientation of quartz with relation to orthoclase, when in graphic intergrowth.

That the crystallographic molecular orientation of the quartz chips in a large field of the graphic intergrowth is the same, cannot be due to any influence of the surrounding felspar, on account of there being no relation between the position of the two minerals. On the other hand it is hardly possible that the pieces of quartz are all in contact with each other; especially when they are not elongated in one direction, as they form but one quarter of the whole mass [3]), and links of any kind are very seldom to be seen in the slide. When a phenocryst of felspar is surrounded by a border of graphic matter, the first quartz rods that sprouted from the crystal were certainly not connected with each other (plate II, fig. 2), although they may have grown into contact later on. The only possibility left for explaining the parallel orientation of the quartzes is that "there must be some orienting influence extending from one crystal of quartz to another through an appreciable distance in the liquid magma" [4]). GUERTLER [5]), in dealing with the eutectic structures

[1]) MÜGGE in: Mikros. Physiographie (ROSENBUSCH) Bd. I Zweite Hälfte Fünfte Auflage 1 Lieferung 1925, p. 186.

[2]) A. L. W. E. v. D. VEEN. Het schijnbare Eutecticum: kwarts-veldspaath. Kon. Akademie v. Wetensch. Amsterdam 1916 (28 April).

[3]) J. H. L. VOGT. Physikalisch-chemische Gesetze der Krystallisationsfolge in Eruptivgesteinen. Tschermak's min. u. petr. Mitt. Bd. 25 (1906) p. 361.

E. S. BASTIN. Bull. U. S. Geol. Survey N°. 445 (1911).

[4]) J. P. IDDINGS. Igneous rocks, volume I (1920) p. 209.

[5]) W. GUERTLER. Metallurgie 1912 p. 161 and 316.

TABLE I.

Plagioclases of the granophyre and the dykes.

No.	Occurence.	Twinning-law.	°/₀ anorthite: DUPARC and REINHARD's diagram.	°/₀ anorthite: control-projection.	Max. extinction zone [010].
1	Granophyre groundmass.	Albite.	36 %	35 %	37 %
2	Granophyre groundmass.	Albite.	35 %	1: 33 %, 2: 34 %	1: 38 %, 2: 34 %
3	Granophyre groundmass.	Albite.	35 %	1: 32 %, 2: 39 %	1: 32 %, 2: 36 %
4	Granophyre groundmass.	Albite.	34 %	1: 36 %, 2: 34 %	1: 35 %, 2: 32 %
5	Granophyre phenocryst.	Albite.	37 %	35 %	37 %
6*a*	Granophyre-dyke, groundmass.	Albite.	29 %	29 %	1: 31 %, 2: 34 %
6*b*	Same section.	Albite.	29 %	1: 31 %, 2: 27 %	1: 34 %, 2: 27 %
6*c*	Same section.	Albite.	30 %	1: 29 %, 2: 32 %	1: 32 %, 2: 36 %
7	Quartz-porphyry-dyke, phenocryst.	Albite.	35 %	34 %	38 %

generated in metal alloys in the solid phase, already concluded that some such process, that he called "Einformen", takes place; not only is new material attracted to existing crystals, but new crystallization-centra are given the same orientation without coming into actual contact with the pre-existing crystals.

Another important question is, what force the polygonal shapes of the quartzes is due to. From what IDDINGS says about the optic axis of the quartz being oblique to the prisms of this mineral (and to the frequent triangular sections too), it is clear that the shapes are not combinations of crystal faces of the quartz. DE SITTER, from observations with the universal stage, concluded that the directions probably do not correspond to crystal faces of the felspar either. The idea that the forms must be due to both constituents is strengthened by the observation

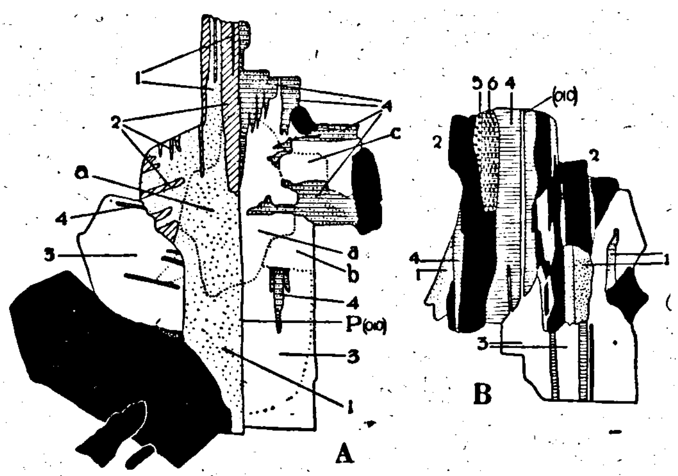

Fig. 18.

Plagioclases from pyroxene-porphyrites; see table II.

that in one felspar two quartz groups with different optic orientation show different directions of the faces bounding the quartz chips (see plate I, fig. 1). As the two constituents must have grown together, it may be that the boundaries that were developed represent a kind of resultant of the competing crystal faces (of the two constituents); being the diagonal of what might be termed: the "parallelogram of speeds of growth" of these.

We will now turn to the results obtained with FEDOROV's method for the felspars of our porphyries.

With the *orthoclase of the granophyre* I had little succes, when trying to find out the twinning laws. Either the twin axis was found in a position unknown for orthoclase; or extinction occurred, in the manner of an optic axis, in two planes of optic symmetry (the third was too close to the plane of the section to be examined). As professor

Reinhard explained to me, this can only be accounted for on assuming crypto-perthite in the orthoclase. The "pseudo-optic axes" just mentioned are found when for the line placed in the direction of the axis of the microscope the total birefringence caused by the successive thin layers of plagioclase in the orthoclase just compensates the birefringence of the latter. With an oil-immersion the felspar could actually be seen to be slightly heterogenous.

In table I the measurements on the *plagioclases of the granophyre and two dykes* are brought together. In the first column of percentages the values found from Duparc and Reinhard's diagram are placed. For these percentages and this twinning law Berek's diagram gives the same amount. In the second column may be found the values obtained from D. & R.'s control-projection; when the two groups of lamellae differ they have been mentioned separately. The last column contains the values, found from the maximum extinction when the composition face of the albite twin is placed vertically. As the felspars were more or less decomposed measurements of the optic-axial-angle did not lead to satisfactory results.

The granophyre phenocryst is only slightly more calcic than the groundmass felspars. The dyke 6 a, b, c is poorer in An; the phenocryst of the quartz-porphyry dyke contains the same amount as the granophyre groundmass felspar. The crystals 6—7 were all undulose, which made the measurements inaccurate. But the higher values found in the last column, as compared with the first, need an explanation. It might well be that a small percentage of potash felspar enters in these crystals, and has this disturbing influence. At any rate Prof. Reinhard is of opinion, as he told me, that zonal structure is largely due to this third constituent.

In the first 4 crystals the albite-lamellae were joined, not only along (010) but also along a plane ⊥ (010). It was not the rhombic section of the pericline law, for it was on an average 68° distant from np and should have been 84½°.

The *plagioclases of the porphyrites* are far more variable than those of the quartz-porphyries. The percentage of An varies from 90 to 40. Generally the crystals are zonal, and contain sometimes a low, sometimes a higher percentage of the orthoclase felspar.

In table II the results for the pyroxene-porphyrite and quartz-biotite porphyrite are brought together. The numbers 1—2, 3—5 etc. represent the combinations of lamellae that are joined in accordance with the twinning law in question; they have also been placed above the percentages that were found from their poles. The letters at the side of the percentage columns apply to the various zones. M and P are the poles of composition planes and twin-axes respectively. The number of underlinings denotes the distance a pole lies from the migration line that it belongs to in the diagram.

Apart from in 8c the combination albite — Carlsbad A — Roc-Tourné (= complex twinning law albite-Carlsbad A) was found; sometimes, as in fig. 18, A, the albite lamellae had joined along (001) as well. The two crystals do not form a real pericline twin however; for the planes

(001) of two triclinic felspars forming an albite twin are not exactly parallel. The composition face observed is only an adoption, not an actual crystallographic plane therefore.

In N°. 9 (fig. 18, B) 1, 2, 3 and 4 form the normal combination of albite, Carlsbad A and Roc-Tourné. The lamellae 5 and 6 are an albite twin that has its twin axis parallel to that of the other lamellae; but they have been rotated over an angle $\alpha = 46°$ round this axis. Probably this juxtaposition is merely accidental. The optic orientation must, however, apart from the angle α, be either that of 1—2 or of 3—4; and whatever the angle α, they will form two "pseudo-twins" with the other albite twin. The "pseudo twin axes" will halve the great circle through corresponding axes of the ellipsoid of the twinned crystals in the manner for a real twin. If in a similar combination the lamellae with corresponding orientation did not happen to be present, there would be no evidence that it was not a real twin. In most cases the poles would not fit onto the diagrams in a satisfactory manner, however. It remains to be seen whether such "pseudo-twins" are of frequent occurrence, which might be the case if there were a certain preference for the crystals to join on to each other with (corresponding?) crystal planes.

The considerable variations of percentage found for the same zone are due to inaccuracies in the measurements, and to disturbances caused by admixture of potash felspar [1]). The latter influence is also responsible for the deviation of the poles from the migration lines. In ocnsequence of this the two diagrams could not be compared so as to ascertain which is the more accurate.

In fig. 19 I have placed the migration lines of the two diagrams on top of each other and added the poles that I found. Apart from a few exceptions they are all diverted to the east, the least from the Carlsbad line, and more in the lower than in the higher percentages. As the axes of the Carlsbad-, albite-, and Roc-Tourné laws must for one crystal always be at right angles, I imagine that when a plagioclase contains potash felspar the ellipsoid is rotated round the crystallographic c-axis (= Carlsbad twin-axis). The points in fig. 19 will then move away from the Albite and Roc-Tourné lines. Besides this the points may have been moved along the lines to which they belong.

The maximum extinction in the zone [010] is not of much use when the felspar contains potash, for this admixture may have an influence, but it would not show itself. On the whole the extinction angle was smaller than what it would have been, had potash been absent.

The quartz-biotite-porphyrite phenocrysts lack the basic centre of those in the pyroxene-porphyrite, and contain less potash felspar; otherwise there is no great difference in the composition.

In table III appear the data of five phenocrysts and one groundmass felspar, all occurring in the same slide. The rock was a brownish red inclusion in porphyrite tuff from the M. Martica of pyroxene-porphyrite. Fig. 20 applies to the first four crystals. I will describe

[1]) See DUPARC and REINHARD, p. 107.

TABLE II.

Plagioclases of the porphyrites.

N°.	Occurence.	Twinning-law.		°/o of anorthite Duparc and Reinhard's diagram.	°/o of anorthite Becke's diagram.	Max. extinction zone [010].
8a	Pyroxene-porphyrite phenocryst.	Albite {1–2, 3–4} Roc-Tourné {1–4, 2–3} Carlsbad/A {1–3, 2–4}	a b	1–2 1–4 1–3 80°/o 80°/o 80°/o 60°/o 65°/o 65°/o	1–2 1–4 1–3 77°/o 80°/o 80°/o 60°/o 66°/o 66°/o	1 2 3 4 73°/o 71°/o 60°/o 49°/o
8b	Pyroxene-porphyrite phenocryst. Fig. A.	Albite {1–2, 3–4} Carlsbad A {1–3, 2–4} Roc-Tourné {1–4, 2–3}	a b c	1–2 1–3 1–4 81°/o 80°/o 80°/o 45°/o 41°/o 39°/o 90°/o	1–2 1–3 1–4 81°/o 81°/o 81°/o 45°/o 42°/o 40°/o 90°/o	1 2 3 4 50°/o 47°/o
8c	Pyroxene-porphyrite phenocryst. One lamella zonal.	Manebach Esterel or Pericline.		M. P. 44°/o 34°/o	M. P. 46°/o 32°/o	
8d	Undulose.	Albite {1–2, 3–4} Carlsbad/A {1–3, 2–4} Roc-Tourné {1–4, 2–3}		1–2 1–3 1–4 76°/o 74°/o 75°/o	1–2 1–3 1–4 76°/o 75°/o 75°/o	1 2 3 4 74°/o 74°/o
9	Pyroxene-porphyrite phenocryst. Fig. B.	Albite {1–2, 3–4, 5–6} Carlsbad/A {1–3, 2–4} Roc-Tourné {1–4, 2–3} Pseudo-twin {3–5, 4–6, 3–6, 4–5}		1–2 5–6 1–3 1–4 87°/o 90°/o 90°/o	1–2 5–6 1–3 1–4 84°/o 87°/o 90°/o	1 2 3 4 5 80°/o 90°/o 90°/o
10	Quartz-biotite-porphyrite phenocryst.	Albite {1–2, 3–4} Carlsbad/A {1–3, 2–4} Roc-Tourné {1–4, 2–3}	a b	1–2 1–3 1–4 60°/o 50°/o 48°/o 44°/o	1–2 1–3 1–4 60°/o 48°/o 50°/o 47°/o	1 2 3 4 53°/o 54°/o 62°/o 48°/o 63°/o 51°/o 50°/o
11	Quartz-biotite-porphyrite phenocryst.	Albite {1–2, 3–4} Carlsbad/A {1–3, 2–4} Roc-Tourné {1–4, 2–3}		1–2 1–3 1–4 46°/o 42°/o 45°/o	1–2 1–3 1–4 46°/o 43°/o 46°/o	1 2 3 4 45°/o 57°/o 47°/o 50°/o

them in a few words as they form a striking exception to the general rule, that all crystals in one slide, when zonal, show the same general arrangement of zones.

A begins with a succession of calcic and more sodic zones (*b* is only slightly different to *a*). Then after having been corroded by magmatic resorption a few alternating zones slowly healed the irregu-

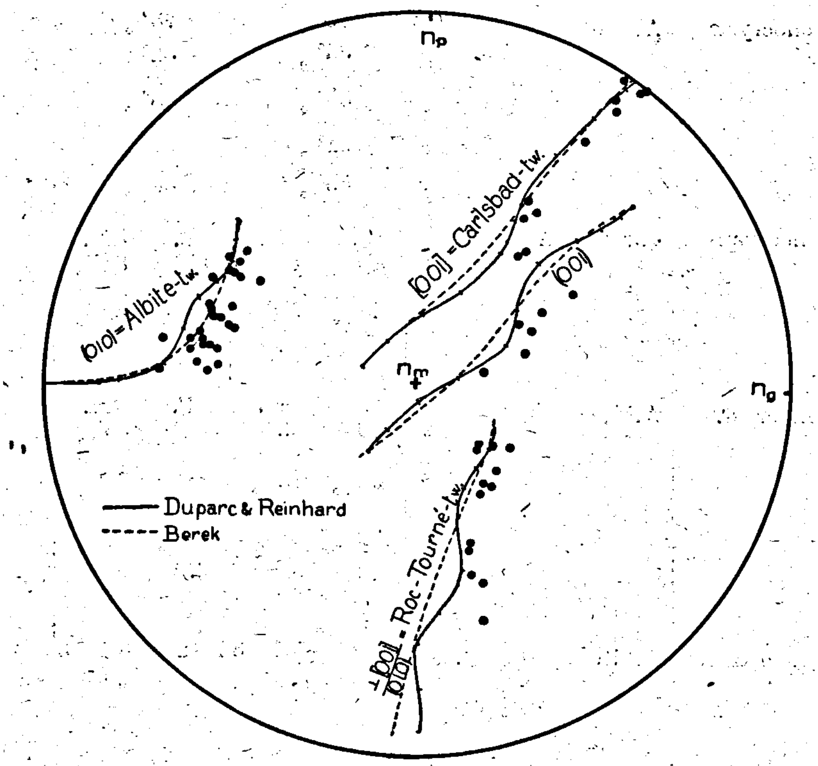

Fig. 19.

Stereographic projection of migration lines, and of poles of composition planes and twin axes in plagioclases of tables II and III.

larities. It is interesting to note that the two lamellae of the same crystal behave in a different manner, as may be seen in fig. 20, **A**.

B has a large very calcic centre (it is likely that the section does not cut through the actual centre of the crystal, but runs through a comparatively thin basic zone). A rim with a far lower An percentage surrounds the centre with a sharp margin. Locally a basic strip recurs; the outer rim *c* is slightly poorer in An than *b*.

C is absolutely different and presents a phenomenon very seldom to be observed. The central parts with 45 % An are partly surrounded

TABLE III.

Plagioclases in one single section from inclusion in pyroxene-porphyrite-tuff.

Nº.	Occurence.	Twinning-law.		% of anorthite Duparc and Reinhard's diagram.	% of anorthite Berek's diagram.	Position of section.
12A	Phenocryst.	Albite.	aa'	70%	73%	Near centre.
			d	53%	52%	
			e	50%	48%	
			c	62%	61%	
			c'	50%	50%	
12B	Phenocryst.	Carlsbad/A.		P. M.	P. M.	Periphery.
			a	88% 84%	86% 84%	
			b	48% 50%	49% 52%	
12C	Phenocryst.	Albite.		P. M.	P. M.	Centre.
			a	40% 50%	40% 50%	
			c	68% 75%	68% 78%	
			e	32% 38%	33% 37%	
			d	40% 55%	45% 55%	
12D	Phenocryst.	Albite 1–3 Carlsbad/A 2–3 Roc-Tourné 1–2		1–2 2–3 1–3 46% 50% 48%	1–2 2–3 1–3 48% 51% 50%	Near centre.
			b	65% 60%	65% 60%	
			c	36%	37%	
			a	40%	40%	
12E	Phenocryst. Undulose.	Albite 2–3 Carlsbad/A 1–3 Roc-Tourné 1–2		1–2 2–3 1–3 61% 60% 66%	1–2 2–3 1–3 63% 60% 66%	Near centre.
12F	Groundmass	Roc-Tourné.		P. M. 32% 42%	P. M. 30% 41%	

by a', slightly more calcic. Then the An percentage quickly increases outwards to the zone c rich in inclusions. Here the maximum of 70 % An is attained. Then the An percentage decreases swiftly to the outer margin, where it is only 35 %. The twinning law was albite, but

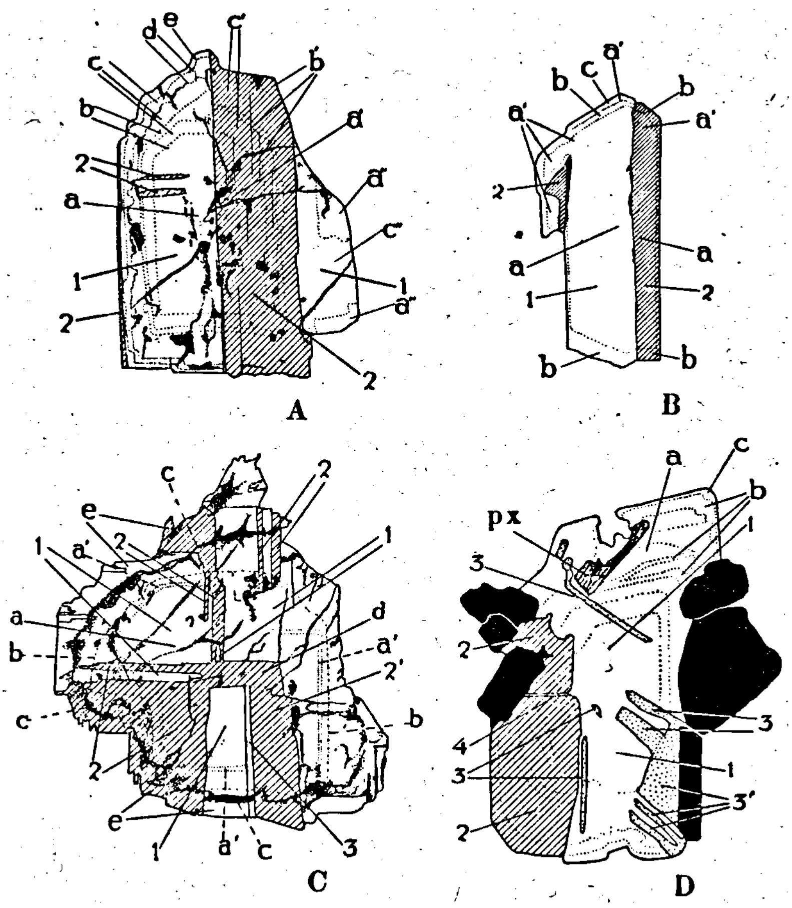

Fig. 20.

Plagioclases occurring in inclusion of pyroxene-porphyrite in tuff; see table III.

(001) as composition plane was also well developed (in fig. 20 **C** horizontal). Lamella 3 was too narrow to allow of determination.

In **D** the zones were irregular in shape, in lamella 2 not enough pronounced to admit separate investigation.

E was undulose but not concentrically zonal.

We might represent these crystals as follows:

A Lamella 1 : 70 → ± 68 | 62 | ± 68 | 62 | resorbtion | 53 | 62 | 53 | 49
„ 2 : 70 → 68 | 50 | 68 | 50 | 68 |
B 86 | 50 | ± 80 | ± 48 |
C 45 | ± 47 | → 70 → 35 |
D 49 | ± 48 | ± 47 | 62 | ± 50 | 62 | 40 | ± 50 | ± 49 | 62 | 36
E 63 undulose

DUPARC and PEARCE [1]) described at length the plagioclases in rocks from Ménerville; these showed no regularity in the zoning and no resemblance of neighbouring crystals. Such cases as these are important for showing how the magma can separate out very different felspar matter onto crystals close together and at the same time resorb others; but these cases must be looked upon as exceptions.

[1]) L. DUPARC et F. PEARCE. Note sur la composition des zones d'accroissement concentriques de certains plagioclases (Ménerville, Algérie) Archives d. sc. phys. et nat. Génève 1899, t. VIII, p. 17.

VI. SUGGESTIONS FOR AN EXCURSION.

Although not difficult, the going is frequently rough, and requires nailed, watertight boots. Especially in Ganna (Albergo Valganna), but also in the other villages accomodation for the night is available.

First day.

Ganna (moraines), road to Casa Valicci to 600 m. (trough shoulder with postglacial erosion, granophyre); along one of the numerous tracks to the stream flowing from the M. Martica to the L. di Ganna at 675 m. (mica-schists, basal-tuffites, coarse and fine, more or less vertical junction with granophyre); round eastern spur of M. Martica 850 m., and along the path to pt. 937 (pyroxene-porphyrite, narrow strip of gneiss, milky quartz vein in granophyre); 50 m. down on other side and along path to pt. 892 (pyroxene-porphyrite-tuff, especially in stream 375 m. south of pt. 937, postglacial gullies superimposed on unglaciated forms); at pt. 892 (exposure of vertical junction between crumpled mica-schists and granophyre); along road to M. Chiusarella (dyke, transgressive sediments, Triassic weathering, on eastern slope of pt. 893 barite in Werfénian); road back and to top of M. Martica (fine exposures of coarse and fine pyroxene-porphyrite tuff and porphyrite); from summit (view on peculiar system of valleys and lakes); down to pt. 845, 500 m. along path to the south and then across fields to road round eastern end of Valmolina (in little stream tuff on schists); along road north of valley (western junction granophyre dyke (sheet-feeder) with schists, especially in valley, gneiss also exposed on road, and numerous smaller and larger pegmatite and granophyre veins in road, but much better in bed of stream); to Brinzio or Ganna for the night; to Ganna via pt. 660 (after C. Valicci keep to the right until having passed a large moraine block of black Valtremola Schiefer, then to the right when crossing stream just beyond).

Second day.

Ganna, road to Bédero (pt. 473 = small moraine with scratched dolomite blocks); into gorge forming boundary with sediments (see description in text); back to road and along road to Mondonico to first bend, here to the left (mica-schists overlain directly by dolomite); back to road and along path to C. Marteghetta (steep little knobs left by glacier, dyke several times, to be recognized by larger quartzes and green colour); down to road Bédero-Brinzio and to the south (just past pt. 455 quarry in much decomposed granophyre, dyke crossing road); when 500 m. past K. 12 to the left a small quarry (with fine and coarse granophyre in contact); pt. 508 (= moraine) and up the slope opposite, another quarry (granophyre with miarolitic cavities with tourmaline and fluorite); tectonic complications at K. 11 (see text); round grass slope before next stream (basal-tuffites and a few meters up the slope quartz-biotite-porphyrite, recognisable by the biotites); before next bend in road (two exposures of same porphyrite); fine waterfall by mill (calcite veins in the porphyrite); above waterfall (see text); between Bédero and Brinzio (postglacial erosion in glacial trough); Brinzio road to C. Valicci (dykes in gneiss).

Other interesting exposures.

Neighbourhood of F. del Cerro (granophyre dyke, with pseudomorphs after fluorite on cracks, gneiss, basal tuffites, pyroxene-porphyrite, quartz-porphyry dyke without biotite phenocrysts large erratic block of Valtremola Schiefer).

Valley of the Caprera, and valley further to the west (fluxional quartz-porphyry, with tuffs; pyroxene-porphyrite with tuffs).

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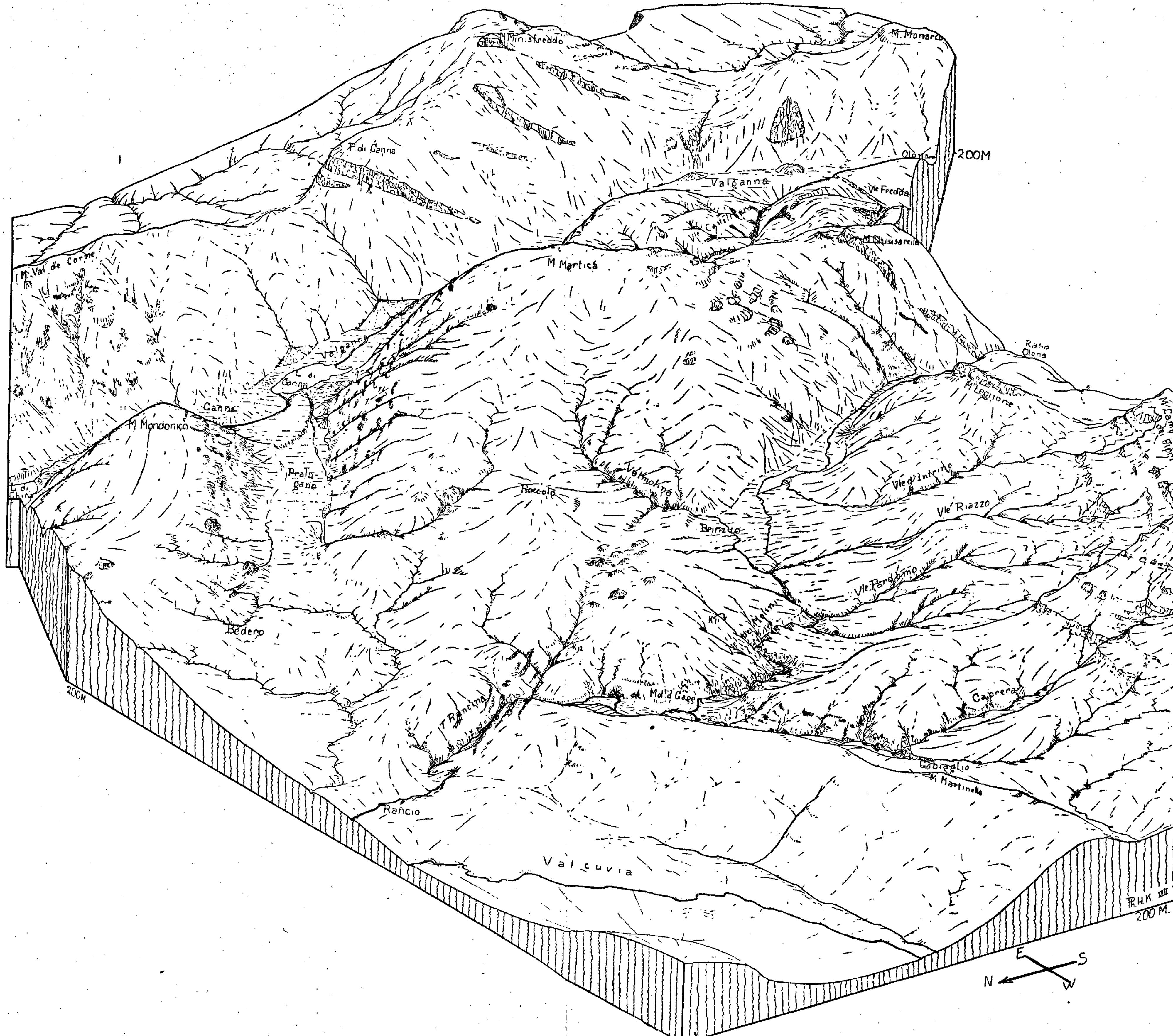
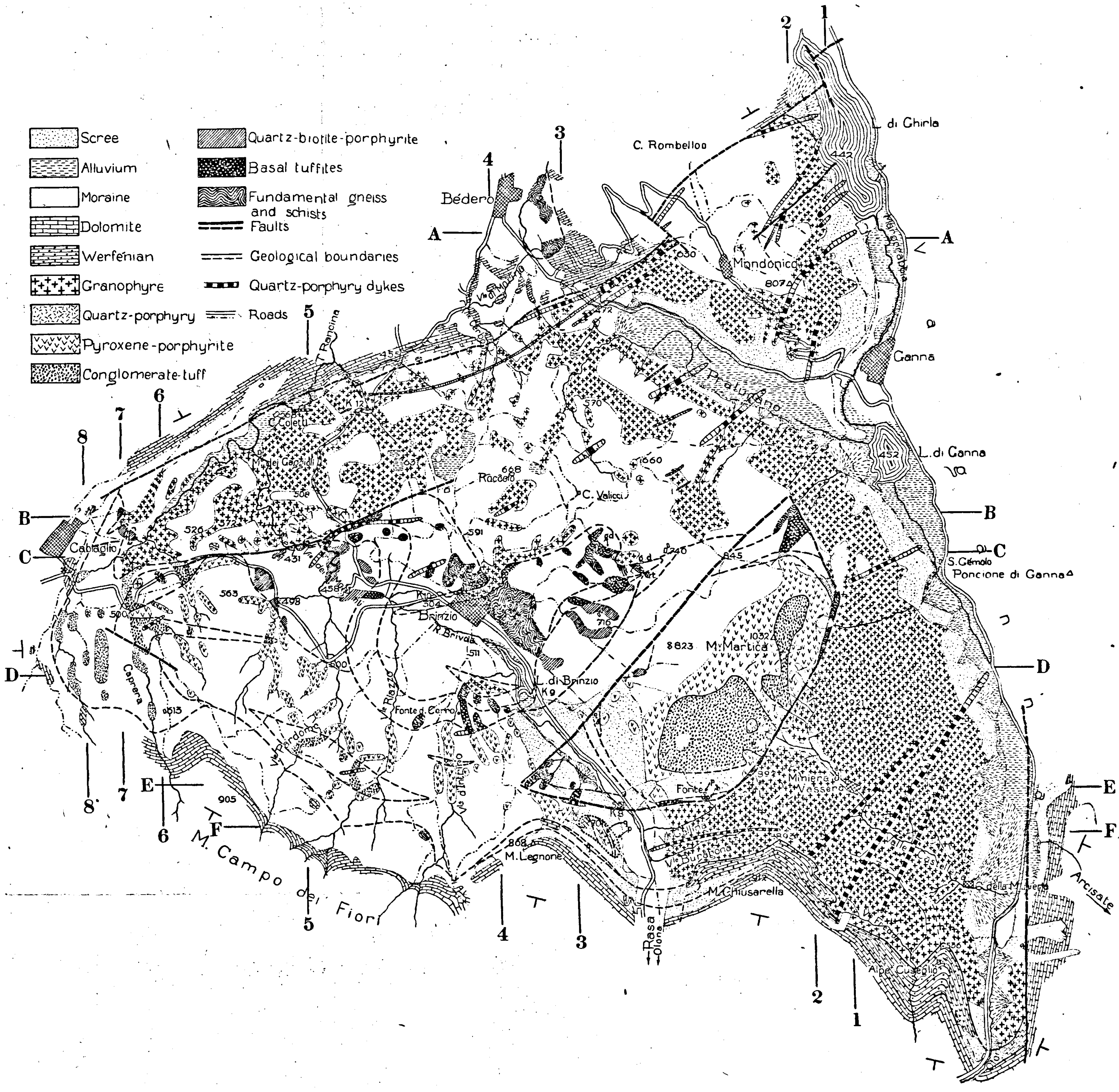


Blockdiagram of the Porphyry district of Lugano, west of the Valganna.

Scale: 1 : 20.000.

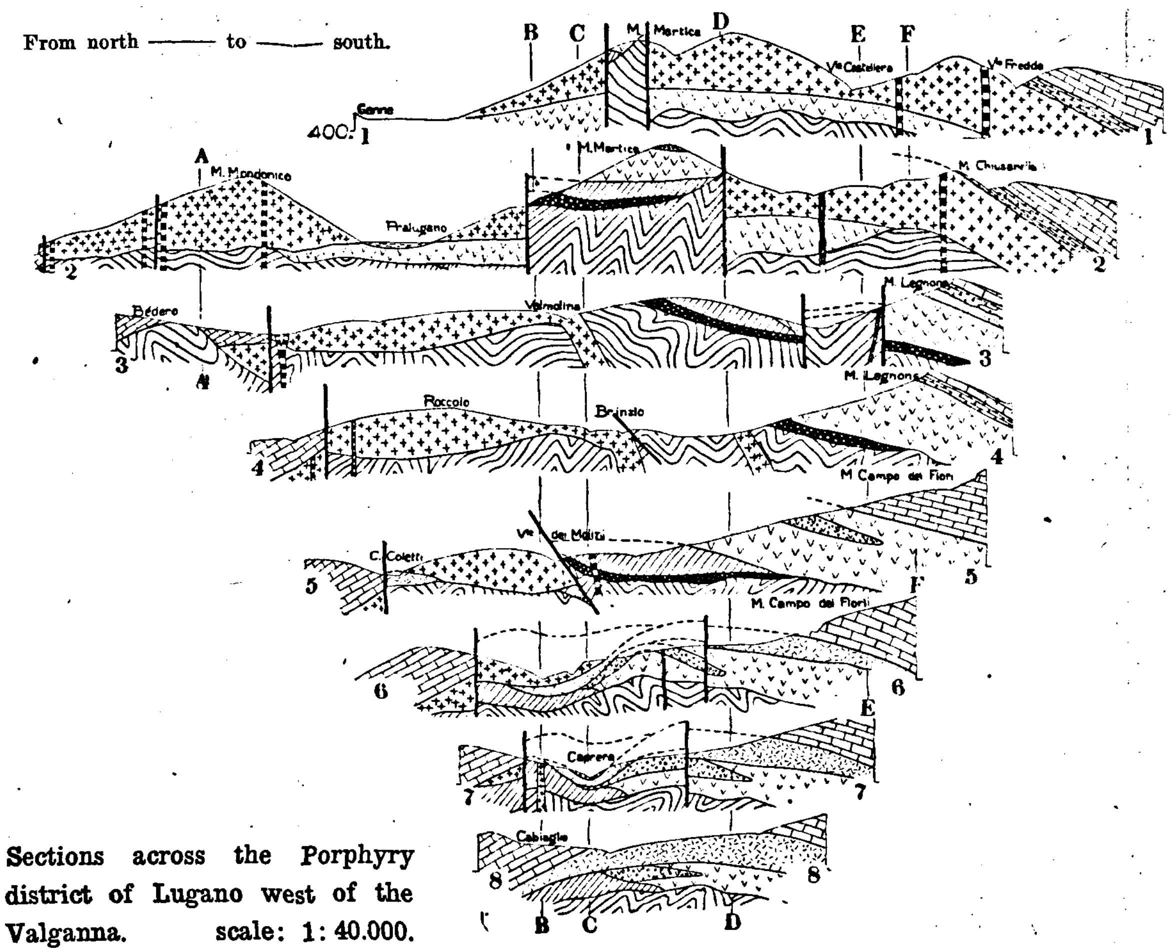


Geological map of the Porphyry district of Lugano, west of the Valganna.

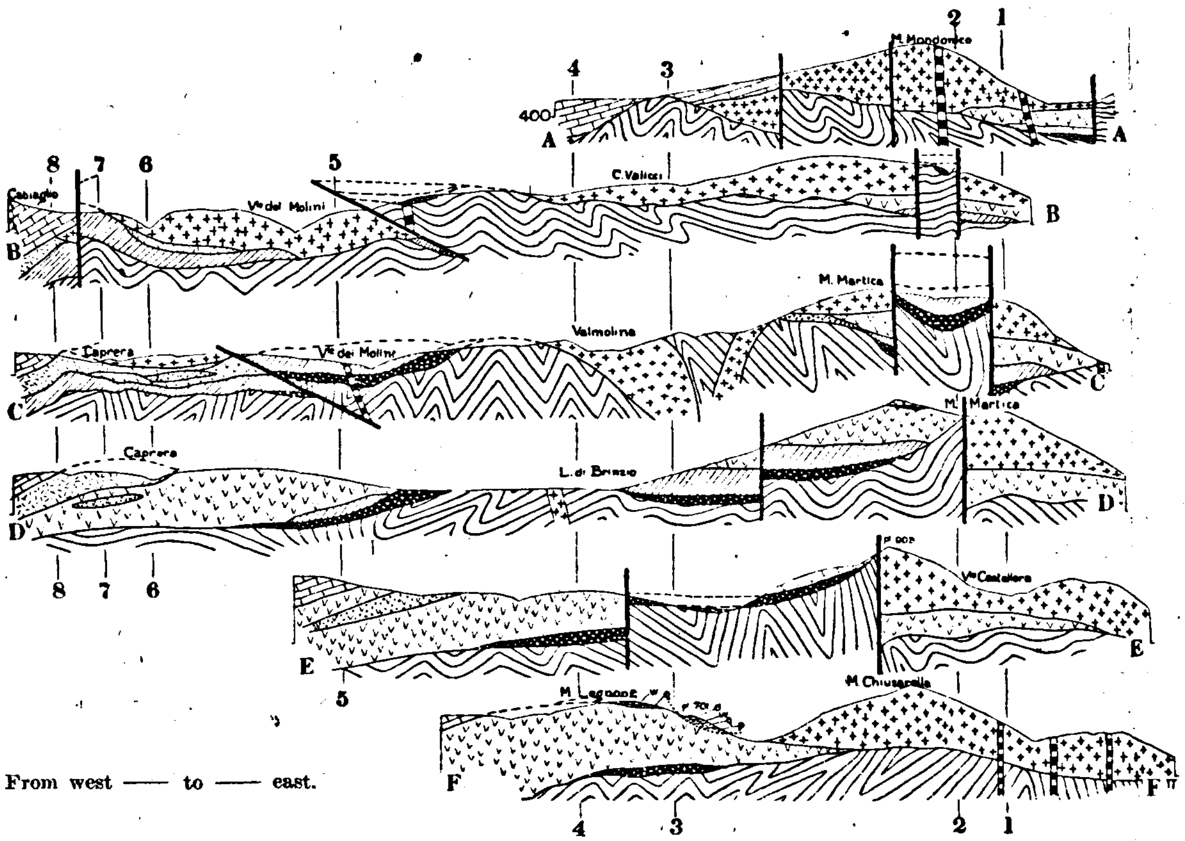
Scale: 1 : 25.000.

By PH. H. KUENEN.

From north —— to —— south.



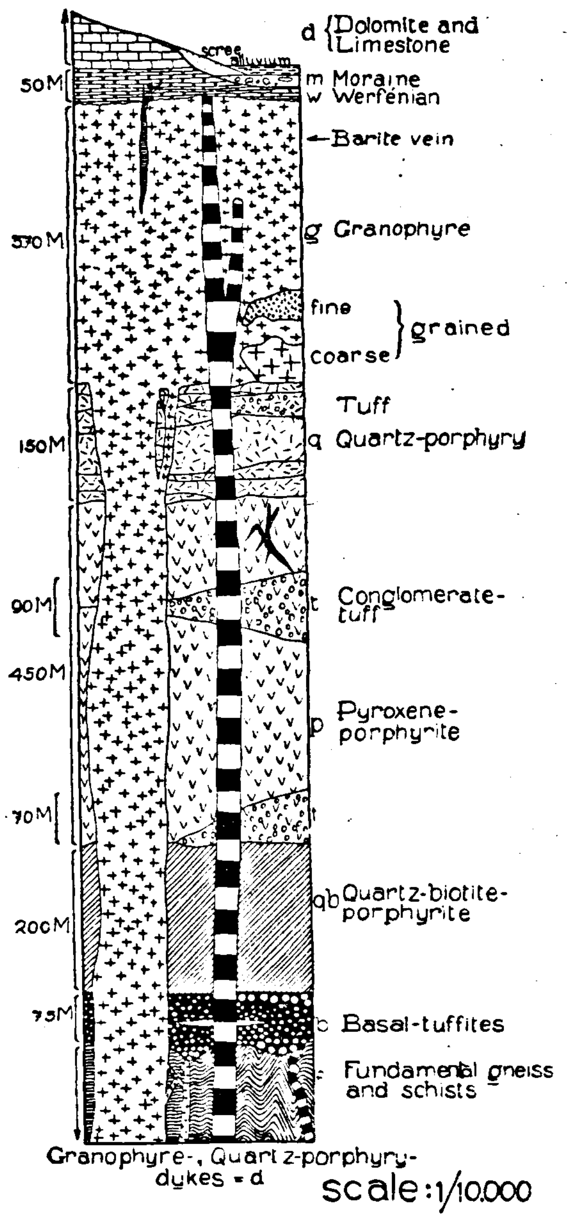
Sections across the Porphyry district of Lugano west of the Valganna. scale: 1: 40.000.



From west —— to —— east.

Reference page for use with:

Chapter III, maps and sections



the drawings of slides for the abbreviations of names of minerals:

Af = Amphibole.
Ba = Barite.
Bt = Biotite.
Cc = Calcite.
Ch = Chalcedony.
Ct = Chlorite.
Fr = Fluorite.
Fs = Felspar.
Gn = Garnet.
Lt = Limonite.
Ma = Magnetite.
Or = Orthoclase.
Pl = Plagioclase.
Px = Pyroxene.
Qu = Quartz. }
c = with corona. }
Sc = Sericite.
Tm = Tourmaline.

A = Amygdales.
CS = Crystalline schists.
g = groundmass.
p = phenocryst.
w = decomposed.
z = zonal.

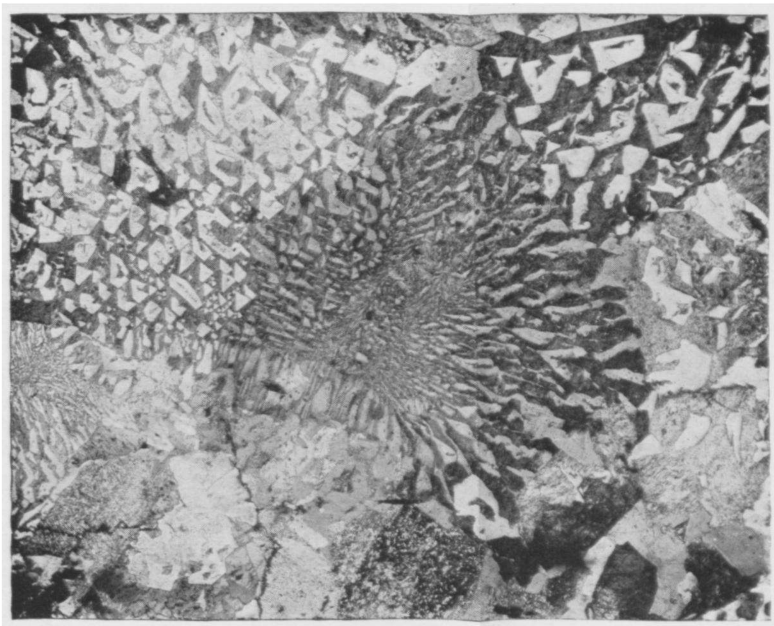


Fig. 1.

Graphic intergrowth of quartz and felspar; nicols +, 23 ×. (page 176). Nearly the whole top part is taken in by one orthoclase crystal; with the change from one quartz-aggregate to another the shape of the chips changes also.

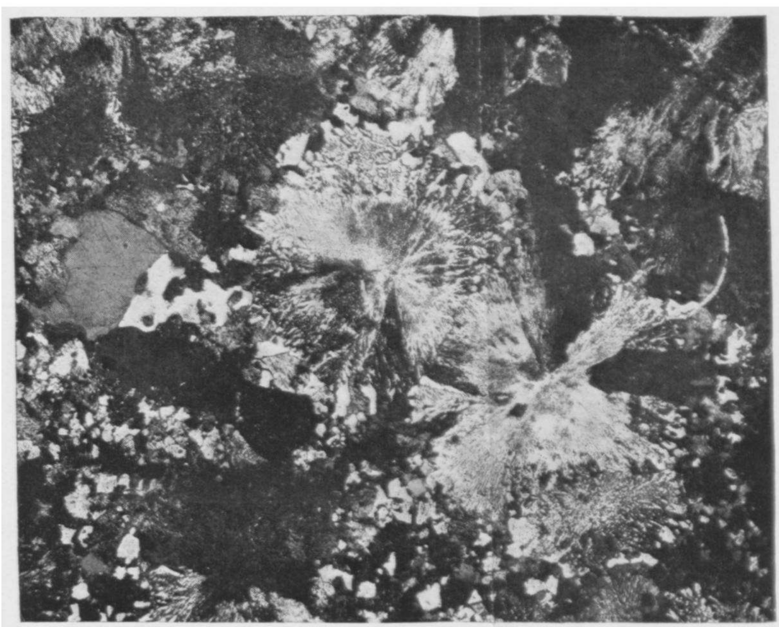


Fig. 2.

Pseudo-spherulites, merging into graphic intergrowth at the margins; nicols +, 43 ×. (page 166).
Weak negative optic character and subdivision into areas with the same extinction throughout.

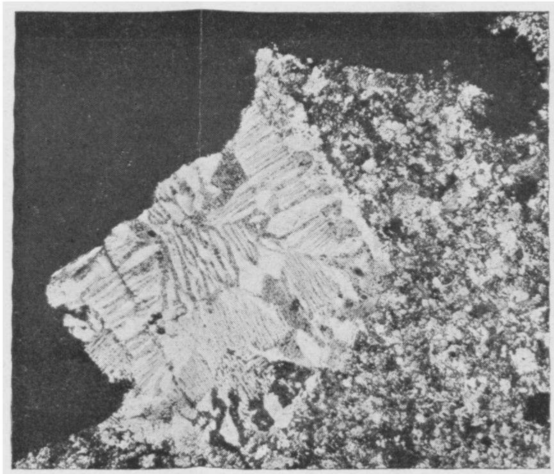


Fig. 3.

Graphic phenocryst with singular regularity in its build, floating in granular groundmass of dyke. (page 166). 35 ×, nicols +.

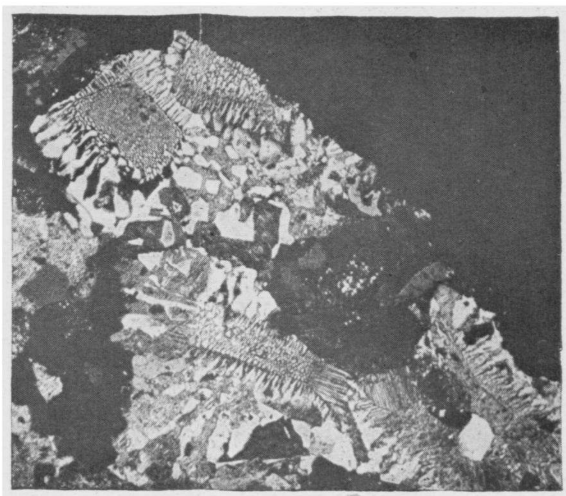


Fig. 4.

Graphic intergrowth around phenocrysts lying outside plane of slide. Dyke, see page 173. 43×, nicols +.