PETROGRAPHIC DESCRIPTION OF SOME IGNEOUS ROCKS FROM THE CORDILLERA OF SOUTH MENDOZA, IN THE ARGENTINE

BY

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INTRODUCTION.

Comparatively little is yet known of the intricate igneous history of the Cordillera of South Mendoza. Almost all the knowledge we have is due to the field- and stratigraphical work of Dr. H. GERTH of Leiden (bibl. 1 and 2), and the petrographic studies of Dr. H. G. BACKLUND (bibl. 3 and 4) on the material collected by the former investigator. A part of this material, however, had remained unexamined at Leiden, and at the request of Dr. GERTH Dr. L. U. DE SITTER began an examination of the 25 slides prepared. After a provisional examination and the determination with the universal stage [1]) of some plagioclases in most of the slides that were not too much decomposed Dr. DE SITTER left Leiden for Dutch East India. Dr. GERTH was so kind as to allow me the further examination, and I have great pleasure in expressing my sincere thanks to him for entrusting me with the valuable material. All data concerning the geological occurrences and field-evidence were supplied by Dr. GERTH. I myself, not having the use of a theodolite microscope for the time being, Mr. CH. HARLOFF was so good as to make some further additions to Dr. DE SITTER's determinations (slides n°. 970, 9, and 28, with the accompanying drawings). The petrographic descriptions are on my own responsability. In a few cases I thought it better to give other names to rocks, that were identical with, or very closely related to specimens already described by BACKLUND, taking Holmes' "Nomenclature of petrology" as a basis. For a pre-tertiary andesite the somewhat antiquated term of "porphyrite" has not been employed.

For the micrographs I used rough tracings made with an optical bench for micro-projection. The general shape and relative sizes of the larger items are therefore accurate.

After each name the number of GERTH's handspecimen is given. The following numbers have been examined: 543, 81, 1013, 967, 970, 1012, 530, 540, 28, 31*a*, 61*d*, 900, 9, 307, 448, 927, 15*e*, 15*c*, 15*a*, 34, 560, 562.

[1]) u-stage.

PETROGENETIC REMARKS.

BACKLUND has published the results of his petrographic investigations in a monograph: "Der magmatische Anteil der Cordillera von Süd-Mendoza" (bibl. 3) (referred to under the letter B), and recently in a short paper in the Geological Magazine: "Magmatic activity and mountain folding in the Andes of South Mendoza" (bibl. 4), he has given the general outlines of the theories and facts of the older, bulky publication in a more handy size and form. As the amount of material at my disposal was small in comparison with that examined by BACKLUND, this paper only aims at a supplementation of his work, and has no separate importance.

It is worthwhile reviewing BACKLUND's petrogenetic conclusions, however, as these are far reaching. I was also able to read the proof-sheets of a paper by Dr. GERTH, that will appear shortly; Geologische Rundschau 1926 (Steinmann Festschrift) (bibl. 2).

The following rules have been found by BACKLUND and GERTH to apply to the many igneous rocks cropping out in the region under consideration. First the intrusions are found to lie roughly in rows following the trend of the north-south anticlines. Secondly the rows have each a fairly constant composition. The data concerning the age of these intrusions are comparatively scarce. The effusive rocks show as a whole a marked tendency to become less salic towards the younger geological periods. Of these the stratigraphical position is on the whole accurately known for the older members; for the tertiary effusives it is based on morphological reasonings.

The scarceness of dyke rocks in the westerly intrusions, as compaired with the more easterly masses might be taken as evidence that they have been denuded of their upper parts; the more acid composition on the other hand, might indicate that they represent the upper part of differentiated magma basins. In the former case they would be younger than BACKLUND takes them to be, for those upper parts must have reached into the younger formations that have now also disappeared. According to him differentiation has not taken place, so that they show the average composition of the whole mass of which they are supposed to be the upper parts.

BACKLUND has proposed the following hypothesis. Each row of intrusions is of uniform age and corresponds to one of the orogenetic cycles that are known, from the examination of the sediments, to have occurred. The effusive rocks can also be placed in groups according to their age, each group belonging to one of the intrusion periods. The more basic masses are the younger, and the effusive magma thus follows the same differentiation process as the intrusive material.

This hypothesis is fascinating and very plausible, but as stated above, field evidence concerning the age of the intrusions is scarce and before a larger part of the Cordillera has been drawn into the circle of observation, and chemical analyses have been made, it should not be accepted without reservation. That the ages are not clearly established may be seen from the fact that in his first paper BACKLUND

regarded the effusive members of a magmatic cycle as younger than the correlated intrusives, but now he believes them in nearly all cases to be older. Further GERTH cannot everywhere agree with the age ascribed by BACKLUND, on petrographic evidence, to intrusions.

A very helpful distinction proposed by BACKLUND is that of "correlated" and "equivalent" effusive rocks. The latter are the direct extrusive parts of an intrusion and are therefore of the same age and composition as the parent magma. The correlated extrusives are due to the same orogenetic cycle, but have undergone different evolutions and may be either somewhat younger or somewhat older, and will generally be of a more basic composition. Differentiation or assimilation not only play their part, but an other portion of the magmatic basin can have contributed to their formation. In the investigated area this distinction seems to have led to satisfactory results, but here also the want of a more detailed field examination is felt, and in other parts of the earth where swift and extreme differentiation and assimilation seem to have acted more than in South Mendoza its application on petrographic evidence would meet with great, or even unsurmountable difficulties.

Among the rocks I examined was one (n°. 15*e*) that occurred as a boss in Co. Desague. It turned out to be much more basic than all the intrusive rocks of the middle tertiary cycle to which the dyke rocks of this mountain were reckoned by BACKLUND. According to GERTH, however, the intrusion lines on BACKLUND's map (bibl. 4 page 419, point 3470), should not bend to the south-east, but to the south-west. Co. Desague, in that case, no longer belongs to the cycle "(d)" but to the youngest "(e)", and as it corresponds to the rocks of this series much better, it need not be looked upon as an exception to the general rules established.

PETROGRAFIC DESCRIPTIONS.

Andesite-bearing-tuff(?) (n°. 543, Ao Infernillo).

The rock n°. 543 was found enclosed in n°. 114*b* (B. p. 58 = "Quarzporphyrit") in irregularly bounded masses. The inclusions in the tuff bear no resemblance to this enclosing rock, but there is reason to suppose the tuff-matrix to have proceeded from a closely allied magma.

The rock under consideration is light reddish brown, with a fairly smooth, almost conchoidal fracture, and a host of varying inclusions. The loose crystals are shiny or opaque variously coloured felspars, rarer quartzes and some dark constituent. Here and there some pyrite occurs. The weathered surface of the rock is darker, and bluish. The reddish colour is occasioned by what u. t. m. is seen to be decomposed olivine. Of the various small and rounded inclusions of other rocks the composition cannot be detected in the handspecimen.

U. t. m. the rounded inclusions are seen to belong to basalt and andesite; they lie wide apart.

The *basalt* inclusions contain idiomorphic phenocrysts of olivine,

sericite masses derived from some dark constituent and plagioclase; the matrix is a finegrained felspar mass with titaniferous magnetite.

The *andesite* inclusions show phenocrysts of some dark constituent and plagioclase, the groundmass consists of small plagioclases in a devitrified glass basis with limonite grains.

The groundmass contains several clear magmatic quartzes and rather weathered plagioclases with polysynthetic twinning, a few apatite and zircon crystals and small patches of zeolites.

The *matrix* of the tuff itself is a devitrified mass with a strong tendancy to the forming of spherulitic structures. With lowered condenser and lifted tube a structure becomes visible that bears a certain resemblance to the vitro-clastic structure. It is, however, by no means certain that it is actually caused by small particles of devitrified glass, for it might be *the glassy matrix of an acid rock* with minute irregular cracks. The number of inclusions is not too large to exclude this possibility.

Andesite-bearing-tuff (n°. 81, Piedra Burrero).

Theoretically I prefer to name a tuff after the rock that caused the explosion, however small a proportion it may form of the total bulk

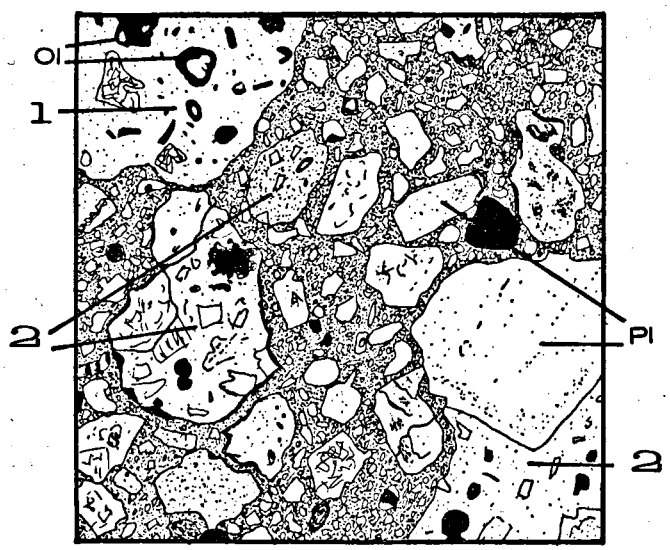

Fig. 1.

Andesite-tuff (n°. 81) 16 ×.

1 = basalt inclusion. Ol = olivine.

2 = andesite inclusion. Pl = plagioclase.

of the ultimate product. Often the inclusions are only accidental and bear no direct relationship to the processes going on in the magma

chamber and the vent. These processes are of more interest than the surface history of the volcano. When, as will generally be the case, this magma is no longer determinable we shall have to fall back on the inclusions for naming our rock, and these inclusions may belong to a totally different rock than that of the erupting lava. It might be well to distinguish the two by calling the latter kind a *"basalt-bearing-tuff"*, the former a *"basaltic-tuff"*. The basalt-bearing-tuff might proceed, for instance, from a rhyolite breaking through solidified basalt; the basaltic-tuff from basalt exploding through schists or any other rock.

In the rock of Malm-age, I must now describe, the eruptive material is no longer to be distinguished as such. Nearly all the inclusions belong to andesites, but some quartz fragments in the matrix suggest that the explosive magma may have been more acid.

The general appearance and geological occurrence resemble that of the rocks 113 etc. (B. p. 98), reconed by BACKLUND as belonging to the middle cretaceous rocks. Field evidence, however, proves that it is older.

Compared with n°. 981 (B. p. 79), a specimen from the same series, the chief difference seems to be the absence of quartz bearing rock fragments; but chips of this mineral in the matrix may proceed from similar keratophyres as well as from the explosive magma.

Megascopically it is a purple tuff-rock with a rough fracture showing the following inclusions: fairly large (up to nut-sized), sharp edged fragments of a green rock with greenish-white felspars and small amphibole or pyroxene columns (some are lighter, some darker in colour), gray fragments with white felspars and an abundance of magnetite grains. The groundmass is composed of countless white and green glistening or opaque felspars and a few quartzes.

U. t. m. the *lighter inclusions* are seen to be *andesites.* The phenocrysts are plagioclase, so far decomposed to calcite, sericite and zoisite that the twinning lamellae can hardly be distinguished. They contain inclusions of magnetite and chloritised amphibole (?) and are small and isometric. The sparse dark constituent, either a pyroxene or an amphibole is represented by pseudomorphs of calcite, zoisite and limonite. The groundmass is slightly fluxional with felspar laths in a matrix of chlorite, sericite and felspar substance that most likely proceeds from a devitrified glass. If this be the case the groundmass was hyalopilitic.

The *darker inclusions* owe their blacker shade to a great richness in limonite, that, though showing up the felspars, has so shrouded the nature of the rock, that we can but guess at its being an *andesite.*

A few inclusions belong to a different type of rock, probably a *basalt.* Besides plagioclase phenocrysts resembling those described above, they contain a decomposed dark mineral, most likely olivine. A thick crust of limonite round a calcite nucleus, slightly tinged by the same mineral is all that remains of this dark constituent. The matrix is composed of isometric hypidiomorphic plagioclases with some limonite.

Between these rock fragments loose crystals and crystalfragments, almost all of *plagioclase,* but some of *orthoclase,* and here and there a *quartz,* lie in a dust of limonite. The felspars are decomposed to chlorite, zoisite and zeolites.

Hornblende-andesite (n°. 1013, A o. d e l F i e r r o).

The irregular sill-rock n°. 1013, and n°. 967 (see page 31) are related to BACKLUND's Melaphyres of the "Malmstamm", both in field occurrence and in petrographic character. The petrographic difference namely is small, for the melaphyres contain plagioclase phenocrysts ranging in composition from 65—30 % An, so that, although there is olivine present, one might term some of them andesites (porphyrites). In n°. 1013 the plagioclase has 60 % An, and all indication of olivine is absent, so that andesite seems the most appropriate denomination.

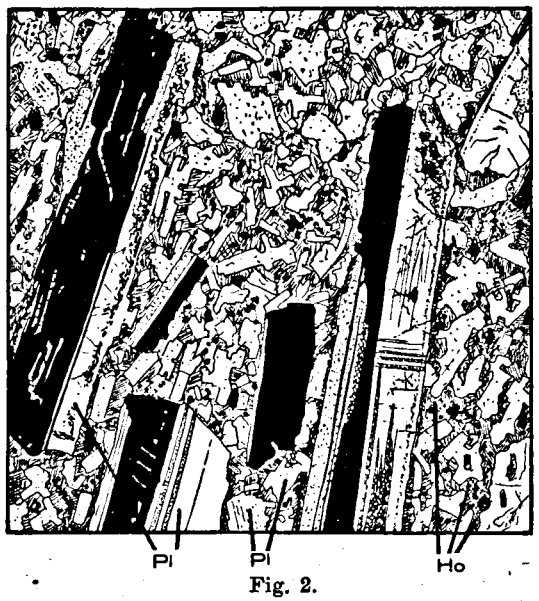

Fig. 2.

Hornblende-andesite (n°. 1013) 9 ×.
With fluxionstructure of the plagioclase phenocrysts (these with crossed nicols).
Ho = hornblende, Pl = plagioclase.

Megascopically it is a dark green rock with a fairly smooth fracture in which the numerous large table-shaped plagioclases lie distinctly parallel to one another. These are colourless with an uncertain lustre. The dark constituent is greenish-black and scarce as phenocryst, forming on the other hand a large part of the groundmass in which it can just be distinguished from the felspars with the naked eye. A few small patches of pyrite are visible.

U. t. m. the large *plagioclase* phenocrysts show Carlsbad A, albite and their complex, sometimes combined with pericline as twinning laws in thin regular strips along the elongated idiomorphic sections. The An percentage is 60 in the central part, with a thin margin in which it sinks to ± 45 (three determinations[1]). A slight sericitisation has begun along the cracks and a thin strip close to the periphery with a sharper edge outwards than inwards is crammed with rounded inclusions of glass and magnetite.

The less markedly tabular plagioclase of the *groundmass* is on the whole more idiomorphic than the hornblende. It forms only slightly more than half the total mass of the matrix. The dark constituent is a green *hornblende* with pleochroism from green to brownish-yellow and yellow. The extinction angle is 20°. To a large extent it is replaced

[1]) DE SITTER.

by a secondary hornblende that is more bluish, has an extinction angle of 22° and a radial disposition. At the same time titanite has been evolved. No phenocryst happens to be present in the examined slide.

As *accessory constituents* a large amount of magnetite occurs in well formed octahedrons, and a much smaller amount of pyrite enveloping idiomorphic felspars.

The parallel position of the felspar phenocrysts is probably due to fluxion before the crystallisation of the groundmass as no indications of pressure can be detected.

Augite-andesite (n°. 967, Pa. Burrero).

The handspecimen, taken from a Malm lava flow belongs to a amygdaloidal porphyritic rock of intermediate composition. It bears no special resemblance to n°. 965 (B. p. 86), that was found nearby.

Megascopically it is a dark gray rock with a rough fracture and a profusion of fairly large amygdales, dull white felspars and a much altered dark constituent. The contents of the amygdales is concentrically layered and either milky white or greenish black with radiating fibrous structure. The matrix is finely sprinkled with green.

U. t. m. the porphyritic character is strongly emphasized. The phenocrysts of *plagioclase* are large and numerous. They fall into two unequal groups. The larger group is formed by idiomorphic crystals tabulated ⊥ [010], that are nearly entirely replaced by calcite, so that the polysynthetic twinning is only just distinguishable. The smaller group is represented by crystals with more arbitrary shapes. With the exception of the nucleus and the edge they are entirely filled with titaniferous magnetite and glass inclusions running roughly in parallel rows. Sericite and calcite are found in minute specks, but the greater part of the matter is still the original plagioclase. The twinning is complicated, polysynthetic; zoning is absent. On account of the great number of inclusions a determination with the U-stage was found to be impracticable. The dark constituent is a *pyroxene* entirely changed to calcite with a thin crust of limonite. The amount of this constituent is very small.

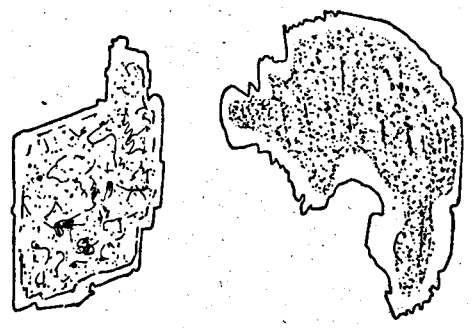

Fig. 3.
Two kinds of plagioclase in n°. 967.

The *groundmass* is hyalopilitic. The plagioclases are twinned and lath shaped, and show calcite in large amount. Of the dark constituent hardly anything can be distinguished, but strings of limonite mark in uncertain lines what might well be pyroxene contours. The original matter has given place to yellowish-green chlorite with a very low double refraction and a high refraction. The glass basis in between resembles the pyroxene filling in colour, but is of course isothrope.

The vesicles are filled with chlorite, calcite and chalcedony, and in some cases with natrolite (?) also.

Diorite (granitic), (nº. 970, Nacimiento del Ao. Burrero).

The rock to be described occurred as intrusion in the continuation to the north of group I, of the four that BACKLUND (p. 94) distinguishes according to their geographical position. He considers them to be of middle cretaceous age. In petrographic character it shows a strong resemblance to the examples that he has described, but may be slightly more basic.

The *handspecimen* is gray, fine grained and with a fairly smooth fracture. The weathered surface is greenish. The felspars are of varying size and colourless to milky white. The quartz is found in small particles. The dark constituent is chloritic and green in minute interstitial grains.

U. t. m. the structure is puzzling, for while some crystals are large enough to be phenocrysts there is no break between these and the smaller crystals that constitute the bulk of the rock. This characteristic seems to be typical of the intrusives of this period. The *plagioclases* are hypidiomorphic, lath shaped, and polysynthetically twinned on albite, Carlsbad A, Roc-Tourné, Manebach-Ala A, and pericline laws [1]). The following compositions were found: in larger crystals: 76—42 (fig. 4); 57; 57—29; 56—24; 48; 40; 39 %; in smaller ones: 45—34; 42; 42—30 % An. The zonal build is the most arresting property. Most of the matter lying without the core, that is of one composition, shows many concentric groups of zones, all groups with the same average percentage of An, the thin margin and the whole body of the smaller individuals show an unzoned, gradual transition to the acid outer margin. Intersections close to the edge of a crystal show only the latter property. Some of the lime-soda felspars are albitised along cracks and the outer edge. Only a small amount of sericite has formed.

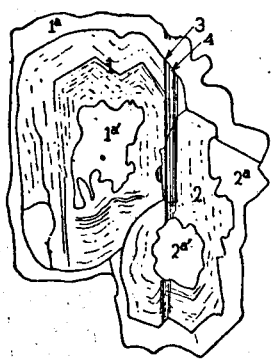

Fig. 4.

Plagioclase crystal from nº. 970. 1-3, 2-4 albite; 3-4, 1-2 Carlsbad A; 1-4, 2-3 Roc-Tourné: all 76 % An; 1-2 Carlsbad A 42 %. 1 and 2 are probably the contents of resorbtion inlets.

Orthoclase is also present but in very small amount. Absence of twinning and zonal build, together with a slightly obscured transparency on account of limonite dust, serve to distinguish it from the lime-soda felspars. It is only met with in small wedges between the more idiomorphic plagioclase.

The *hornblende* does not occur in large crystals, but is found in allotriomorphic masses that only slightly impeded the growth of the

[1]) HARLOFF.

plagioclase. It is of light greenish-yellow colours with a weak pleochroism and 18° oblique extinction. Weathering products are: chlorite, sericite (?) and yellow epidote, and a fine dust of titanite (?). On account of the far advanced decomposition of this allotriomorphus hornblende the possibility must be admitted of there having been a biotite also, that was intimately intergrown with the hornblende.

The interstices left between the afore mentioned minerals is filled by *quartz* in clear little patches, containing a number of inclusions.

Diorite (n°. 1012, Co. Potrerillo).

This intrusive diorite belongs, according to its geographical position to the groups II—III of BACKLUND (p. 98). The composition, however, is more basic than what should be expected.

It is a light greenish-gray rock with a rough fracture and fine grain. The white felspars are milky and dull. Besides a lot of magnetite and much less limonite, there is also an undeterminable blackish-green mass, formerly the dark constituent.

U. t. m. the *felspar* is seen to be nearly all plagioclase, but far gone decomposition into sericite has rendered it impossible to ascertain the exact amount of orthoclase. The plagioclase crystals are only slightly tabular and indistinctly show the remains of polysynthetic twinning and zonal structure. The sericite fills up the centre and is thickly distributed in the outer parts. The very edges may now and again have remained clear. The small corners left between the plagioclases are occupied by smaller plagioclase and orthoclase crystals, both frequently still clear in parts.

The *hornblende* is pleochroic (yellowish-green to greenish-yellow) with an extinction angle of 18° in the smallish crystals. In general they are idiomorphic, but sometimes the plagioclase is encircled and may even fill the hornblende poikilitically in small individuals. The forming of chlorite, magnetite, zoisite, and epidote has not yet advanced beyond the preliminary stages. Titanite in irregular and branching patches is, in part at least, due to the same decomposition process.

Apatite and *zircon* are the rare accessory constituents; the latter shows pleochroic haloes in the chlorite.

Hornblende-biotite-andesite, quartz bearing (n°. 530, Rio Valenzuela).

Only small differences distinguish this intrusive rock from that described under the name "Masanite" by BACKLUND (n°. 113, p. 98), I can hardly agree, however, to calling it so, for a masanite is a adamellite porphyry with quartz phenocrysts, which are absent in our rocks. As this rock n°. 530 was found in the next valley to the South of that in which n°. 113 crops out it might well be part of the same intrusion.

Megascopically it is a light gray, rough fracturing rock with white

opaque and glittering felspars, so unevenly distributed in the groundmass as to be absent in some parts and closely packed together in others. In the centre small patches of greenish-gray epidote are to be seen. There are two dark constituents: a mineral replaced by chlorite in silky threads is the most frequent, a brownish-black biotite in glistening crystals is scarcer. In addition to a large number of magnetite grains there are a few bits of pyrite.

Fig. 5.

Hornblende-biotite-andesite (n°. 530) 9 ×.
Ep = epidote, Ho = hornblende, Pl = plagioclase, Qu = quartz.

U. t. m. the phenocrysts are seen to be predominantly of plagioclase, some of hornblende and a still smaller number of biotite. The *plagioclase* is clear and slightly tabular. The twinning by albite, Carlsbad A, and Roc-Tourné laws has produced a great number of narrow lamellae. With the u-stage [1]) in one crystal ± 40 % An, in another ± 35 % An was found, but a rich admixture of potash (?) rendered the measurements uncertain. To illustrate this phenomenon: the albite twin gave 45 % An, the Carlsbad A 36, and the complex 32 %; in the control projection n_g 48, n_m 44, n_p 44 %; in the same order for the other crystal 40, 32, 28; 44, 35, 35 %, all points falling beside the corresponding lines in the migration diagrams. It should be noted that this uncertainty as to the An-percentage is not a consequence of the use of the method of Fedorov, but a lack of knowledge of the optical properties of potash (?) bearing plagioclase. The older methods would not even have revealed the existence of the uncertainty.

On the whole the crystals are only slightly zonal. A few inclusions of hornblende and apatite, or a rim of minute inclusions close to the edge, are of frequent occurrence. In the slide the uneven distribution of the felspars is as marked as in the handspecimen. While many crystals float loose in the matrix, others are so closely packed and intergrown as to form large balls. Albitisation along cracks and the outer

[1]) DE SITTER.

margin may be followed in almost all crystals. In some sericite has formed.

The *hornblende* is strongly pleochroic from green to brownish-green and brown. The extinction angle is 18°, so that it must be a common hornblende with a brown colour. It further shows twinning and is poikilitically embedded with small plagioclases. Decomposition into chlorite has started round the edges.

The *biotite* is a rich brown lepidomelane in thin tablets, partly altered to chlorite.

The *accessory constituents* are represented by a few needles of apatite, a large number of magnetite crystals, and a very few zircons. Products of decomposition are a large amount of strongly pleochroic epidote, some sericite, calcite and titanite. The epidote occurs in large radiating crystals; a few central parts differ from the general pleochroism in having a dark brown to olive green colouring.

The *groundmass* consists of plagioclase, quartz, biotite, and hornblende. The lime-soda felspar crystals are small laths with zonal construction far more marked than twinning. The quartz occurs in smaller and larger masses that show a slight tendancy to micrographic intergrowth with the felspar matter. The total amount is small. Apart from their smaller dimensions the crystals of the dark constituents are the same as the phenocrysts.

Granodiorite-porphyry (n°. 540 [2]), Ao. Pampa, Rio Grande).

This rock is practically identical with n°. 533 (B. p. 104 = "granodiorite"), and is obviously of the same intrusive period; a complete microscopic description is therefore superfluous. It was found as intrusion in the rock n°. 539 (B. p. 114 = "Labradoritporphyrit"), supposed by BACKLUND to be an extrusive rock of the same cretaceous cycle. The rock n°. 540 conforms very well, therefore, to BACKLUND's ideas, for it is younger and more acid than the "correlated effusive" membres.

The handspecimen shows a light green, finely grained rock with a rough fracture, white opaque felspars, a dirty green, decomposed pyroxene, some light greenish-yellow epidote, and specks and grains of pyrite and magnetite. Part of the rock, sharply defined towards the remainder, is richer in the dark constituent, found in much smaller crystals.

U. t. m. the following differences to n°. 533 were found. The decomposition of the phenocrystic crystals of *plagioclase* is far less advanced. Two crystals examined with the u-stage [1]) showed 50 % An and 48 % An in the centre, with albite, Carlsbad A and Roc-Tourné laws of twinning; this is about 10 % more than what BACKLUND found. The *orthoclase* and *quartz* show micrographic intergrowth.

Only very small amounts of titanite and tremolite have been

[1]) DE SITTER.
[2]) Bibl. 2, fig. 1: G 3 at right hand side of the section.

formed from the decomposing augite; but on the other hand a largé amount of epidote has made its appearance. Although the pseudomorphs are sometimes quite clearly after pyroxene, it is not impossible that others are after *biotite*. Orthite has not been formed.

Adamellite (n°. 28, see BACKLUND p. 134).

In a slide from the same handspecimen as the slide described by BACKLUND (p. 134) a number of plagioclases was determined with the u-stage by Mr. HARLOFF. As will be seen the average for the central parts is ± 40 % An, the rim reaching down to 24 %. These results agree very well with those of BACKLUND.

Besides the crystal of fig. 6 the following percentages were found Carlsbad A: 36 % An; albite: 55 % in the centre, 40 % in the rim; pericline: 38 % in the centre, 33 % in the rim; Carlsbad A: 42 %; Ala B: 38 %; Ala B: 37 %.

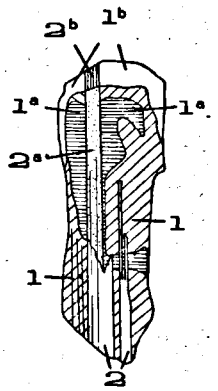

Fig. 6.

Plagioclase crystal from n°. 28. Carlsbad A:
1 – 2 = 40 % An;
1a – 2a = 34 % An;
1b – 2b = 24 % An.

Augite-quartz-diorite (n°. 31*a*, Co. Puchen).

The rock under consideration belongs to the plutonic rocks that form part of the same intrusion series as the Adamellite of BACKLUND (p. 134, n°. 28), but was found at some distance. Only a detailed field-examination could show whether it is a differentiation in situ or a separate intrusion. The petrographic resemblance to the rocks described by BACKLUND from this group is marked, but the occurrence of augite instead of hornblende and the higher An percentage of the felspars denote a more basic character.

Macroscopically it is a gray rock with rough fracture in which dull or semitranslucent felspars may be distinguished, with a greenish-black granular mass in between.

U. t. m. the felspars are seen to be of greatly varying size. The *plagioclase* shows albite, Carlsbad A, pericline and Roc-Tourné twinning in frequent repetition, sometimes down to lamellae of 0.002 m.m. in thickness. They are distinctly zonal, containing 60 % in the centre, 44—48 % in the chief mass and 30 % An in the outer edge of the thin margin [1]). In a late stage in the crystallization some *orthoclase* formed in the interstices. Now and then it showes Carlsbad twinning and a slightly undulose extinction.

The dark constituent is an *augite* with an extinction angle of 45° and a slight pleochroism in light greenish-yellow colours. Many of the

[1]) DE SITTER.

crystals are idiomorphic and show twinning. Hornblendisation has taken place to a large extent, the new mineral showing an extinction angle of 20° and a blue pleochroic colour. In its turn it has been chloritised and serpentinised. Generally the hornblende has an irregular or radiate position. Of the influence of the acid, alkali-rich magma that could have caused the change to hornblende ("uralitisation") no other evidence remains, so that it is more likely the augite became unstable without the addition of substance. The original amount of augite was not large.

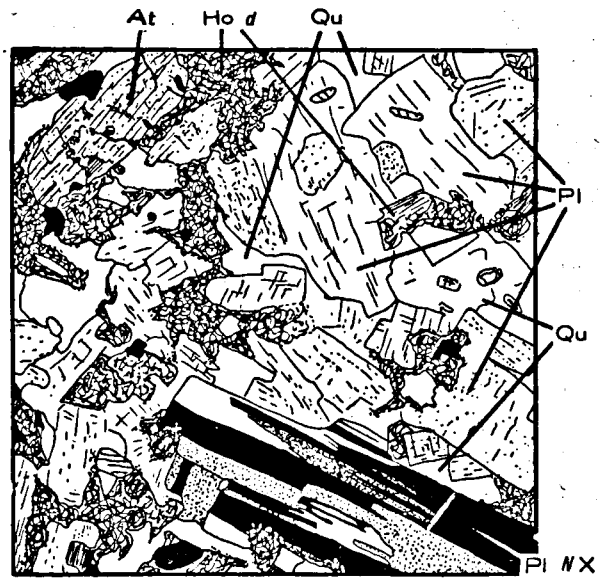

Fig. 7.

Augite-quartz-diorite (n°. 31*a*) 33 ×.
Ho = hornblende, *d* = decomposed, Pl = plagioclase, *N* × = nicols crossed, Qu = quartz, At = augite.

The last mineral to crystallize was the *quartz*, that lies in-between the felspars showing no crystal faces of its own. Arranged according to their abundance the chief minerals are: plagioclase, orthoclase, and quartz.

The *accessory* constituents are: zircon in small crystals or grains, numerous small needles and larger patches of apatite, and a small amount of anidiomorphic pyrite.

Hornblende-biotite-dacite (n°. 61*d*, A o. A l a m o).

The sample of this intrusive rock was procured from the same region as n°. 917 (B. p. 136 = "Quarzdioritporphyrit"), but on microscopic examination turned out to be in a far better state of preservation. It is quite likely of the very same rock complex, in which case the pseudomorphs after the dark constituent that BACKLUND determined as rhombic pyroxene and a monoclinic pyroxene must originally have been either hornblende or biotite.

In the *handspecimen* this rock is gravish-green, with a rough fracture showing clear, shiny and opaque, white and brown felspars, very thick and quite thin, sharply cut biotite disks, rounded dirty quartzes and glistening, black hornblende columns of varying size.

U. t. m. the phenocrysts of this very distinctly porphyritic rock are seen to be plagioclase, quartz, hornblende, biotite, and magnetite in order of their relative amounts.

Fig. 8.

Hornblende-biotite-dacite (n°. 61*d*) 11 ×.
Plagioclase phenocrysts with crossed nicols.
Bt = biotite, Ho = hornblende, Pl = plagioclase, Qu = quartz.

The *plagioclase* is zonal, sometimes to a marked degree, and the twinning, though complicated, is characterized by its low amount of repetition. With the theodolite microscope [1]) 45% An in an albite twin was found (BACKLUND determined 58 %). The shape is idiomorphic, but the edges are mostly rendered uneven by the joining on of groundmass material. In a few crystals the central part contains numerous small hornblende, biotite, and magnetite crystals, and has a slightly different extinction. Calcite, chlorite and sericite are to be found along numerous cracks and in hollows, and have in some cases replaced nearly the whole of the crystal. Albitisation hardly found place.

The *quartz* occurs in larger and smaller, partly resorbed crystals which still show prisms and pyramids. The bigger quartzes are somewhat smaller than the largest plagioclases.

The *hornblende* has an extinction angle of 20° and pleochroism from grayish-green to light yellow; the crystals are large and numerous with rounded off shapes. One is poikilitically intergrown with a number of biotite and plagioclase crystals.

The *biotite* is a lepidomelane also in large and frequent crystals, often grown onto the hornblende. They are six cornered thin tablets, and in decomposition have yielded magnetite, chlorite and calcite.

The *groundmass* is a fine grained allotriomorphic granular compound of quartz and zonal plagioclase in isometric shapes. Decomposition has resulted in the formation of calcite and chlorite, the latter probably from some dark constituent (biotite?).

[1]) DE SITTER.

The *accessory* constituents are apatite in a few small sharp needles and some larger rounded rods; and magnetite and limonite in several rounded crystals.

Augite-hornblende-andesite (n°. 900, Co. Alquitran).

The two rock specimens n°. 900 and 904 (B. p. 144 = "Hornblende-andesit, dioritporphyritisch"), although of practically the same composition and found also close together, show typical, though slight, differences, that prove them to be from different bosses. Those characteristics especially, which render n°. 904 diorite-porphyritic are absent in n°. 900.

In the *hand-specimen,* n°. 900 is a spotty, gray rock with a slightly brown crust of weathering, and a rough fracture. In the dark matrix lie small, glittering and opaque, yellowish felspars and shiny black amphiboles of small but varying sizes. There are also minute pores filled with limonite. The pyroxene is only visible in the slide.

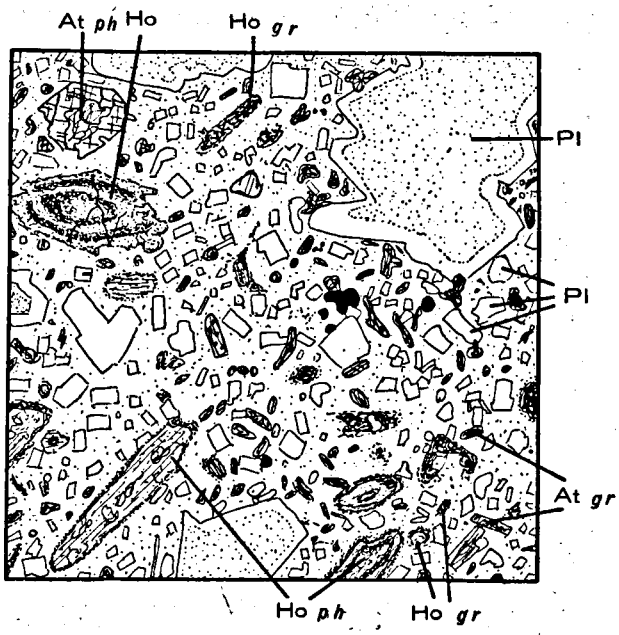

Fig. 9.

Augite-hornblende-andesite (n°. 900) 18 ×.
At = augite, Ho = hornblende, Pl = plagioclase,
ph = phenocryst, *gr* = groundmass.

U. t. m. the phenocrysts in order of their relative amounts are: plagioclase, hornblende, and augite, forming together a relatively large proportion of the rock.

The *plagioclase* phenocrysts are fairly large though of varying size and idiomorphic with a clean-cut margin. They show isometric shapes, with fairly complicated twinning, almost without repetition, however; and are frequently joined in small clusters. With the u-stage [1]) albite, Carlsbad A, pericline, and Roc-Tourné laws were found, giving 62-55-50 % and 66-60-50 % An in two phenocrysts in successive zones, the same percentage as BACKLUND found in n°. 904. The central parts are of uniform chemical composition and larded with untold yellowish

[1]) DE SITTER.

glass inclusions. The outer margin is absolutely free from inclusions and shows an abnormally strong progressive zoning.

The *hornblende* is strongly pleochroic from olive green to greenish-yellow and dark green. The individuals are somewhat smaller than the plagioclases, excepting one that is quite as large and contains poikilitically many small rounded plagioclases. On the whole the shape is more or less idiomorphic, the margin itself jagged. Twinning is frequent. At first sight they appear to be zonal, but this is only the cause in so far that there are sometimes two or three concentric zones darkened by a large number of magnetite inclusions. The extinction angle for both light and dark parts is 16°. It is not improbable that the iron was at some earlier time contained in the hornblende, and the same origin is likely for the iron now found in the shape of magnetite grains surrounding the hornblende crystals as a dark margin in the matrix.

The *augite* is light green with an extinction angle of 45° and a slight pleochroism. This constituent is also zonal. The crystals are nearly all quite small, but they are very numerous. They are elongated according to the c-axis, and seldom strictly idiomorphic, although the margin itself is sharp. No signs of decomposition are to be seen.

The *matrix* consists of plagioclase, augite and magnetite forming a hyalopilitic groundmass with devitrified intersticial glass. The plagioclase is isometric, idiomorphic and zonal, and of strongly varying size. The augite is the same as in the phenocrysts. Although there is no possible doubt that the structure is porphyritic, an exact line cannot be drawn between phenocrysts and groundmass crystals, neither of the plagioclase, nor of the augite.

The *accessory* constituents are represented by a large amount of magnetite in the groundmass with a few larger octahedrons and some apatite needles.

Olivine-basalt (n°. 9 and n°. 307, Co. Botamallin).

The handspecimens n°. 9 and 307 were both taken from the same series of basalt flows as n°. 9*a* and 304 (B. p. 166 and 167). In spite of their occurrence as flows BACKLUND has grouped these with the dyke rocks of this period on account of their diaschistic (lamprophyric) character. The specimens to be described here do not show this tendency to differentiate. The number of plagioclase phenocrysts, it should be noted, is low, the composition very basic, but this does not indicate a lamprophyric character in a basalt. The two rocks n°. 9 and 307 are closely related, the former, however, is more basic.

Macroscopically they are very dark reddish-brown rocks with a lighter weathered surface and a rough knobbly fracture. A large number of rounded light brown olivines, with a clear resin coloured core appear on the surface together with a number of dark green augite crystals and a few colourless glittering felspars. There are further a few milky white, opaque amygdales with zeolites. In n°. 307 the amount of augite and olivine is slightly smaller, that of felspar somewhat larger than in n°. 9.

U. t. m. the *basaltic augite* is almost colourless, zonal and undulose with an incomplete extinction of 42° (nearly 10° difference in one crystal). It encloses some olivine crystals and rounded calcites, and may be found in aggregates of many small individuals, sometimes with twinning. The idiomorphic shape is somewhat lost by growth in the groundmass period.

The *olivine* is colourless with a thin skin of limonite and is coloured by the same mineral along cracks and in its outer edge. The shape is idiomorphic with large and deep corrosion inlets, and here and there an inclusion of plagioclase.

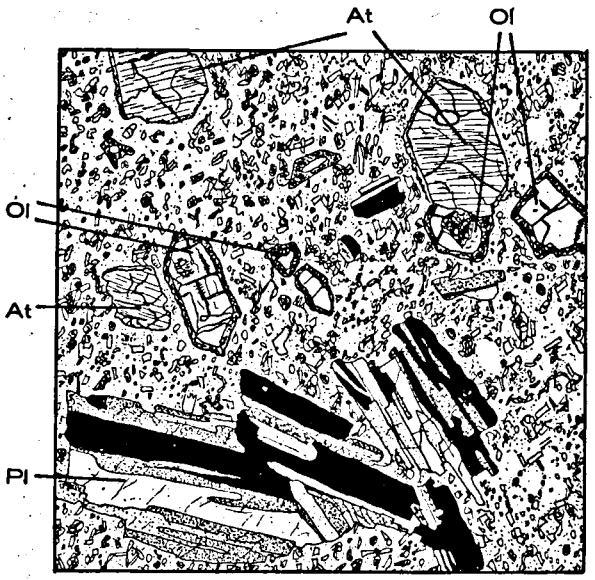

Fig. 10.

Olivine-basalt (n°. 307) 19 ×.
Plagioclase phenocrysts with crossed nicols.
At = augite, Ol = olivine, Pl = plagioclase.

The *plagioclase* is by far the most scarce of the phenocryst minerals. The shape is often idiomorphic, tabular with twinning on albite, Carlsbad A, and Roc-Tourné laws with a low degree of repetition. The central parts contain [1]): in two crystals in n°. 307 88 % and 86 %, and in one 62 % An; the outer margin of the last 50 %, with a gradual transmission. In n°. 9 the following measurements were made [2]): 90 % (fig. 11 B); 82 %; 95 % with in the margin 85 %; 76 %; 88 %; and 85 % (fig. 11 A). This is more basic than BACKLUND found (83 %).

The *matrix* is intersertal, built up of long felspar laths with augite and olivine crystals all three hypidiomorphic. The latter two form more than half the groundmass in approximately equal quantities. Further there is a considerable amount of magnetite in small grains. The distinct fluxion structure is apparently due more to the movement of the phenocrysts than to that of the whole mass, for it is developed specially clearly round the correspondingly orientated ends of all crystals, as if these had sunk a little in the consolidating mass.

[1]) DE SITTER.
[2]) HARLOFF.

In n°. 307 the plagioclase phenocrysts are not so rare, and the amount of this mineral in the groundmass is also larger. The olivine and augite phenocrysts are smaller. The rock is evidently less femic.

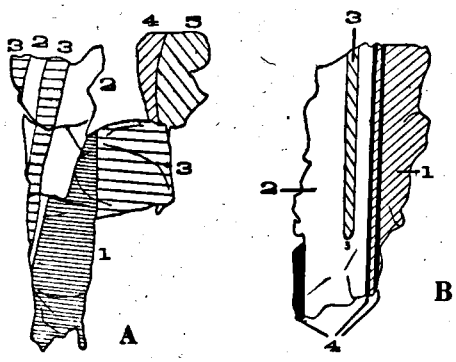

Fig. 11.

Plagioclase from n°. 9.

A 1—2 Albite.
1—3, 4—5 Carlsbad A.
2—3 Roc-Tourné.
3—4 tendency to Scopi.
3—5 tendency to albite.

B 1—4, 2—3 albite.
1—3, 2—4 Carlsbad A.
1—2, 3—4 Roc-Tourné.

Granodiorite (n°. 448, South of Estrechura, Ro. Salado).

The rock of which n°. 448 is a handspecimen is an intrusion similar to n°. 116 (B. p. 173 = "Windsorit"), and is related to this mass from a petrographic point of view as well. The percentage of biotite is even lower, however; and more important still: the An percentage of the lime-soda felspar is much higher. The orthoclase is not abundant enough to denote an alkali affinity, moreover. To the other side of the intrusion under consideration lies a rock n°. 926 (B. p. 174 = "Quarzaugitdiorite") which contains augite instead of hornblende and has a porphyritic structure, but which is otherwise closely allied.

Megascopically it is a fine grained, light pinkish-white rock, with a rough fracture. Most of the felspar is a dull or shiny white plagioclase, the remainder a dull, light pink orthoclase. There are many minute miarolitic cavities in which the orthoclase grows with free ends. The mafic minerals are a greenish-black glittering amphibole and a green chlorite.

U. t. m. the structure is seen to be dioritic. The *plagioclase* is comparatively unaltered and contains[1]) 67 % An in the centre and progressive zoning with 54, 44, 40, and 30 % towards the edge (crystal showing albite, Carlsbad A, and their complex twinning law), and 45—40 % in another with the same twinning laws. The shape is slightly tabular and shows an idiomorphic tendency. The size varies considerably. Besides albitisation, sericite has been formed. The *orthoclase,* that forms less than one third of the felspar matter is dusty with limonite and is evidently younger than the lime-soda felspar, forming a mesostasis with the quartz, and seldom occurring in larger crystals. The *quartz* is clear, and is in part even later than the potash felspar. In amount it stands far behindhand with both felspars.

The crystals of *hornblende* are of good size, but continued their

[1]) DE SITTER.

growth too long to retain crystal faces. Their number is not great. The pleochroism is weak in blue-green and yellow tints; the extinction angle amounts to 18°. Chlorite marks the beginning of decomposition, and part of the titanite may be attributed to the same cause. One minute brown rectangle in the hornblende was probably *biotite*.

A few rounded grains of zircon and several idiomorphic or rounded crystals of apatite generally together with the magnetite prefer the vicinity of the hornblende.

Miarolitic cavities were not to be found in the slide as it had slipped apart into small bits.

Augite-andesite (n°. 927, Ao. Amarillo).

The examined handspecimen was procured from the same exposure as n°. 926 (B. p. 174 = "Quarzaugitdiorit"). Although the two show a marked resemblance, even in minor details, n°. 927 is of a more porphyritic habitude. For this reason I have named it an andesite, not a diorite. BACKLUND describes, however, what I should certainly also name a porphyritic texture with a coarse groundmass. Further the composition is slightly more basic, the small amount of alkali-felspar and quartz of n°. 926 being absent.

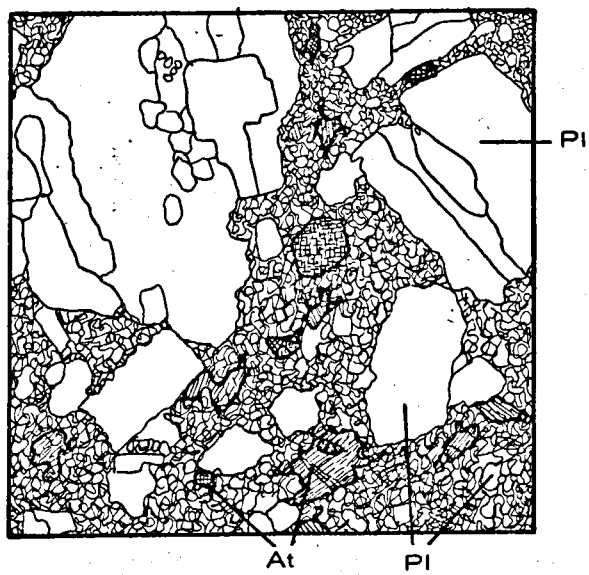

Fig. 12.

Augite-andesite (n°. 927) 6.5 ×.
At = augite, Pl = plagioclase.

N°. 927 is a light coloured rock with rough fracture. Without the aid of the microscope the phenocrysts and groundmass are not easily distinguished; neither is the character of the olive green, irregularly bounded, dark constituent to be determined. The white felspars are opaque or semitranslucent.

U. t. m. on the other hand the porphyritic structure is strongly emphasized, the phenocrysts forming nearly half the total mass of the rock. The felspar phenocrysts are all table shaped plagioclases. With the u-stage [1]) 44, 48, and 50 % in three individuals was determined

[1]) DE SITTER.

(BACKLUND found in n°. 926: 52, 54, 57 %); a thin more acid skin with 20 % An marks the close of their growth. In many instances the extinction is slightly undulose. They show fine polysynthetic twinning with the albite, Carlsbad A, and Roc-Tourné laws. Further they contain a number of small inclusions of augite and magnetite, and some few of biotite and apatite. Their idiomorphic shape has disappeared to a great extent by the adhesion of groundmass matter. In part they are riddled with sinuous roots and enclosed in a thin coat of a more acid plagioclase with a smaller refraction and double refraction (albitisation?).

The *augite* phenocrysts are of a pale green diopside-augite. They show no crystal planes, from having continued their growth up to a late stage of the crystallization of the matrix. As a rule they occur packed in masses of varyingly sized and shaped individuals. Irregular twinning after (100), sometimes with repetition, occurs. Inclusions of magnetite and apatite may be seen in abundance, and decomposition into chlorite has started in places.

The *matrix* consists of isometric plagioclases and augites, both hypidiomorphic, the former with albite twinning, sometimes so fine as to resemble microcline, and containing ± 20 % An.

Apatite in fairly large allotriomorphic and idiomorphic crystals, and dark brown biotite in tiny individuals are scattered here and there in the other minerals. Secondary titanite is found in slightly pink, allotriomorphic crystals, mostly in contact with the augite, and containing inclusions of apatite and zircon. Calcite in small patches is wedged between the smaller felspars; magnetite is only represented in a very few small grains.

Augite-diorite (n°. 15*e*, Co. Desague).

The rocks from Co. Desague, as we have already seen, probably all appertain to BACKLUND's pliocene cycle. The An percentage of the plagioclase in n°. 15*e*, higher (70 %) than of any of the abyssal rocks known from S. Mendoza, is also indicative of the relationship to the cycle "(e)" not "(d)" of BACKLUND. Of all the specimens GERTH collected from this spot none has such a definitely abyssal character as n°. 15*e*. It was also the only one occurring in an intrusive boss.

It is gray with a reddish weathering surface and a rough fracture. The felspar is white or pink with a dull lustre. A chloritic substance, that cannot with certainty be refered to any mineral, and magnetite in countless small grains are the cause of the dark colour.

U. t. m. the structure is seen to be hypidiomorphic granular with a tendency to the ophytic. The felspar is a zonal plagioclase with 85 % An in the centre and 54 % towards the margin; in a smaller individual 97 %—68 %—50 % was found (determinations with the u-stages [1]). It is tabular but almost without crystal faces. In part the calcic felspar matter has been albitised along the outer edges and numerous cracks.

[1]) DE SITTER.

The dark constituents are in large part changed into chlorite, titanite, magnetite, epidote, and zoisite, and as they were originally without crystallographic shapes there is no great certainty as to their nature and relative amounts. The largest quantity seems to have been *augite* as there is still a fair amount of this mineral present. It is colourless to bluish-green, the extinction angle ± 45°. Its decomposition seems to have given rise to a blue hornblende with an extinction angle of 19°, and all or almost all decomposition minerals just mentioned, in smaller amounts. The titanite occurs in colourless rounded grains, the chlorite evidently as a further breaking up of the hornblende. The magnetite occurs exclusively intergrown with the mafic minerals, and does not show crystal shapes, although occurring in fairly large patches. Moreover it contains numerous parallel slots filled with epidote (?), and is probably a pseudomorph after some mineral (biotite?). The epidote is colourless or yellow pleochroic with a not very high double refraction. It is found either in small irregularly shaped patches or in neat little spherules. The α-zoisite is colourless, and has a very low double refraction. No crystal faces are shown by the fairly large patches in which it occurs, neither when in the felspar, nor when in the ferromagnesian minerals.

Hornblende-basalt (n°. 15*c*, Co. Desague).

The rock under consideration belongs from a petrographic point of view to the group of dykes with basaltic habitude distinguished by BACKLUND, but was found as dark differentiated streaks in the augite-diorite n°. 15*e*.

In the *handspecimen* it is a dark gray rock with a rough fracture, enclosing numerous small, shiny, white felspars, and a fair number of smaller and larger isometric hornblendes, that contain epidote and felspar inclusions. The augite is hard to distinguish on account of its small size and the light green colour, that hardly shows up from the groundmass.

U. t. m. the felspar is seen to be a *plagioclase* that is so much altered (albitised?), that the original An-percentage can no longer be ascertained. It is idiomorphic without, however, showing a sharp margin, the crystallographic b-axis is short, and the twinning polysynthetic, probably on the albite and Carlsbad A laws.

The *hornblende* is light brown, pleochroic with an extinction angle of 23°. The large crystals are more or less idiomorphic, but the contours are irregular with minute inlets and a reaction rim. This rim is darker through containing a profusion of magnetite and titanite grains. In parts the hornblende shows an intense emerald green colour, now with the same, now with a stronger birefringence, and more perfect cleavage. In addition to these there are rounded hollows filled by calcite crystals.

The *diopside-augite* is found in smaller and fewer crystals, with crystallographic shapes and an oblique extinction of 43°. The colour is very slightly pink. A chlorite pseudomorph, with calcite centre, after a mineral that was probably *olivine* represents the most rare phenocryst.

The *groundmass* is hyalopilitic with plagioclase, augite, and hornblende (?) in a devitrified glass. The plagioclase crystals are minute laths, with twinning and a pronounced zonal structure. The augite is colourless, showing an extinction angle of 45° in very small rods. A rich admixture of chlorite, calcite, epidote, and limonite, the decomposition products of a hornblende (?) is evenly distributed throughout the devitrified felspar glass.

Finally small filled up hollows are found with idiomorphic plagioclases, chlorite (when green with anomalous blue interference colours, and when blue with beautiful anomalous reddish-purple colours), titanite and epidote. Magnetite is the only accessory constituent observable. It occurs in many smaller and a few larger grains richly strewn throughout the matrix.

Amphibole-quartz-andesite (n°. 15*a*, Co. Desague).

Another rock specimen belonging to this group of dykes is the sill n°. 15*a*. It is of less basic character than n°. 15*c*, and also falls in BACKLUND's division of rocks with effusive character (p. 182). The most obvious difference from the examples he describes is the absence of pyroxene, together with the presence of quartz in the matrix. It is probably slightly aplitic.

It is light gray, porphyritic, with a smooth, subconchoidal fracture, dull white felspars and numerous, but small amphiboles.

U. t. m. the *plagioclase* phenocrysts turned out to be in large degree altered to calcite. They are small, isometric, with sharp-cut idiomorphic shapes. The twinning is simple and the zoning only slightly marked.

The *amphibole* is represented by pseudomorphs of calcite and chlorite with limonite and titanite grains. The chlorite that surrounds the carbonate is grass green with a notable pleochroism. In some cases it has a radiating structure and is at the same time zoned. The shape of the original crystals was idiomorphic with slightly rounded corners in thin rods. Frequently they are intergrown with the felspars.

The *groundmass* is a hypidiomorphic granular mixture of quartz grains and short plagioclase rods, with a considerable amount of chlorite, and minute titanite and magnetite grains. The felspar matter has the upperhand.

The *accessory* constituents are apatite and magnetite. The apatite crystals are subangular and to be found more especially in the amphiboles, and the larger magnetite patches.

Andesite (n°. 34, Ao. Torrecillas).

The geological position of this rock was the same as of its neighbour n°. 34*c* (B. p. 188), namely a sill; but the chemical composition and the structure are widely different. N°. 34*c* is an alkali rock ("Soda-lithbostonit"), whereas n°. 34 belongs to the calc-alkali tribe, and from a chemical point of view comes under the diorite group of BACKLUND.

The structure, however, is not that of an abyssal rock, but pronouncedly porphyritic.

Megascopically n°. 34 belongs to a light greenish-gray rock with a brown weathering surface, and a rough irregular fracture. In the aphanitic matrix dull white felspars, patches of pyrite and limonite, and a scarce, milky green mafic mineral appear. There are also fairly large, black patches, probably filled up vesicles.

U. t. m. the porphyritic structure is also pronounced. The *plagioclase* phenocrysts are fairly large and numerous, with isometric shapes and complicated twinning. They are apt to clog together, but are otherwise idiomorphic. Besides being strongly albitised they are much decomposed, giving place to sericite, chlorite and calcite so that the composition is no longer ascertainable. Zonal structure was not pronounced.

Of *dark minerals* two seem to have been present as phenocryst, one in a few larger, the other in small less rare crystals. All that now remains of the former is a pseudomorph of large undulose calcite patches, with a notched edge of yellow epidote and titaniferous magnetite, in shapes that may either have been of amphibole or of pyroxene. The other ferromagnesian mineral is much darker, through containing a higher percentage of ilmenite, and has sharper edges. The small number renders it impossible to determine between pyroxene or amphibole. It is to be found in the plagioclase or the other dark constituent.

The *groundmass* is hypidiomorphic granular and consists for the greater part of plagioclase in minute short rods. A fair amount of a decomposed dark constituent represented by chloritè and titanite is evenly scattered in between. The presence of some orthoclase is not impossible. Pyrite is the only accessory constituent.

Finally there are a small number of little amygdales filled with a few clear quartz crystals along the margin, and green and brownish chlorite pseudo-spherulites in the centre.

Hornblende-andesite (n°. 560, Co. Tronquimalal).

Although the almost total decomposition of the dark constituent renders a comparison between this rock and n°. 446 (B. p. 249 = "Hornblendeandesit, spessartitisch") difficult, these two dyke rocks, that crop out close together, are certainly closely allied. N°. 562 (p. 33) is diaschistic and is therefore not related.

The *handspecimen* is bluish-gray with a rough fracture and a weathered surface that is slightly brownish. The felspars are fairly clear and glistening, the numerous small hornblendes are greenish-black. With the naked eye we can also see small hexagonal prisms of a clear shiny mineral that turned out to be apatite.

U. t. m. the phenocrysts of plagioclase, hornblende and apatite contrast strongly with the fine grained groundmass. The plagioclases show a complicated build. They are almost quite clear and have an idiomorphic, sharply cut shape. Several laws of twinning are often combined but on the whole without repetition (albite, Carlsbad A, Roc-Tourné, Baveno,

pericline). In some individuals, however, the lamellae are so fine and their numbers so great as to produce an impression as of zoning. The position, however, of the "pseudo-zones" at right angles to the crystal faces, and therefore to the actual zoning, immediately proves their real nature. With the u-stage the following measurements were made[1]): 55%—45%—40% in one, 50%—38% in another section. The ellipsoid axes did not fall on the corresponding lines in the projection, and the longest axis for the different compositions showed a tendency to lie parallel to one another (see L.G. Mededeelingen next number). There are small rounded hornblende inclusions and generally a narrow sharply defined zone crowded with minute inclusions just inside the outer edge of the crystal. The zonal build is most striking, without as a rule the difference in composition being more than slight.

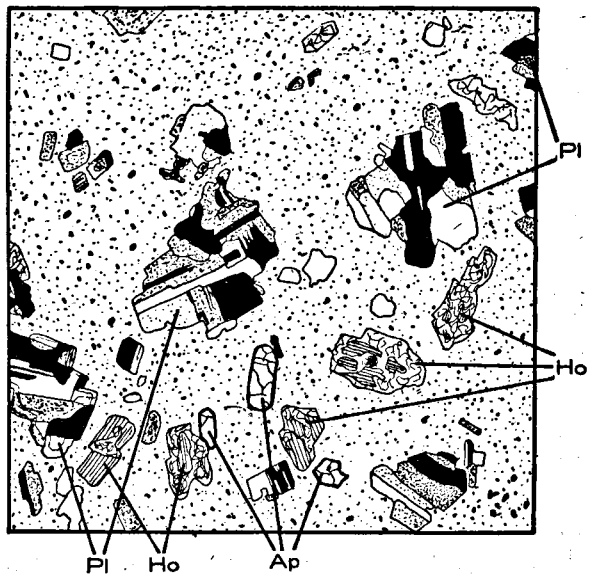

Fig. 13.

Hornblende-andesite (n°. 560) 13 X.
Plagioclase phenocrysts with crossed nicols.
Ap = apatite, Ho = hornblende, Pl = plagioclase.

The *hornblende* is bright green with a well developed pleochroism. The extinction angle is 22°. Nearly all of it, however, is changed into calcite with some chlorite and epidote. It is by no means impossible that these minerals proceed in part also from a rhombic or monoclinic pyroxene. This possibility is suggested by BACKLUND's having found these minerals in n°. 446. The original shape of the hornblende was that of long idiomorphic prisms. The *apatite* is colourless and clear in prisms of 1 mm. long. The magnetite occurs in numerous small octahedrons.

The *matrix* is hyalopilitic with short plagioclase rods, zonal with subordinate twinning, lying in a devitrified felspar glass. A certain amount of chlorite and calcite is all that remains of a former dark constituent. Magnetite is evenly and richly distributed throughout. A large number of small, clear, sharp apatites is also present. A fluxion

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structure is discernible, but it is not very marked. Further there are several amygdales filled with calcite, chlorite and quartz.

Augite-hornblende-spessartite (n°. 562, Co. Tronquimalál).

The tertiary rock n°. 562 occurred in a dyke and on microscopic examination turned out to be a spessartite. It belongs to the same set of dykes as n°. 8 (B. p. 251). It is not clear to me why BACKLUND termed this rock a kersantite as his description says it is "fast glimmerfrei", which is the typical characteristic of a spessartite as compaired with a kersantite.

The light greenish-gray rock has a rough fracture on which the dark phenocrysts are very conspicuous. They consist of a large amount of greenish-black hornblende only slightly elongated and a light green augite in smaller and fewer crystals. The groundmass consists of dull white, small felspars and a small grained dark green interstitial matter.

U. t. m. the large *hornblendes* show a pleochroism from olive green to very light greenish-brown, here and there with a few small, bluish patches. They are slightly zonal both in colour and extinction, and show twinning. The average extinction angle is 20°. A fine rim with a darker tone and an irregular outer border, possessing a smaller angle of extinction belongs most likely to the groundmass period. Inclusions of small crystals of augite, plagioclase and magnetite were noticed. One of the crystals is almost entirely changed into chlorite and epidote forming a lemon yellow, flaky mass.

The *augite* phenocrysts are pale yellow with an extinction angle of 42°. They also, are undulose, and do not become quite black between crossed nicols. Their shape is idiomorphic (except when occurring as inclusion) with a sharp clear-cut margin. They contain only magnetite as inclusion. Although the number of crystals equals that of the hornblende their total mass is but a fraction.

The *matrix* consists of plagioclase, augite and quartz. The first is too badly weathered to allow of exact determination, but is a labradorite with a more acid rim, and twinned probably after albite, and Carlsbad A laws. The larger crystals are more idiomorphic, but on the whole they are less so than the augites. The augite is abundant in colourless crystals with small inclusions of magnetite.

The *quartz* is rare in small, irregular grains, the magnetite on the other hand is scattered, also in small grains, but in large amount, thoughout the whole of the matrix. Intersticial between the components just mentioned, filling up the angular spaces these have left, lies a yellow crystalline mass consisting principally of chlorite and serpentine.

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For a complete bibliography see n°. 2 and n°. 3.

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