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ON THE PETROLOGY OF THE VOLCANIC AREA OF THE GOENOENG MOERIA (JAVA)

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FOREWORD AND ACKNOWLEDGEMENTS

The detailed petrological investigations which have been carried out on rocks of the Goenoeng Moeria (Java) have been stimulated by the outstanding work of Prof. Dr A. HOLMES and Dr H. F. HARWOOD on the rocks of the volcanic area of Bufumbira (Uganda). The present author wishes to express his thanks for the support he could derive from their work.

In preparing the English text the writer has in many instances made use of expressions and passages encountered in the work of English and American petrographers. Only in those places where use has been made of the scientific content of expressions the authors concerned have been cited. In many other instances textbooks or publications have been used as a vocabulary. The writer trusts that the result of his work in this way has been notable improved, philologically as well as ideologically. In any case he is indebted in some way or other to a score of petrologists of which, however, only a few writing on the subject under discussion have been listed in the bibliography.

Finally the writer is indebted to his colleagues Dr J. A. BAAK (†) and Dr J. H. DRUIF *for their suggestions and helpful criticism.*

This paper has been concluded in 1942, but war circumstances caused the delay of its publication.

F. A. VAN BAREN.

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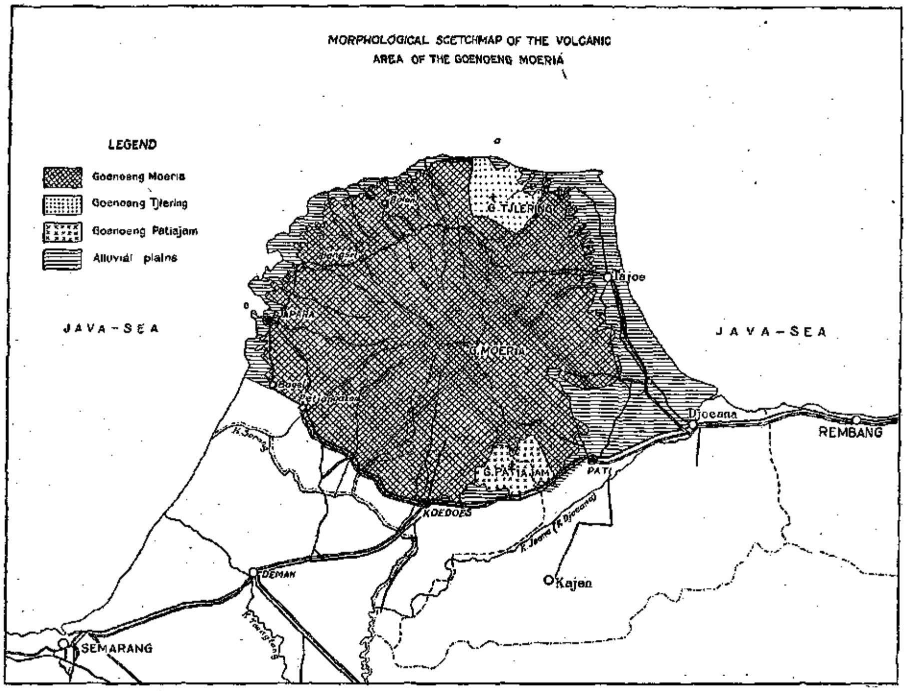

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CHAPTER I

INTRODUCTION

1. During the field work on behalf of the Soil Survey of Java an interesting collection of rock samples of the Goenoeng [1]) Moeria, G. Tjlering and G. Patiajam has been collected. Although the first object of the collectors has been the study of the relation between rock and soil and therefore no attention has been paid to the geology of the area, the present author has made a rather detailed study of the specimen collected in order to investigate whether an indication to the origin of these alkaline rocks could be derived from their petrological examination.

2. The late-tertiary volcanic area of the Goenoeng Moeria complex includes the main volcano Moeria and two smaller volcanic hills, viz. the Goenoeng Tjlering situated north of the Moeria and extending its north slope to the coast of the Java Sea, and secondly the Goenoeng Patiajam south-south-east of the Moeria. The Tjlering is built up of compact eruptive rocks whereas the Patiajam is composed mainly of loose tuffaceous ejectamenta. The first geological description of the G. Moeria we owe to KOORDERS who published a study on this subject in 1887. Discussing the petrography of this volcano he mentions leucitites and augite-andesites as the principal rocks. In their well known work on the geology of Java and Madoera the volcanic area is more extensely discussed by VERBEEK and FENNEMA. They classified the rocks of the Moeria, Tjlering and Patiajam as tephrites, leucite-basalts and leucitites (VERBEEK & FENNEMA 1896, I pp. 254-262). A more recent study of the petrography of the Moeria-complex appeared in 1915 when IDDINGS and MORLEY published their contribution to the petrography of Java and Celebes. Discussing the alkaline rocks of this region they distinguish leucite-tephrites, leucitites, olivine-leucitites, absarokites and shoshonites.

From the studies mentioned and from own observations it appears that there is a definitive consanguinity between the rocks of the Moeria and those of the G. Tjlering and Patiajam; in the following pages they are therefore discussed as one unit.

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1) "Goenoeng" (G.) is the Malayan name for mountain, pronouce gunung.

3. In a paper on the origin of the Malayan potash provinces VAN BEMMELEN (1937) comes to the conclusion that the alkaline rocks of these provinces may be explained as differentiates of the pacific magma type, which has locally been desilicated by limestone-assimilation. Hence he promotes the hypothesis of carbonate-syntexis which was originally adopted by DALY (1914) and is supported by SHAND (1929), RITTMANN (1933) a.o.

In order to explain the fact that in the alkaline rocks the percentage of potassium is equal to or larger than the percentages of sodium, whereas in the andesitic-basaltic rocks, which should have been subjected to the limestone-contamination, the sodium content exceeds the content of potassium to a large extent, he introduces *Rittmann's principle of passive potash accumulation as the result of the escape of soda into the surrounding contact region and into the atmosphere.* That on the other hand nearly all the volcanoes lying in the volcanic inner arc extending from Sumatra to Goenoeng Api yet belong to the normal pacific tribe, although layers rich in limestone are cut by the feeding canals, is obviated by the hypothesis that the chambers of these volcanoes should lie too deep. The cutting of the limestone by a vertical neck should establish insufficient contact to cause active assimilation and desilication.

4. That this hypothesis is open to criticism is pointed out by WILLEMS (1939), who in a study on the magmatic provinces in the Indonesian Archipelago raises the following objections to VAN BEMMELEN's considerations:

a. It is rather arbitrary to presume that everywhere in the volcanic arc Sumatra - G. Api the magma chambers are too deep seated for a wholesale assimilation of limestone.

b. In the case of limestone assimilation CaO takes the place of Na_2O. According to the equation $2\ NaAlSi_3O_8 + 5\ CaO = CaAl_2Si_2O_8 + 4\ CaSiO_3 + Na_2O$ inconceivable quantities of limestone have to be dissolved. Therefore, the total content of CaO in the alkaline rocks would be expected to be distinctly higher than in rocks of the pacific tribe. This, however, is contrary to the facts.

c. The content of molecular K_2O should also be slightly lower in the potash rocks according to the assimilation of limestone and consequently the increase in calcium. This too is contradictory to the chemical facts as the absolute potash content reaches rather high percentages.

5. Some more contributions to this subject have made it doubtful whether the contamination-hypothesis can have general application to the origin of potash-rich rocks. Especially the work of HOLMES & HARWOOD on the petrology of the Toro-Ankole volcanic fields (1933) and on the volcanic area of Bufumbira (1937) is of outstanding value. In these volcanic fields of Uganda potash-rich tuffs and lavas are developed on a gigantic scale that is out of proportion to the minute quantities of carbonate minerals found in the basement rocks. From a mass of petrological facts and a detailed study of field relations the authors draw the conclusion that no systematic association of either leucite-rocks or melilite-rocks with carbonate-rocks exists.

Neither with regard to occurrences of alkaline rocks on a small scale there is need to assume assimilation of limestone. This may be concluded a.o. from the occurrence of an alnoitic nephelite-hauynite from Winnett, Montana, as described by ROSS (1926). This rock has been developed without the assimilation of limestone and in the absence of any excessively large lime contact.

SHAND (1929), on the other hand, is of the opinion that melilite should be a sure indication of the contamination of pre-existing rock with calcium-rich material. In accordance herewith is the occurrence of nepheline- and melilite-bearing rocks in the Ninagongo volcanic area (Belgium Congo), which are the result of the assimilation by the alkaline lava of calcium-rich rocks (SIMMONS 1929). The same author states however that in this region the leucite-basanites occur on such a large scale that it does not seem reasonable to postulate assimilation.

Even DALY, the first promotor of the assimilation-hypothesis, writes in his "Igneous Rocks and the Depth of the Earth" on page 542, referring to the occurrence of leucite rocks: *The reason why leucite was there developed or why potash should be enriched so greatly in some leucitic types remains obscure. A more or less obvious guess, following the general hypothesis, is that syntexis with dolomite or magnesium limestone, might under certain circumstances produce the rare leucitic eruptives, syntexis with purer calcium carbonate giving soda-rich types. But neither field relations nor facts derived from physical chemistry furnish solid ground for retaining that idea. Its inadequacy is all the more to be suspected since* HOLMES *and* HARWOOD *published their paper on the leucitic volcanic rocks near Ruwenzori, Uganda.*

That indeed the Roman Potash Province itself yields insufficient evidence with regard to the importance of limestone-contamination for the development of leucitic rocks may be drawn from the fact that, as pointed out by RITTMANN, the parent magma is already rich in potash (viz. trachytic). The mediterranean character of the Somma-Vesuvius suite was therefore evident from the start.

6. The interesting discovery by BROUWER (1928) of limestone-inclusions in the andesitic lava of the Merapi volcano (Central Java), however, seems to support the syntexis-hypothesis. According to the petrographic description a metamorphic limestone block, large 50 × 50 × 30 cm shows zones of different composition in which leucite is a common mineral. Furthermore, phonolitic and trachytic zones mostly with phenocrysts of leucite or orthoclase are of importance. Next to these feldspathoitic zones, mineral associations from other xenoliths are described viz. wollastonite-diopside; garnet-wollastonite-epidote; garnet-wollastonite-epidote-plagioclase-diopside. These associations are normal for contact metamorphic limestones and do not seem to have suffered any further alteration due to the contact with the andestic magma in which they occur as xenoliths.

On the other hand BROUWER writes that in the large metamorphic block the mineral associations in a certain zone change from place to place. There are zones with wollastonite and calcite, whether or not with plagioclase and augite, whereas the leucite is found accompanied by basic plagioclase, biotite and augite.

How important this discovery may be from a minero-chemical point of view, it seems doubtful whether it provides evidence in support of the assimilation theory, as has been emphasized by VAN BEMMELEN. The occurrence of the described minerals may be also due to highly energized volatiles. In the case described not the andestic magma has suffered contamination by the limestone, but instead the limestone has been acted upon by volatiles which produced locally potash-bearing minerals such as leucite, biotite and even orthoclase. This is the more remarkable as according to the investigations of ENDELL (1913) sodium transfuses more rapidly into a lime-rich inclusion than potash, whereas potash is transfused in larger amounts than sodium, if the inclusion is rich in magnesia.

7. ALLING (1936, p. 245) discussing the problem of assimilation from a theoretical point of view, points to the necessity of heat to get a wall rock into solution, first for raising the temperature to the

melting point and than for supplying the latent heat for fusion. It is open to criticism whether sufficient superheat in andesitic to basaltic magma is available to assimilate carbonate rock in sufficient quantity. A striking example in this respect provides SHAND (1930) with his description of the small foyaite-ijolite body in the Bushveld-complex (Transvaal). He states that theoretically 100 parts of granite need 65 parts of limestone in order to produce 60 - 80 parts of foyaite. However, 100 parts of granite have insufficient superheat to dissolve the quantity limestone needed; perhaps 1000 or 10 000 parts can provide sufficient heat so that small bodies of the alkaline rock are to be expected. The Bushveld occurrence supports this assumption.

8. NIGGLI (1937, p. 328) writing on the same problem states: *Eine weitgehende Assimilationskraft können Magmen nur unter folgenden Umständen besitzen: 1. Stark überhitzter Zustand, d.h. Temperaturen weit über den Erstarrungstemperaturen. Ständige Wärmezufuhr oder grosses Magmareservoir. Es ist sehr wenig wahrscheinlich, dass in der Natur derartige noch überhitzte Magmen mit festem Gestein häufig in direkten Kontakt kommen...... 2. Besitzt das Magma normale Temperaturen (d.h. Temperaturen wenig oberhalb des Erstarrungsbeginnes oder innerhalb der Kristallisationsepoche), so ist seine Assimilationskraft stets eine beschränkte oder selektive.*

In the case of the Merapi (see par. 6) insufficient superheat seemed to have been available to melt even a relatively small limestone-xenolith.

The same applies to the Bunyuaraguru volcanic area as described by COMBE (1932). The crater in which Lake Kigezi lies was blown through a grey, bedded limestone without feldspathoid minerals having been formed. In discussing the volcanoes of Napah (Uganda), where ijolite hills rise to some 5000 feet only thin limestone beds, together with conglomerates, sandstones and mudstones are at the base of the volcanic succession of ashes, tuffs and lava. The writer is moreover of the opinion that there is no question as to the igneous origine of the limestone. At any event the assumption of assimilation of carbonate-rock on sufficient scale to produce the ijolite hills is irrelevant.

9. From the foregoing data may be concluded that the limestone-contamination hypothesis is insufficiently supported by petro-

logical and geological facts. HOLMES & HARWOOD (1937) have laid stress upon another possibility viz. the transfusion of pre-existing rocks by emanation. Transfusion is applied figuratively *to a process suffered by rocks (e.g. metasomatism, pyrometasomatism, anatexis, magmatisation)*. Alkali-enrichment by magmatic emanations has been already suggested by BRAUNS (1922) for the alkali-rocks of the Laachersee-area. A clear example of the formation of biotite and augite by the action of emanations from the Copper Mountain Stock of British Columbia has been described by DOLMAGE. HOLMES & HARWOOD write furthermore in discussing the biotite-pyroxenites and peridotites of Bufumbira: *The action of volatiles is revealed by the observation that the biotite is, at least in part, a microscopically replacement of the earlier minerals.*

For further informations on this subject the present author refers to the work of HOLMES & HARWOOD just cited, p. 243 and following. Their ultimate suggestion as to the possible origin of feldspathoid rocks, however, may be quoted: *Instead of feldspathoid-rocks resulting from desilication of granite magma by limestone-assimilation (with differentiation of the resulting syntectic magma), it is more likely that such rocks represent the "undersaturated" end-products of syntexis between pre-existing sialic rocks (including granite) and highly energized alkali-rich emanations, the latter being the desilicating agent from the start.*

10. In the following paragraphs a detailed description of the rocks of the G. Moeria will be given. Whether the results of the examination contribute to the solution of the problem of the origin of these mediterranean rocks will be discussed in a later chapter.

CHAPTER II

NOMENCLATURE, CLASSIFICATION AND DESCRIPTION OF MINERALS

Nomenclature and classification of the rocks

11. In the chapter on nomenclature of igneous rocks GROUT (1932, p. 49) states quite correctly that the custom of systematics in petrography has long been to select a new name for each new species and even for varieties. He quotes WASHINGTON (1923) who says: *It seems better to revert to the simple method of employing certain fundamental names ..... the total number would never be very large and their meanings being broad and simple could be remembered with comparative ease.* This well known petrographer, however, has caused the present author some rather straining hours by using, in his study on the petrology of the Roman Comagmatic Region, such terms as: *biotitic leucite-granophyro-ciminose-auruncose* just meaning a leucite-tephrite of special character (WASHINGTON, 1906, p. 84).

The nomenclature and classification of the present study is based both on ROSENBUSCH's system (1926) and on that of JOHANNSEN (1932-1937). The determination of the rocks has been achieved by taking into consideration only their mineralogical composition. In this respect he joins JOHANNSEN who writes on p. 351 of tome IV of his handbook in discussing the definition of leucitites and leucite-basalt: *In the present classification, the presence of olivine is accepted as the separation line, since chemical composition cannot be taken into consideration in a mineralogical classification.*

12. The rocks described in this paper are mostly extrusives; only one typical plutonic rock and one intrusive exponent of the same magma-type are included. According to the field observation the plutonic rock occurs as a huge block in the marl deposits north-east of the volcano Tjlering so it has been probably ejected. Some of

the rocks have been collected as boulders in a river bedding or as fragments in the volcanic soil which has been deposited as a lahar (volcanic mudstream). The plutonic rock is a monzonite, the intrusive exponent a monzonite-porphyry.

The rocks include five series which are described under the following names:

A. MONZONITE-LATITE SERIES
B. TEPHRITE-LEUCITITE SERIES
C. LEUCITE-BASANITE SERIES
D. AUGITITE-LIMBURGITE SERIES
E. SHOSHONITIC-ABSAROKITE-TRACHYTE SERIES

Transitions between the series as well as between the rock types mentioned occur. In most cases, however, an exact classification was possible.

The rocks described belong essentially to two groups namely the latites and the leucite-tephrites. Next to these the leucite-basanites and leucitites are the most important. Of the other series mentioned only a few specimen are present in the collection studied.

Description of the minerals

13. The most important components of the rocks are plagioclase, augite and leucite. Next to these, however, several minerals occur in often conspicuous or at least characteristic quantity, whereas also a few rare specimen are listed below. Among the latter are included melanite, anatase and rutile. Of the secondary minerals only the zeolites analcime and natrolite are mentioned in this summary. The more common products of alteration as chlorite, calcite, limonite a.o. are to be found in the description of the rocks. Attention may be drawn in this place to the occurrence of a hydrous silicate probably related to riversidite and crestmorite (see par. 31) and to a chloritic hydrous alumunium silicate intermediate between daphnite and amesite (see par. 105).

Plagioclase. The general name of plagioclase has been maintained throughout the description; only in a few cases the anorthite content is mentioned. In these cases this content has been measured with the aid of the Fedoroff-universal-stage. The method has been applied for the rocks containing porphyritic plagioclase, unless this mineral was either to much zoned or showed undulatory extinction.

All of the feldspars are twinned to various laws, the most abundant being the albite-twinning and the Carlsbad-twinning. Zonal structures are common especially in the more basic types.

The anorthite content ranges between 44 and 80 percent. The hornblende-trachyte and the leucolatite alone contain plagioclase of the composition $An_{35}Ab_{65}$. The micro-phenocrysts as constituents of the groundmass and of a second generation are generally more acid than the porphyritic crystals.

Orthoclase. This potash-member of the feldspar group occurs as a phenocryst only in a few rocks belonging to the monzonite-latite series, in one leucite-tephrite and as constituent of the trachytes. In the series first mentioned and in the trachytes it is present as sanidine, occurring in often very large longshaped prisms mostly twinned after Carsbad. As micro-phenocrysts the mineral occurs in slender twinned laths; however, insufficient evidence was available to permit a choice between the alternatives sanidine-orthoclase. The latter name was in most cases preferred. Potash-feldspar as interstitial material is widespread. It is abundantly present as a zone of later growth around the plagioclase.

The determination soda-orthoclase as given among others by WASHINGTON (1906), which is based on the estimation by ROSIWAL's method, seems rather irrelevant. The probable relationships between optic properties and chemical composition of the orthoclase (adularia)-albite series are based on too scanty and unsatisfactory data to allow a microscopic determination, in any case not of interstitial material or of small prisms as constitute the groundmass (WINCHELL, 1933, II, p. 352-358).

Leucite. This feldspathoid is present in the leucite-bearing rocks as large nearly ideal idiomorphic crystals, as rounded microcrysts and as interstitial material. In some rocks it was only detected as mesostasis by using a strong magnification and the selinite plate which revealed that the interstitial material showed hardly perceptible birefringence. Symmetrically arranged microlites were seldom observed. Alteration to zeolite is common; in one case the mineral occurred as probable deuteric filling of a cavity (see par 30).

Nephelite. The occurrence of this mineral has been determined with certainty in two cases only. It occurs as interstitial material in a leucite-basanite (see par. 100) and in leucite-limburgite (see par. 111). Doubt existed as to its possible presence as a mesostasis in some leucite-tephrites. Close examination of the groundmass where in contact with the canadabalsem, the refractive index of which in some cases purposely was determined, revealed however, that the mesostasis here is orthoclase. In both rocks mentioned a chemical test was necessary to permit a definitive identification.

Augite. The mineral next important to plagioclase and in some cases even more abundantly present, is augite. It occurs in several varieties. The most common type is the yellowish green aegeritic augite. The crystals of the second generation are usually richer in aegerite-molecules as is deduced from the dark green colour of these microcrysts. The porphyritic augite has often a diopsidic core rimmed with an aegerite-rich zone although the reverse phenomenon also can be observed. The aegeritic augite is in most cases rather conspicuously pleochroitic. A non-pleochroitic pale green augite also is met with. Greyish purple titaniferous augite showing zonal and occasionally hourglass structure is a less abundant component. The fourth variety is the colourless magnesium-diopside of the limburgite (see par. 112). The occurence of yellow aegerite-augite is described by Brouwer (1913) as a constituent of inclusions of andesite in a leucitite from the G. Ringgit (East Java). He considers this variety to be of neogene origin as a result of resorption and pneumatolitic metamorphism.

Hypersthene. This orthorhombic pyroxene occurs only in one rock called a hypersthene-latite (see par. 47) in which it is present as a subordinate but nevertheless characteristic component. The mineral is, however, badly altered and has typical ragged features. The pleochroism is that of the common hypersthene; X = brownish, Y = yellow, Z = green.

Olivine. The rocks of the basanite series, the olivine-leucitite and the shoshonitic-absarokite contain nearly colourless olivine either of porphyritic character or as microcrystal constituent of the groundmass. The optic properties are normal. In some rocks a conspicuous quantity of sections normal to the optic axis was observed in which the straight isogyre was readily recognized.

Alteration to chlorite, serpentine, calcite, iddingsite and limonite is common, indeed hardly any of the crystals encountered are fresh. One remarkable occurrence of xenolithic olivine surrounded by a kelyphitic rim is described in paragraph 95.

Hornblende. Of subordinate importance as a rock constituent is the hornblende. It is confined to some of the latites in which it is present as a green brown variety, strongly pleochroitic from yellowish brown to dark green brown. In the hornblende-trachyte it has a more arfvedsonitic character, whereas in the monzonite it shows a typical barkevikitic appearance. Sheaf-like bundles of hornblende needles are described in paragraphs 28 and 48.

Biotite. According to the present author the biotite in the feldspathoitic rocks of the volcanic area of the Goenoeng Moeria is essentially a product of late magmatic, deuteric origin. It was found in two varieties viz. as rather conspicuous crystals of a strongly yellow green to sepia brown pleochroitic character, absolutely fresh even in severely metamorphosized rocks and as minute flakes in often totally corroded pyriboles. The fresh deuteric biotite is also present as inclusion in augite and in a certain case it encloses one part of a cleaved plagioclase, the other part of this mineral which shows the same optic orientation, however, being excluded (see par. 107). In case of corrosion of the rock minerals the original ferromagnesian components were altered to abundant small ore pellets. In some instances they are arranged after the cleavage planes of hornblende, as well in parallel orientation after (010) as in basal sections showing the cleavage angles of this mineral (see par. 37 and fig. 1, plate III). The filling material between the ore grains is, as far as could be distinguished, groundmass and the mentioned biotite flakes. The pleochroism of this variety is very markedly from colourless to dark brown red. The optical angle proved to be practically 0°, the character being as usual negative. The double refraction is less than commonly observed.

This variety seems not unlike the titaniferous biotite as described by HOLMES & HARWOOD (1937, par. 89 et seq.) which invades the common biotite of the biotite-pyroxenite from Lutale and sometimes has the appearance of being a later replacement. It is important that the biotite occurs in nearly all the Moeria-rocks as hydrothermal-pneumatolitic replacement of hornblende or augite. Of normal porphyritic character bearing no evidence as to a possible metasomatism of previous pyriboles, it is especially conspicuous in the monzonite-porphyry. This normal biotite resembles in its development the biotite described from Bufumbira. It sometimes occurs as radial arranged *filling* material of cavities and standing on the wall of vesicles. According to the detailed studies of HOLMES & HARWOOD this seems to bear evidence of the activity of highly charged emanations. They mention that the occurrence of biotite in vesicles is confined to fine-grained lavas of holo-magmatic or nearly holomagmatic types belonging to the series: Nurambite — Kivite B — Absarokite — Shoshonitic Absarokite — Banakite. The likerwise occurrence in the Moeria-rocks is, however, a less common phenomenon detected convincingly only in a biotite-latite (see par. 20), which as a whole had suffered a rather severe alteration. Both varieties of the biotite are also mentioned by BROUWER (1913) in his paper on the leucite-rocks of the G. Ringgit (East Java). He describes a totally corroded biotite mostly altered to ore except for strong pleochroitic patches and a fresh biotite of apparently the same features as that of the Moeria.

Apatite. This is a common accessory, sometimes occurring rather abundantly. It is present as inclusion in the augites, in one case even up to 22 crystals in one augite (see par. 39), and as a constituent of the groundmass. It has mostly a cloudy appearance and is sometimes nearly black. The dimensions vary from very small slender prisms to conspicuous coarse rounded crystals, whereas in one instance thin non-terminated needles are characteristic (see par. 94).

Melanite. Interesting on account of its rareness is the mineral melanite. It was noted only once, viz. in the altered hornblende-trachyte as a conspicuous constituent. As well euhedral single crystals as rounded less idiomorphic clusters of this chestnut coloured mineral were encountered. In the Bufumbira series it is mentioned as a constituent of the biotite-pyroxenite in which it is described as the last formed mineral developed at the cost of biotite (HOLMES & HARWOOD, 1937, par. 92). It does not seem to occur in the Roman feldspathoitic rocks, although it is mentioned as a constituent of the "sperone" from Latium, a metamorphic rock transitional to black leucitite (A. LACROIX: Etude mineralogique des produits silicatés de l'éruption du Vésuve. Nouv. Archives du Muséum 4de serie, IX, 1907, cited by BROUWER (1913)). Nor it is described as a component of the Celebes series. In the Moeria-rock it is metasomatically replacing hornblende (see par. 122).

Anatase. In one rock, a biotite-latite, this variety of the titan-oxydes was detected as crystals of only 5 micron diameter. It is probably a product of alteration of titaniferous augite (see par. 32).

Rutile. This mineral was detected in a leuco-kali-trachyte in hardly perceptible nearly submicroscopical prisms. Some showing the characteristic geniculated twinning. It is assumed to bear evidence as to contact of the trachyte with older argillaceous sedimentary material (see par. 119).

Ore. A very common constituent occurring in all the rocks described in quantities varying from scanty to very abundant is black ore. As no definite proof as to its chemical composition could be given the general name "ore" has been maintained throughout the description, except for some cases in which its identity could be easily recognized as magnetite on account of its crystal habit. It occurs in magmatic porphyritic crystals as well as in secondary grains.

Analcime. A rather common product of alteration of the leucite is analcime. The identity of this mineral has been established by a chemical test. The mineral was treated with slightly warmed dilute hydrochloric acid and afterwards the presence of sodium could be determined by means of zinc-uranyl-acetate — $Zn(C_2H_3O_2)_2.UO_2(C_2H_3O_2)_2$ (after the method described by CHAMOT and MASON (1931, II, p. 52)).

Natrolite. This zeolite was observed in a few rocks as the filling of a small vesicle and once as some very thin veins running through the rock. It occurs as a colourless fibrous mineral of low birefringence and low refractive index. As from a mineralogical point of view the alternative tridymite had to be taken into consideration, the slide for that reason was treated with acid. After the treatment the veins and vesicles proved to be fully gelatinized, the identity of the mineral thus being established. In a second case it occurred as large radial slightly yellow brown fibres, stained by iron-oxyde. The appearance of the mineral, the parallel extinction and its optical orientation (being length-slow) were sufficient arguments for the determination.

Other minerals. The other minerals noted are all of secondary origin and include calcite, chlorite, serpentine, nontronite, iddingsite, limonite and chalcedony as products of alteration of the ferromagnesian minerals augite, hornblende and olivine. In a special case the magmatic origine of the calcite was vouched for, when it occurred as a conspicuous radial fibrous filling of cavities (see par. 22).

CHAPTER III

DESCRIPTION OF THE ROCKS

A. MONZONITE-LATITE SERIES

a. Monzonites

14. The monzonite type of rock may, according to JOHANNSEN (1937, II, p. 94), be considered as the plutonic equivalent of the latites. They are defined as granular plutonic rocks containing approximatively equal amounts of orthoclase and plagioclase with brown biotite, green hornblende and green augite as the common dark minerals. Of rocks whose mineralogical composition is in agreement with this definition, at least with respect to the feldspathic components, only two specimen were collected. One is a typical plutonic granular rock occurring at 300 feet on the east slope the Goenoeng Tjlering (Nr. 71924), the second is of more hypabyssal, phaneritic character and is called a monzonite-porphyry. It occurs as a boulder in the bedding of the river Sampok at 300 feet on the east slope of the G. Moeria (Nr. 70939).

15. **Hornblende-monzonite (Nr. 71924).** The hand specimen is typically plutonic with black hornblende and white feldspar as the megascopically recognizable components (fig. I, plate I). In section the rocks appear to consist of plagioclase (An_{64}-An_{54}) and orthoclase as the felsic minerals and barkevikitic and arfvedsonitic hornblende as the mafic constituents. Abundant long shaped, mostly perfect idiomorphic apatite is also a conspicuous mineral. Plagioclase and orthoclase are present in about equal quantity. The former is idiomorphic against orthoclase, this mineral being the last to crystallize. This is emphasized by the occurrence of about one square cm of xenomorphic orthoclase enclosing poikilitically plagioclase and hornblende (fig. 2 plate I).

16. **Augite-biotite-monzonite-porphyry (Nr. 70939).** The hand specimen is a coarse porphyritic rock with abundant black augite in a grey feldspathic groundmass (fig. 4, plate I). In section the

phaneritic texture is characteristic. Abundant large green aegeritic augite measuring up to 7 mm (fig. 3, plate I) and strongly pleochroitic biotite (X = pale yellow, Z = reddish brown) are the megaporphyritic minerals. The latter mineral is strongly corroded and partly or totally altered to ore. Rather large blebs of anhedral ore, probably of secondary origin, are also present. The groundmass is composed of micro-porphyritic turbid plagioclase prisms and rather clear sanidine crystals in about equal quantity with interstitial xenomorphic orthoclase. Apatite is a conspicuous constituent occurring mainly as large crystals (0.4 mm) enclosed in augite (fig. 1, plate II). Remarkable is the abundance of basal sections of this mineral. Owing to the alteration of the feldspar the groundmass has a very dusty appearance.

b. Latites

17. The first group of quantitative importance is that of the andesitic and basaltic looking rocks, which have next to plagioclase of intermediate chemical composition the potash-feldspar orthoclase and/or sanidine as a characterizing constituent. They are in this respect transitional to the andesites and with increasing orthoclase content to the trachytes. The pyribole is mostly more or less aegerite-bearing augite. Hornblende of the dark green strongly pleochroitic variety as well as biotite also occur in some of the rocks belonging to these series. The biotite has in all cases a deuteric appearance often replacing early hornblende after corrosion of this mineral. This phenomenon could in most cases be deducted from the shape of the relics which resembles often very closely that of the green brown hornblende. Feldspathoids did not occur in this group as indeed the presence of such minerals should have been reason to classify the rocks as tephrites. Glass did seldom occur and in minor quantity only. As to the name there has been some difficulty to classify the rocks according to the prevailing systems. ROSENBUSCH (1923, p. 414-418) describes as trachy-andesites those rocks, which are transitional between alkali-trachytes and phonolites on one side and trachy-dolerites on the other. Feldspathoids are no essential constituents, nor natron-bearing pyriboles. In such cases it is according to ROSENBUSCH, however, hardly possible to decide between andesites and trachy-andesites. The type rock from the Siebengebirge bears plagioclase (An_{40}-An_{80}), brown hornblende, brown biotite, both often altered, pyroxenes (diopside and hypertsthene) and magnetite, in a

groundmass consisting of oligoclase laths, short rectangular and/or xenomorphic interestitial sanidine, with subordinate magnetite, diopside in small prismoids and accessoral apatite. As pointed out by ROSENBUSCH, the latites as introduced by RANSOME, belong to this group. The statement of JOHANNSEN (1937, III, p. 100) that ROSENBUSCH used the name trachy-andesite for orthoclase-plagioclase rocks carrying a feldspathoid, or aegerite, riebeckite, etc., is therefore no true reproduction of the description given by ROSENBUSCH. As, however, the name trachy-andesite has been used by different authors in a quite different meaning, JOHANNSEN prefers the name latite, as introduced by RANSOME in his description of the lava-flows of the western slope of the Sierra Nevada. The description of these rocks as given by JOHANNSEN, fits the rocks of the G. Moeria sufficiently to adopt the name latite for this type. As will follow from the descriptions below the predominant dark mineral is diopsidic to aegerite-bearing augite, hornblende is confined to some rocks and biotite as a well developed mineral is also rather scarce, occurring mostly in patches between the ore grains of corroded pyribole. It seemed therefore adequate to drop the prefix augite as being a mutual constituent and to use the prefixes hornblende, biotite or hypersthene for those rocks in which these minerals are characteristic, be it not always abundant or even conspicuous, components.

18. HOLMES & HARWOOD (1937, par. 53) use the name latite with the prefix hypersthene for rocks which are rather unique in the area which has been subject of their investigations. The Sabinyo lavas constituted by these rocks were formerly described as trachyandesitic (FINCK) and as andesitic (SIMMONS). According to the authors mentioned the rocks, however, are mineralogically, as well as chemically practically identical to many of the latites of western America, this being the reason why this name is adopted. They consider this rock type as a member of a shoshonite-latite series of which the more basic associates are distinguished as shoshonites, with either olivine or biotite as a conspicuous constituent, and of which the latites are characterized by hypersthene, differing moreover in being oversaturated in respect of silica. Olivine is a regular be it rare component. With exclusion of the olivine the description of the shoshonite shows a remarkable similarity with the Moeria-rocks even to the extent that the latter rocks also contain xenolithic inclusions, or polysomatic aggregates of augite-plagioclase, augite-biotite-plagioclase and biotite-plagioclase.

19. Megascopally the rocks can be divided into different groups varying from a light coloured coarse andesitic to a dark grey compact basaltic appearance. The rocks of andesitic appearance are numbers 61485, 61505 (1) and 71822 (1) collected on about 3000 feet, near the summit of the G. Moeria on the south slope. Rocks of medium to fine grained light grey aspect are the numbers 61498, 66986, 70898, 71068, 71093 (2), while somewhat differing in texture and colour are the numbers 70938 (1), 71361 (5) and 72001 (3). Samples 61498 and 71361 (5) occurred near the summit, the numbers 70898, 70938 on the west slope at 200 feet, 71093 (2) at 500 feet on the north-west slope; number 71068 was collected at the farthermost boundary of the volcanic area near the coast north of Djapara; Nr. 72001 (3) on the north slope near the road Bangori-Pati, whereas Nr. 66986 was found on the south-east slope at about 700 feet. A large group of basaltic rocks was collected mostly on the south and south-west slope, three specimen occurring near the summit (61743, 68846 and 71383) on about 5000 feet, one near the summit of the G. Tjlering (71933) and one north of this volcano near the coast of the Java Sea (68824) (1)). This last number occurs as a huge block which seems to have been ejected and eventually transported by mudstreams. Two rocks are of diverging aspect as will be described below (Nrs. 68846 and 71923). The distribution of the rocks in the volcanic area seems rather at random. The latites have been collected in an area that in broad lines is confined to the summit and the west-south-west slope, except for some boulders which were found at a great distance of the summit on the utmost boundaries of the volcano. As, however, at this moment no geological field observations are available to elucidate the possible relations between the types distinguished (see hereto par. 1) a further discussion of this point must be reserved for the future.

1. Rocks of andesitic appearance

20. **Biotite-latite (Nr. 61485).** Megascopically the rock belongs to the coarse light grey coloured type. Abundant iron-stained patches are visible. Biotite flakes are conspicuous, plagioclase is less abundant. Xenolithic dark hornblende of about 15 mm and enclosures of dark grey fine grained volcanic rock are recognized. Calcite filling of cavities is clearly visible. Brick red phenocrysts are probable altered hornblende. The nature of the rock xenolith could not be revealed.

Microscopally the rock appeared to consist of large phenocrysts of twinned plagioclase, very abundant, remarkable fresh, conspicuous biotite together with abundant totally calcified and sometimes chloritized augite, only recognizable by its outward shape. Brown green hornblende is scarce.

Abundant calcite is present, as well secondary as in typical irrigular radial fibrous, probable pneumatolitic filling of cavities. The biotite is also considered to be of deuteric origin on account of its freshness and mode of occurrence, as filling of vesicles. A xenolithic biotite aggregate, enclosing a few plagioclase crystals and some apatite, is observed, the orientation of neighbouring flakes often being in perpendicular direction, some flakes crystallographically stretched after the c-axis.

The trachytic groundmass consists essentially of slender plagioclase laths. The mesostasis is xenomorphic orthoclase. Calcite dust is sprinkled throughout the slide (fig. 2, plate II).

21. **Latite (Nr. 71505 (1)).** Light grey coarse grained andesitic rock with phenocrysts of black augite and plagioclase in a yellowish grey base. Patches of brown biotite are recognizable.

Under the microscope the same minerals are met with. Conspicuous plagioclase phenocrysts, which dominate over green to dark green augite are the porphyritic constituents. The plagioclase is mostly zoned and provided with a rim of orthoclase. Biotite occurs as corroded streaks and blebs, with abundant tiny ore pellets. It is strongly pleochroitic and resembles closely the biotite later to describe as a metasomatized hornblende. No conclusive evidence in this respect, however, could be obtained. Small orthoclase prismoids occur. The groundmass consists of plagioclase laths with interstitial orthoclase and rather abundant chlorite and limonite-like alteration products. Sparse apatite crystals and subordinate ore are present.

22. **Latite (Nr. 71822 (1)).** This rock has the same megascopic appearance as the previous number, the plagioclase however being slightly more conspicuous This is also revealed by the microscope, zoned and orthoclase-rimmed plagioclase being predominant over augite, which now is of a light green diopsidic variety. Biotite is of the same appearance, orthoclase prismoids are present. A conspicuous semiradial aggregate of calcite suggests the magmatic origin of this mineral. The slightly trachytic groundmass is like that of Nr. 71505 (1), calcite as a secondary mineral being present.

23. **Latite (Nr. 61498).** The hand specimen is of the light grey andesitic type. It is medium grained; abundant irregular shaped feldspar and small prisms of augite are recognizable. Microscopically the rock shows a holocrystalline rather coarse grained base in which large phenocrysts of plagioclase with orthoclase rim, some prisms of sanidine, minor augite and a few flakes of biotite occur. The groundmass consists of orthoclase and plagioclase, the former being in excess; it occurs in subhedral prismoids with undulose extinction and as interstitial xenomorphic material. Augite grains and ore are less abundant and glass is very rare. In the rock taken as a whole plagioclase and orthoclase are present in about the same quantity. The former mineral is in excess as a phenocryst, the latter in the groundmass. Transition to the monzonite-porphyry is probable.

24. **Hornblende-latite (Nr. 66986).** This specimen has approximatively the same megascopic appearance. The feldspar seems more prismatic, one large crystal apparently poikilitically enclosing augite. Small augite prisms are common. In the slide the rock consists of conspicuous twinned and zoned plagioclase (An_{54} - An_{46}) and equally abundant green augite. Both minerals show idiomorphic terminations. The augite is also present in polysomatic clusters. Some sanidine, subordinate barkevikitic hornblende with a reaction rim of ore pellets and subhedral ore occur. The groundmass is a fine grained hypocrystalline fabric of plagioclase and orthoclase laths, small aegerite-augite grains with interstitial orthoclase and some glass. Accessories are apatite and ore grains; secondary calcite is present.

25. **Hornblende-latite (Nr. 70898).** The megascopic character of this rock is the same as that of the previous number. The feldspar and augite are a slightly more porphyritic, some slender prisms of hornblende are observable. The microscopic study of the slide, however, revealed that the augite is abundant over plagioclase (An_{64} - An_{50}), the former mineral also being richer in aegerite. Barkevikitic hornblende is also more conspicuous. The mafic components are corroded; the augite has a small rim of ore pellets, the hornblende is intensively altered into a pure concentration of ore. The groundmass consists of plagioclase laths, rather abundant augite grains with interstitial orthoclase and minor glass. Accessoral apatite occurs.

26. **Latite (Nr. 70938 (1)).** This rock has a more felsic character and is of lighter grey colour than those previously described. Rather abundant microtine-like feldspar and less abundant pyribole occur in a white speckled base. The microscope revealed plagioclase (An_{64} - An_{55}) as the predominating phenocryst with aegerite-augite as the dark mineral, again provided with a rim of ore grains and in some cases even altered into one ore bleb with calcite concentration. The groundmass is conspicuously trachytic (fig. 3, plate II) and consists essentially of plagioclase laths, with minor augite grains embedded in allotriomorphic orthoclase and a buff coloured granular isotropic mass, the nature of which could not be ascertained. Apatite is the accessory. Secondary calcite is abundant. It is not impossible that the isotropic material is interstitial leucite, however, in the leucite-bearing rocks to be described later on leucitic mesostasis of this kind has not been met with. It seems therefore more probable that the material encountered here is some kind of zeolite.

27. **Hornblende-latite (Nr. 71068).** The hand specimen is a compact rock of dark grey colour. The plagioclase is less conspicuous whereas rather abundant slender prisms of hornblende and short-prismatic augite could be recognized. Microscopically the rock is a typical hornblende-latite as this mineral of barkevikitic character is equally abundant as the augite and plagioclase. Next to these minerals a large sanidine crystal occurs. The potash-feldspar suffered some alteration; this is evident from the sericite-filled cracks perpendicular to the crystallographic elongation. Included in the sanidine are augite, plagioclase and ore. A very thin outer rim of plagioclase was detected. The mineral has a remarkable shape, like a stretched drop wedging with a sharp point into the groundmass, by which it is apparently resorbed. The size is about 4 mm to 1.5 mm. The groundmass is a fine grained fabric of augite grains, alkali-feldspar laths and mesostasis, some glass, minor ore and accessoral apatite, mostly included in augite.

28. **Latite (Nr. 71093 (2)).** Grey fine grained rock containing megascopic augite and feldspar. In the slide green aegerite-bearing augite appears to be the main constituent next to less abundant but conspicuous plagioclase with orthoclase rim and some large crystals of sanidine. One of the plagioclase phenocrysts forms a polysomatic cluster consisting of several twinned plagioclase crystals enclosing

poikilitically small augite prismoids and very thin needles closely alike the barkevikitic hornblende needles described in paragraph 48. Other plagioclase crystals are for the greater part resorbed by the groundmass. Corroded relics are pretty abundant, their previous character being difficult to establish. Euhedral ore is common. The groundmass is a fine grained fabric of abundant slender plagioclase prisms and very small augite grains with interstitial orthoclase and minor glass. Ore pellets are sprinkled throughout the base. Cloudy apatite is a common accessory.

29. **Biotite-hornblende-latite (Nr. 71361 (5))**. This rock is of slightly different appearance, being of a brownish grey colour and of rather fine texture. Next to some conspicuous dusty white feldspar, small crystals of dark minerals are to be observed. Large sanidine up to 10 mm length is met with. In general this mineral, however, is rather sparse so that in several slides only a few small individuals were encountered. Under the microscope the plagioclase appears to be calcified to a large extent. The dark minerals are aegerite-bearing augite, conspicuous strongly pleochroitic barkevikitic hornblende and some pretty large sized biotite. The latter mineral occasionally shows a sferulitic structure and its further mode of occurrence suggests a deuteric origin. Large apatite and euhedral ore are rather abundant. The turbid groundmass has plagioclase laths for its chief constituents. Aegerite-augite occurs in minor quantity. The mesostasis is xenomorphic orthoclase and some glass. Accessories are apatite and ore pellets, secondary calcite is scattered through the slide. A remarkable phenomenon is the occurrence of a large calcite crystal embedded in a colourless granular white isotropic base of low refractive index which resembled analcime. The calcite and the isotropic mineral fill a cavity of about 2 mm diameter.

30. In order to study this phenomenon more in detail a slide was cut from the hand specimen in which after detailed megascopic examination an inclusion of apparently the same nature was detected. The section revealed the same material which, however, after careful observation appeared to be weakly birefringent, showing the same twinning as described for the leucitic mesostasis of the leucite-tephrite (Nr. 68845 (2), see par. 73). In the center of the xenomorphic leucite or leucitic mass calcite was again concentrated, in this case showing the features common for secondary calcite. The

contact between the leucitic filling of the cavity and the groundmass has a rather ragged appearance, several thin microlites of feldspar being seemingly teared loose from the groundmass and subsequently surrounded by the leucite. In a second hand specimen of the same location (Nr. 71361 (4)) a still more interesting inclusion of the same nature could be studied. A rounded cavity of 8 mm diameter was filled up with a border of leucite showing weak double refraction. This leucite border showed the same ragged contact with the groundmass. Towards the central concentrated calcite, however, the idiomorphic termination of the leucitoëder was developed (fig. 4, plate II). This border of leucite had a mean thickness of 2 mm. At the contact between leucite and calcite a small rim of turbid material was observed. Some parts of the leucite showed a birefringence higher than normal. The optic properties of these parts are biaxial positive, oblique extinction X : c' = 7° for one distinct case. It is suggested that these parts represent a random section of orthorhombic β-leucite to which in normal cases the double refraction is due (RAMDOHR, 1936, p. 581). The refractive index of the parts studied is exactly the same as that of the isotropic leucite. Next to this orthorhombic leucite a rather conspicuous birefringent colourless filling of cracks in the leucite could be observed, which has a distinctly higher refractive index. Also a turbid fibrous filling of some small cavities in the inclusion is present, which probably is natrolite.

31. A same enclosure as described was cut from the hand specimen and carefully crushed. After embedding the fragments in nitro-benzene (n = 1.547) the following components were met with: leucite, calcite, natrolite and an unknown colourless mineral which is probably the crack-filling material described above. At the first superficial observation the mineral resembles chalcedony except for the rather suspicious index of refraction. Examined under the binocular loupe microscope the mineral appeared to be present as a thin platy coating built up of numerous sferulites not unlike those known from the concentric calcite of for instance travertine. The material is neither solved nor decomposed by hot strong hydrochloric acid. The refractive index is 1.603 for Y or Z, the optic orientation is Z = c (elongation). The most remarkable feature, however, was that, be it hardly perceptible, the traces of the rhombohedral cleavage of calcite could be observed through the rows of sferulites. The only conclusion which can be drawn from these observations is

that this for the present unknown mineral is replacing calcite. With regard to the refractive index the specimen comes rather close to the hydrous silicates riversidite and crestmorite, the first having $Z = 1.603$ and the second $Y = 1.603$. Both, indeed, have Z = c (elongation), but are decomposed by hydrochloric acid (WINCHELL 1937, II, p. 409). The occurrence of these minerals, which are very rare, is apparently limited to metamorphic limestone and calcite. It seems therefore not impossible that the mineral described here is in some way or other related to these hydrous silicates. Insufficient data are, however, for the present available to permit a more decisive answer.

32. **Biotite-latite (Nr. 72001 (3)).** The hand specimen is a greenish grey rock with porphyritic plagioclase, a few conspicuous crystals of sanidine, some biotite and augite. Microscopically it is a remarkable rock on account of the alteration of its phenocrystal pyroxenes and the resorption of the feldspar next to the occurrence of very fresh biotite and feldspar. The pyroxene which probably is augite is altered to an aggregate of calcite, chlorite and quartz and streaks or patches of iron-oxyde. In the quartz very minute crystals of anatase, measuring only .005 mm across, occur. They could be recognized by their characteristic bi-pyramidal and in some cases square tabular habit and by very high refractive index. Some of the augite was totally calcified, with a dark brown product of alteration filling the cleavage cracks. Of the plagioclase most crystals were calcified and opalized and moreover resorbed by the groundmass. Next to these corroded and resorbed minerals very fresh biotite and even fresh hardly resorbed plagioclase were conspicuous. Some of the plagioclase is provided with a rim of orthoclase. The groundmass consists of abundant small plagioclase laths and interstitial orthoclase. Iron-oxydic dust and tiny ore pellets are scattered through the rock. Apatite is the common accessory. In a second slide very conspicuous sanidine was present measuring up to 10 mm and enclosing plagioclase crystals of normal size (.8 mm).

2. Rocks of basaltic appearance

33. **Latite (Nr. 61743).** This rock of basaltic appearance is dark grey with local iron-staining. Porphyritic plagioclase with central or peripheral concentration of ore dust and not very abundant greenish, slightly chloritized augite, are the phenocrysts. Totally

corroded and occasionally biotitized hornblende is a common constituent. The groundmass is a fabric of rather short prismatic plagioclase laths, interstitial orthoclase and buff coloured glass. Secondary calcite, chlorite and iron-oxyde are present. Ore grains are sub-ordinary. The porphyritic plagioclase is commonly provided with a rim of potash-feldspar.

34. **Latite (Nr. 61811).** Being of the same external character as Nr. 61743 this rock contains in section more abundant aegerite-bearing augite and zoned plagioclase with a more conspicuous border of orthoclase. The corroded relics are also more plentiful. The resemblance of these relics with totally corroded hornblende is in some cases striking, in other cases no evidence as to their previous nature is available. One single corroded relic may have been augite in which now plagioclase crystals, and patches of groundmass are intruded. The groundmass is a fabric of the same nature, with the same accessories and products of alteration of the rock previously described.

35. **Latite (Nr. 68824 (1)).** This rock collected on the north slope of the G. Tjlering is closely alike the former. The groundmass is locally iron-stained and contains augite and plagioclase of somewhat larger size. Of both minerals crystals occur which show the result of magmatic resorption, these have no sharp boundaries but merge vaguely into the groundmass. Limonitic and chloritic material is common, ore pellets are sprinkled throughout the rock.

36. **Latite (Nr. 70643).** This rock too has no special features. Corroded relics are less conspicuous, whereas magmatic resorption is also less evident. Some of the feldspars (An_{56} - An_{52}) are indeed of beautiful idiomorphic habit. The augite shows in many cases fair twinning after (100). For the rest the rock is a typical representative of the basaltic type.

37. **Latite (Nr. 70660).** The hand specimen is dark grey with a greenish hue. Feldspar is rather abundantly, megascopic augite, however, sparsely present. In section the rock shows a fine grained groundmass of occasionally hypofluidal arranged abundant plagioclase laths, rather sparsely aegerite-augite grains and small rectangular ore crystals. Orthoclase is the interstitial material. The phenocrysts are green, often twinned augite and typically zoned plagioclase with orthoclase rim. Corroded ferromagnesian minerals are abundant. As previously described the relics consist for the

greater part of ore pellets with some felsic groundmass, chlorite and smaller or larger patches of strongly pleochloritic biotite. Phaenomonologically the relics show a distinct resemblance hornblende. In one case a remarkable structure of the ore pellets was detected, matching closely the lamellar arrangement after (110 and $1\bar{1}0$) of the hornblende cleavage as observed in a section normal to the c-axis. An angle of 56° and 124° between the two directions was measured (fig. 1, plate III). This phenomenon is considered a strong point in favour of the hornblende-metasomatism hypothesis.

38. **Latite (Nr. 70664).** Megascopically the rock is slightly more felsic, plagioclase being rather abundant. This is confirmed by the composition as revealed in the slide. Large, conspicuous plagioclase (An_{64} - An_{44}) is distinctly abundant over augite, which occurs in small prisms. The same relics of corroded minerals and large crystals of ore are present. In the groundmass plagioclase laths, less augite, nearly square ore crystals and accessoral apatite are embedded in a base of twinned prismoids of orthoclase and interstitial potash-feldspar showing undulose extinction.

39. **Latite (Nr. 70671).** In this specimen of about the same appearance and composition as the rocks previously described, proof is again supposed to be present as to the deuteric origin of the biotite. In the slide a large phenocryst of augite occurs which includes the same colourless to red brown pleochroitic biotite in several small patches. The primary occurrence of these biotite patches as inclusion in augite seems highly improbable. The same augite shows one more remarkable feature, which points to a magma rich in volatiles, namely the presence of not less than 22 crystals of apatite included in this crystal (fig. 2, plate III). The occurrence of apatite included in augite is itself a common phenomenon. A concentration of this mineral as found in the present case, however, is very interesting. Discussing some theoretical aspects of contamination in acid magmas NOCKOLDS points to the importance of volatiles in relation to the abundance of apatite, which in those cases is characteristically developed in thin needles penetrating the other minerals (1933). At the same time the corrosion phenomena are conspicuous, whereas the resorption activity of the groundmass finds expression in the ragged crystal faces of the pale green augite and the invading tongues of groundmass in crystals of the same mineral. Apatite is also abundant as a component of the groundmass.

40. **Latite (Nr. 70764).** Megascopically the hand specimen shows abundant augite phenocrysts and plagioclase crystals in a dark grey base. Under the microscope diopsidic augite with a green core appears to be slightly abundant over twinned plagioclase with small orthoclase rim. Idiomorphic ore is common. The fine grained groundmass has for its chief constituent augite in combination with abundant minute ore grains. Plagioclase laths are subordinate. The mesostasis is orthoclase and minor glass. Apatite is the common accessory, secondary calcite occurs. A remarkable coarse grained enclosure of augite, corroded slender prisms of probable hornblende, plagioclase and large concentrations of interstitial calcite was met with. The augite occurs often as polysomatic aggregates.

41. **Hornblende-latite (Nr. 70949).** In this fine grained rock abundant pyribole phenocrysts are recognizable. The feldspar occurs macroscopically only in irregular patches, no porphyritic crystals being observed. In the slide green augite and twinned plagioclase mostly in polysomatic clusters are conspicuous. These clusters in which the plagioclase is predominant over augite are considered to be xenoliths, although no symptoms of resorption of the inclusion could be detected (fig. 3, plate III). One more inclusion is present being of monzonite-porphyritic character. Strongly pleochroitic hornblende, occasionally showing twinning after (100), provided with a corrosion rim of ore pellets is a characteristic component. Porphyritic ore is met with.

The groundmass consists of subhedral to anhedral plagioclase and augite prismoids with abundant interstitial orthoclase and minor glass. Ore grains are common.

42. **Latite (Nr. 70981).** Megascopically the rock resembles the foregoing specimen. In section, however, the absence of hornblende and of the xenoporphyritic inclusions of plagioclase and augite provides the principal difference. Instead of the hornblende, relics of corroded and, be it very inconspicuously, biotitized pyribole occur. The thin minute patches of biotite which are detected between very abundant ore pellets are of the strong pleochroitic variety, colourless to red brown. The ore pellets show an arrangement following the prismatic cleavage after (010). Whether hornblende or augite has suffered the alteration cannot definitely be proved. It seems, however, probable, in view of suchlike phenomena as repeatedly described, that the original mineral has been hornblende. The

groundmass is a felsic mass consisting of plagioclase laths in mesostasis of orthoclase, some glass and minor augite. Ore grain are common, apatite is the accessory.

43. **Latite (Nr. 71383).** This specimen has no special externa features but is a typical representative of the latites except for som slight alteration with subsequent staining of the rock. The feldspa occurs in rather small phenocrysts, the augite in green to dark gree prisms. Streaks of corroded relics are plentiful, euhedral ore i common. The groundmass is the usual fabric of plagioclase and augit with interstitial orthoclase and minor glass. Apatite is present.

44. **Latite (Nr. 71392).** The hand specimen is a grey rock with rather abundant ,weathered, cloudy feldspar and short prisms of augite. Microscopically dark green augite is the more conspicuous constituent. The feldspar is mostly altered and slightly opalized except for the orthoclase rim which surrounds most of the plagioclase crystals. As could be expected the processes of katamorphism have had distinctly more influence on the rather calcic plagioclase than on the acid potash-feldspar. Corroded relics and medium sized ore are present. The fine grained also slightly opalized groundmass consists of subhedral feldspar, hardly any prismatic laths being detected. This feldspar is mainly orthoclase. Ore grains are plentiful, cloudy apatite is accessory.

45. **Latite (Nr. 71816).** Phenocrysts of plagioclase, some with peripheral orthoclase, light green augite and numerous relics of totally corroded minerals here consisting of the well known association of ore pellets, felsic groundmass, patches of strongly pleochroitic biotite, chlorite and occasionally calcite, occur in a feltlike trachytic groundmass of tiny plagioclase laths, interstitial orthoclase, abundant specks of chlorite, ore pellets and subordinate blebs of biotite of the same red brown to colourless pleochroitic variety. Cloudy apatite crystals are largely represented.

In a single case an inclusion in a plagioclase crystal is altered in the way described. The same crystal also contains patches of feldspar of distinctly lower refractive index and filling of sferulitic chlorite-like material with a rather high birefringence suggesting prochlorite. The optical orientation, however, is Z//c instead of X//c, as is mentioned for the variety with a sufficient high double refraction.

46. **Hornblende-latite (Nr. 71933).** The hand specimen is a dark grey typically basaltic rock with large phenocrysts of dark pyribole. No feldspar crystals were recognizable. In the slide the rock appeared to contain chiefly pale greyish augite, minor calcified plagioclase and conspicuous often long prismatic hornblende as phenocrysts. The hornblende was present in all phases of corrosion. Some relics still contained a core of dark green hornblende, others only consisted of ore pellets. Brown red biotite patches were rare, but could be detected by careful examination. One hornblende was especially interesting as the individual not only was surrounded by a thick zone of submicroscopic ore, but internally showed signs of an optical reorientation, the lower part of the crystal showing straight extinction, the greater upper part having an extinction angle of 16°. In this upper part a cavity in the crystal was filled up with groundmass material and several patches of biotite of the red brown variety (fig. 4 and 5, plate III). The inconspicuous trachytic groundmass is of the common association of minerals including abundant secondary calcite and chlorite. In some small feldspar crystals orthoclase was seen to alternate with plagioclase lamellae. Weakly birefringent glassy interstitial material, probably leucite, was detected.

47. **Hypersthene-latite (Nr. 68846).** This is the only rock containing hypersthene as a porphyritic component. It occurs near the summit of the G. Moeria at about 3000 feet. It is a grey rock megascopically containing abundant irregular patches and a few phenocrysts of plagioclase. Ferromagnesian minerals could not be detected. In section abundant plagioclase phenocrysts and some slightly corroded hypersthene are embedded in a very fine grained groundmass of plagioclase; plentiful brown patches of iron-oxyde give the mass a light brown to locally dark brown colour. The interstitial material is iron-stained orthoclase and some glass. Ore is common, secondary chlorite rather abundant as an alteration product of pyroxene which in most cases appeared to be hypersthene. Small non-chloritized, but ragged hypersthene is scarce but characteristic. Apatite is present as cloudy often rather large crystals. The groundmass is of a slightly trachytic structure.

48. **Leuco-latite (Nr. 71923).** This rock which has been collected on the utmost north slope of the Moeria differs externally as well as microscopically from the specimen previously described. It is

a yellowish green leucocratic rock with megascopically some conspicuous feldspar and copper brown dendritic stains of secondary origin. In section the leucocratic character is very evident. Some large phenocrystal plagioclase (An_{35}) with broad rim of orthoclase occurs in a rather coarse grained trachytic matrix of plagioclase laths and orthoclase mesostasis. The dark mineral is barkevikitic hornblende which is present in very thin, nearly submicroscopic needles sometimes arranged in sheaflike bundles, often concentrated in the orthoclase-rim of the plagioclase.

B. TEPHRITE-LEUCITITE SERIES

49. As the rocks of these leucite-bearing alkaline suite are more or less transitional from the latite to the leucitite on account of the increasing content of leucite the division into four sub-groups according to this content, has been thought suitable to indicate the position of the rocks in these series. The tephrites are rocks in which the leucite is a characteristic component which occurs however less abundantly than plagioclase. The leucite-tephrites contain leucite in about equal quantity as plagioclase, in the leucitite-tephrites the feldspathoid is predominant over plagioclase, whereas in the leucitite group the plagioclase only occurs as a rare constituent being sometimes present in small laths in the groundmass. The present author follows in this respect the classification of JOHANNSEN, who was the first to distinguish between the leucite-tephrites and leucitite-tephrites. The external features of the rocks of each group again make a division into a basaltic and an andesitic type possible.

a. Tephrites

50. Of the rocks of the leucite bearing series only a few were collected in which leucite is a minor component as compared with plagioclase. Three of these are of basaltic appearance viz. the samples 70694, 70712 and 71862 occurring on the south slope of the G. Moeria on the 750 feet contour-line and on the west slope at the same level. As tephrites of andesitic appearance were collected Nr. 70679 and Nr. 70792 on the lower part of the south slope and Nrs. 71361 (3) and 71384 (2) near the summit, whereas one lava-block (Nr. 68798 (1)) and one tuff (Nr. 70838) were found respectively on the south slope of G. Tjlering and on the south-west slope of the Moeria near the road from Koedoes to Djapara.

1. Rocks of basaltic appearance

51. **Tephrite (Nr. 70694).** Megascopically this specimen is a compact dark grey rock in which only rare phenocrysts were detected. Feldspar in irregular patches is abundant. Microscopically the rock is characterized by small augite prisms and black streaks of a corroded mineral, which occur in a groundmass consisting of abundant plagioclase laths, augite grains, some leucite and interstitial orthoclase. Apatite and ore grains are accessories. Secondary chlorite and calcite are present. The microscopic characters resemble very much those of latite except for the presence of leucite. The rock is evidently transitional to latite.

52. **Tephrite (Nr. 70712).** The hand specimen shows numerous small augite phenocrysts and occasionally biotite-like blebs and irregular feldspar in a dark grey groundmass. In section green augite is largely predominant over plagioclase. Euhedral ore and corroded relics occur. The groundmass consists of plagioclase, aegerite-augite, minute ore grains and nearly isotropic leucite, both as euhedral and as interstitial material. The euhedral form can be easely recognized by the symmetrically distributed augite inclusions. Minor glass is present. Apatite occurs only as inclusion in augite.

53. **Tephrite (Nr. 71862).** This rock is dark grey with inconspicuous augite. In the slide yellowish green augite prisms are predominant over irregular shaped, zoned plagioclase with orthoclase rim. Euhedral ore is also porphyritic. One large plagioclase of remarkable habit was met with (fig. 1, plate IV). The core is plagioclase with a small orthoclase rim. It is of the same termination as the whole mineral, which again has a thin border of potash-feldspar. The crystal is riddled with irregular blebs of calcite. Some augite crystals are enclosed. The groundmass is a fabric of xenomorphic undulose plagioclase, very small augite grains, subordinate isotropic leucite, interstitial orthoclase and glass. Secondary ore is common, apatite is a rare inclusion of the augite. Some corroded relics are present.

2. Rocks of andesitic appearance

54. **Tephrite (Nr. 70679).** The hand specimen is a grey andesitic rock with a few apparently weathered feldspar phenocrysts and some conspicuous augite crystals in a groundmass with abundant

feldspar patches. In section it appears to be a hypocrystalline rock with phenocrystal diopsidic augite with aegerite-rich rim, sometimes with a totally corroded core consisting of ore grains. Zonal plagioclase with occasional orthoclase rim is of importance. The groundmass consists of abundant augite grains,automorphic and allotriomorphic plagioclase, the latter showing undulatory extinction, minor interstitial orthoclase and anhedral leucite. Glass occurs subordinate, accessoral apatite is fairly abundant.

55. **Tephrite (Nr. 70792).** Megascopically the rock is dark grey, fine grained, with small phenocrysts of augite and feldspar; some of the latter occurring as coarser clusters. In the slide plagioclase phenocrysts are predominant over green to dark green augite. Corroded relics of the appearance as described in the latite series are plentiful. The plagioclase (An_{57} - An_{47}) occurs in one case with augite in a polysomatic cluster. The groundmass contains abundant very small grains of light coloured augite, a few plagioclase laths, orthoclase as xenomorphic material and very inconspicuous, but after close examination rather abundant specks of rounded leucite, which could be recognized by the symmetrically arranged inclusions. Biotite flakes, chlorite and apatite are the accessories, the latter mineral being rather abundant.

56. **Tephrite (Nr. 71361 (3)).** Among the rocks of andesitic appearance this specimen proved to be interesting on account of the abundance of large sized phenocrysts of augite and biotite and the presence of xenolithic olivine of 3 mm diameter. Megascopically the rock showed a dark grey compact groundmass with abundant prismatic augite and clusters biotite of conspicuous size and less conspicuous feldspar. Under the microscope the augite appeared to be of a yellowish green to brown green colour, in some cases showing hourglass structure. There is a marked yellow to green pleochroism. Some of the crystals are resorbed, merging vaguely into the groundmass. In some cases the resorption resulted in the solving of parts of the mineral and the invading of groundmass material. The second important dark mineral is biotite, which is present in very fresh crystals up to 4 mm length, bordered by a small reaction rim of ore pellets. The mineral occurs also as an inclusion in augite. The feldspar of this rock is more conspicuous as could be expected from the megascopic examination. The plagioclase (An_{72} - An_{60}) occurs in single twinned or zoned crystals of medium size as well as in

xenophyres of plutonic or intrusive character, consisting of numerous crystals of various dimensions. One of the xenolithic aggregates has a size of about 6 mm by at least 3 mm, being broken off at the border of the slide. Cracks after the cleavage planes and the contact between individual crystals are stained by ore intrusion. Next to augite and biotite one single olivine crystal of 3 mm diameter was found. It is rather fresh and bears inclusions of and is surrounded by small augite and biotite crystals. The whole association of minerals itself is bordered by a thin reaction rim of ore pellets. Brown iron-rich streaks run along the cleavage lines of the olivine. A conspicuously large apatite was found too cut //(0001) (fig. 2, plate IV). The groundmass in which these minerals occur is a dark fabric of very minute augite, thin needles of plagioclase, inconspicuous tiny leucite, some apatite and abundant ore grains, with a mesostasis of doubtful character which consists probably in part of leucite and in part of glass.

57. It seems unlikely that the groundmass of such a rock as this one has crystallized from the same magma as from which the xenoporphyritic components are derived. There is, however, insufficient evidence as to the probable origin of these xenoliths. Combining the dark components an olivine-biotite-pyroxenite results. As will be shown later on there are more indications that rock material of this type has contributed to the formation of the alkaline rocks. A satisfactory explanation as to the origin of the feldspar xenolith, however, meets greater difficulties. Describing plagioclase-rich inclusions in the leucite-basanites (kivites) of Bufumbira, HOLMES (1937, par. 361) considers them to be parts of the plagioclase-rich matrix of kentallenite. In the present case there seems to be no inducement for the same conception. The absence of even a single crystal of orthoclase in the xenolith would make such a suggestion for the present occurrence rather arbitrary. Until further details and more data in connection with this problem will be available a further discussion must be considered futile.

59. **Tephrite (Nr. 68798 (1)).** The only typical lava of these series is macroscopically a mauve grey rock wit a compact glassy groundmass with abundant irregular shaped small holes. Rather conspicuous augite and small feldspar crystals are the porphyritic minerals. In section it appears that augite and plagioclase occur in about equal quantity, the former being of somewhat larger size.

Corroded minerals occur abundantly. It is not possible to decide as to their original character. Remarkable is the occurrence of plentiful very cloudy to nearly black micro-porphyritic apatite. The groundmass is yellowish brown owing to abundant tiny limonitic concretions and brown hematite-like patches. In this base plagioclase laths and small leucite with included augite-microlites are embedded in a mesostasis of soda-rich plagioclase and conspicuous glass.

60. **Tephrite (Nr. 67016).** This specimen, collected on the south slope of the G. Patiajam, is a fine grained andesitic rock without conspicuous phenocrysts. In the slide an irregular fabric of small sized plagioclase and augite, seldom of macro-porphyritic dimensions, is visible. The augite is dark green aegeritic. The plagioclase occurs in twinned and zoned crystals, some of the latter provided with a rim of orthoclase. Corroded relics are common, showing the usual features. Micro-porphyritic ore is present. The groundmass is a matrix of plagioclase, interstitial leucite and glass. Tiny augite grains and ore pellets are less abundant. Only a few slender apatite prisms were detected.

61. **Tephrite-tuff (Nr. 70838).** The hand specimen is a greenish grey, easily pulverized rock in which megascopically different rock fragments are to be recognized. In the slide it is a typical polymictic tuff consisting of leucite-poor to leucite-rich fragments of rocks of the tephrite-leucitite series. As none of them is dominant over the other the neutral name of tephrite-tuff is given to this specimen.

b. Leucite-tephrites

62. As previously stated these rocks differ from the tephrites by their greater content of leucite. Three rocks of a basaltic appearance were collected near the summit (Nrs. 61505, 61765 and 71361 (2)), one near the 1500 feet contour line on the west slope (Nr. 61784) and one in the lower parts of the south-west slope. Of andesitic character eleven rocks samples could be studied. According to the degree of coarseness of the rock and the mode of occurrence of the phenocrysts some sub-groups can be distinguished. The rocks 61638, 61718, 61724, 61818, 68824 (4), 68845 (2), 70729, 70875 and 71421 are of fine grained texture. They were collected near the summit (Nrs. 61638, 61718, 61724, 68845 (2) and 71401), at the utmost north of the volcano near the coast of the Java Sea (Nr. 68824 (4)), at 1000 feet on the south-west slope (Nr. 61818) and at a height of about 150 feet on the south and south-west slope of the mountain

(Nrs. 70729 and 70875). Of about the same texture but with more conspicuous augite phenocrysts is the specimen 71421 collected on the south-east slope on 1500 feet. Of diverging external features is rock Nr. 67089 (3), a grey lava collected on the south-east slope at a height of 2500 feet and a brownish-grey sandy tuff of the G. Patiajam (Nr. 66996).

1. Rocks of basaltic appearance

63. **Leucite-tephrite (Nr. 61505).** The hand specimen is dark grey with scarce small short prismatic augite. A few large phenocrysts of this mineral are also present whereas one or two leucite crystals were observed. Very conspicuous is the occurrence of a large xenolithic biotite of nearly 20 mm diameter and a thickness of 4 mm. This xenolith is surrounded by a white bleached rim of probably the original groundmass. The microscope revealed few phenocrysts of augite, subordinate plagioclase and clear euhedral leucite, showing weak double refraction. The leucites carry no inclusions. The groundmass consists of numerous slender prismoids and grains of aegerite-augite, automorphic leucite and thin plagioclase laths, embedded in a mesostasis of interstitial plagioclase, anhedral leucite and some glass. Accessories are cloudy apatite, ore and thin streaks of a corroded mineral, probably augite. Only one small biotite bleb was detected.

64. **Leucite-tephrite (Nr. 61765).** This rock is very alike the previous number. It is fine grained with a dark coloured groundmass in which phenocrysts of augite and biotite can be recognized. Enclosures of lighter grey rock fragments and rare calcite concentrations are present. Of the enclosure a slide has been prepared which is described below. Few medium sized augite prisms and minor plagioclase are the porphyritic minerals. Leucite is abundantly present as micro-phenocrysts in the dark coloured groundmass being surrounded by numerous augite microlites and slender plagioclase laths. The interstitial material is anhedral leucite, orthoclase and some glass as the last product of solidification. Small ore grains and apatite are the accessories. No biotite was encountered. The enclosure in this rock appeared to be a coarse grained leucite-tephrite consisting of a few phenocrysts of augite, plagioclase and small porphyritic leucite in a felsic groundmass with abundant plagioclase and aegerite-augite in a mesostasis of anhedral leucite and some glass. Some of the augite was corroded.

65. **Leucite-tephrite (Nr. 61784).** The rock is a rather unfresh specimen which, however, shows a core of typical basaltic appearance with small phenocrysts of augite and feldspar. In the slide augite and plagioclase (An_{64} - An_{54}) appear to be present in about equal quantity, next to pretty abundant leucite and minor biotite. Biotite blebs are also part of totally corroded relics consisting of numerous ore grains. Large euhedral crystals of ore are present (fig. 3, plate IV). In the groundmass no second-generation-leucite was found. Plagioclase laths, augite grains, ore specks and accessoral apatite are the minerals embedded in a mesostasis of allotriomorphic less calcic plagioclase and turbid glass. Secondary yellowish brown staining by limonitic iron was observed.

66. **Leucite-tephrite (Nr. 61795).** Megascopically the rock has a glassy dark grey base with rather abundant augite and inconspicuous feldspar. Under the microscope aegerite-bearing augite and plagioclase are the phenocrysts. Clusters of augite + plagioclase + ore occur plentiful. One flake of biotite with a thick rim of ore was observed. Porphyritic ore, resorbed and invaded by the groundmass, is abundant. The groundmass itself is composed of a leucite-rich base with abundant plagioclase microlites and augite grains. Leucite occurs in tiny euhedra and as xenomorphic material. A turbid interstitial mass showing weak double refraction may be altered nephelite. Apatite is present as few cloudy prismatic crystals. Secondary chlorite and ore pellets are common products of alteration.

67. **Biotite-leucite-tephrite (Nr. 71361 (2)).** In this rock of typical basaltic appearance some conspicuous augite, weathered rounded clusters of probably leucite and rare olivine are to be recognized. In the slide very large augite and biotite occur next to few rather large clusters and some smaller crystals of plagioclase. The augite reaches a length up to 3 mm. The biotite is in most cases remarkable fresh, strongly pleochroitic from yellowish brown to dark brown. Some crystals, however, occur which have suffered resorption, being deeply invaded by tongues of the groundmass. The same is the case with some of the augite xenocrysts. The impression is created that the biotite occurs as xenoporphyritic mineral as well as a product of deuteric magmatic action.

The dark groundmass has the character of the leucitites to be described later on, consisting essentially of leucite euhedra and augite microlites, with very subordinate thin needles of plagioclase.

The interstitial material is also leucite. Apatite occurs in large crystals preferably associated with the augite. The following xenolithic aggregates were observed:

augite + biotite + ore + apatite
augite + plagioclase + ore + apatite
augite + ore + apatite
plagioclase + ore + apatite
ore + apatite

Olivine was not detected in the slide. This strengthens the impression that the crystals which were macroscopically visible, are indeed xenoliths as no evidence came forward that the mineral is an orthomagmatic constituent of the rock. The xenolithic aggregates are probably of the same origin as those described in paragraphs 56 and 57.

2. Rocks of andesitic appearance

68. **Leucite-tephrite (Nr. 61638).** The hand specimen is a fine grained grey rock in which next to white patches of probable feldspar few small and one or two large crystals of augite are recognized. In section few small augite phenocrysts of the common aegerite-bearing variety and still fewer but more conspicuous plagioclase are the porphyritic minerals. Only one corroded relic was detected. Leucite as a macro-phenocryst is wanting. In the groundmass, however, it is a rather abundant constituent both as euhedral and as interstitial material. Aegerite-augite and plagioclase are present in abundant quantity, mostly surrounding the euhedral leucite. Minor orthoclase, some glass and hypautomorphic leucite fill the interstices. Apatite is the common accessory, ore grains are subordinate.

69. **Leucite-tephrite (Nr. 61718).** This rock has the same external feature as Nr. 61638. Under the microscope the porphyritic minerals appear to be more abundant, augite, plagioclase and primary ore being the phenocrysts. They occur in a groundmass of which augite is the main constituent, next to abundant nearly isotropic rounded euhedral leucite and slender twinned plagioclase laths. The mesostasis is interstitial leucite and minor, probably some orthoclase. Ore occurs in the customary small grains. No apatite was detected.

70. **Leucite-tephrite (Nr. 61724).** A grey, weathered, fine grained rock without megascopically recognizable phenocrysts. In section a slightly turbid groundmass is visible. The only porphyritic mineral is aegerite-bearing augite; leucite and plagioclase are confined to the groundmass which consists essentially of the former mineral in tiny euhedra which are partly analcimized. Abundant augite prismoids and some plagioclase needles are filling the interstices, with xenomorphic isotropic leucite and some sparse feldspar. Opalized feldspar is met with. Brown limonite-like grains and isotropic light brown colloform are the secondary products. Apatite is the accessory.

71. **Leucite-tephrite (Nr. 61818).** The hand specimen is a medium grained rock with conspicuous sanidine and plagioclase and more abundant smaller crystals of augite. In the slide yellowish to green pleochroitic aegerite-bearing augite and plagioclase (An_{52}) are the main phenocrysts next to some large crystals of sanidine. The latter encloses often small plagioclase and augite prisms. One of the plagioclase crystals (An_{80} - An_{72}) shows remarkable complex twinning (fig. 4, plate IV). Leucite occurs abundantly as micro-phenocrysts and as interstitial material in the groundmass consisting of small irregular shaped patches of plagioclase and a few crystals of augite. Ore is a macrocrystal component. Minor glass occurs. Interesting is the character of an alkali-feldspar crystal showing alternating zones of albite and orthoclase, an outer rim of labradorite surrounding the mineral.

72. **Leucite-tephrite (Nr. 68824 (4)).** Macroscopically the rock is nearly identic with the former specimen. In section, however, augite appears to be the only phenocryst. This mineral of the common variety occurs in a groundmass of aegerite-augite, very slender plagioclase laths, euhedral leucite and rather abundant cloudy apatite. The interstitial material is xenomorphic leucite. Corroded biotitized relics are present as rather conspicuous components. Small ore grains and minor antigorite-like material are the products of alteration.

73. **Leucite-tephrite (Nr. 68845 (2).** This sample has a typical andesitic appearance. Augite is abundantly present in mostly short prismatic although sometimes slender crystals. In the slide the augite shows the features characteristic for this type of rock. Zonal and occasionally hourglass structures are observed. It is the only

porphyritic mineral in the fine grained groundmass of plagioclase laths, minute augite and iron-oxyde embedded in a glassy mesostasis which gives the rock a hypocrystalline to even vitrophyric appearance. Careful examination of the mesostasis, using a high power objective, selenite plate and strong illumination revealed, however, that the groundmass-material consists essentially of xenomorphic leucite in which a very faint twinning characteristic for this mineral could be detected. Some glass is present in minor patches, the refractive index being about 1.51. Accessoral apatite, ore grains and chloritic products are present.

74. **Leucite-tephrite (Nr. 70729).** The hand specimen is a very fine grained rock in which the dark parts of the groundmass are predominant over the feldspathic patches. Only a few porphyritic augite crystals are present. A dark brown xenolith is enclosed, the contact zone being markedly more felsic. A section of this xenolith, which measured 10 to 15 mm was prepared and is described below. Under the microscope the rock appears to be of the same hypocrystalline character as the previous number. Porphyritic minerals are wanting, except for a few microcrysts of augite and idiomorphic ore which occur in a glassy groundmass of aegerite-augite, plagioclase fibres, leucite crystals and abundant nearly isotropic interstitial leucite. Minute ore grains are sprinkled throughout the section. No apatite was detected.

75. **Xenolith of limburgite in leucite tephrite.** The xenolith mentioned in the previous paragraph appeared to be an iron stained fragment of probably limburgite. In a groundmass consisting of nearly submicroscopic diopsidic augite grains occurred some altered microporphyritic augite and iron-oxydic and opalized relics of what may have been small olivine grains. Very rare small laths of plagioclase were detected. Isotropic patches are likely leucite. Ore grains and iron-oxyde are plentiful lending the xenolith its dark brown colour. Excluding the alteration and iron-staining the rock is closely alike the limburgite described in par. 113.

76. **Leucite-tephrite (Nr. 70875).** The hand specimen has the features typical for the andesitic group. The only noteworthy microscopic character is the occurrence of fresh biotite as a marked enclosure in augite. Corroded relics and plagioclase are slightly more conspicuous. Orthoclase occurs as small interstitial patches. Apatite and chlorite are present. The rock is otherwise alike those already described.

77. **Leucite-tephrite (Nr. 71401).** This rock of light grey and sitic appearance contains macroscopically abundant augite prism plagioclase being less conspicuous. Under the microscope phenocryst of augite and plagioclase are present in about equal quantity, next t conspicuous fresh small crystals of biotite and euhedral ore. Occasic nally a poikilitic intergrowth of plagioclase and biotite may b observed. The groundmass is a very fine fabric of abundant mor or less analcimized leucite surrounded by slender prisms of plagic clase, minor augite and ore grains. Apatite is the accessory. Th biotite is strongly pleochroitic; X = brownish yellow, Z = brown black. The augite is of the pale yellowish green and bluish greer variety.

78. **Leucite-tephrite (Nr. 71421).** In this rock augite is megascopically predominant. Under the microscope the green augite is the abundant phenocryst next to minor plagioclase. The outer borders of the augite are sprinkled with ore grains. In several crystals the core has been replaced by green hornblende. This is the only rock in which this, in itself not uncommon replacement, has been observed. Corroded and biotitized hornblende occurs, whereas in one augite crystal biotite inclusions were detected. The groundmass contains plagioclase, augite, leucite and interstitial orthoclase and leucite. Ore grains are abundant, analcime and accessoral apatite are present.

79. **Leucite-tephrite (Nr. 67089 (3)).** A grey porous lava block with many round and oblong shaped pores. In section many of the pores appear to be inwardly coated with limonitic yellowish brown iron, some are nearly filled up with green chlorite-like material. The porphyritic minerals are augite, plagioclase, a few biotite crystals and pretty abundant euhedral ore. The groundmass is a very fine grained matrix in which tiny ore grains are predominant, giving the mass a melanocratic appearance. The minerals are plagioclase laths, tiny rounded augite grains, abundant leucite as euhedra and as interstitial filling, next to xenomorphic feldspar and some glass. Apatite is present with secondary chlorite, nontronite and calcite.

80. **Leucite-tephrite-tuff (Nr. 66996).** This rock collected near the summit of the G. Patiajam is megascopically a brownish grey fine-grained tuff-sandstone with small plagioclase crystals and abundant non-recognizable mineral fragments. In section it appears to be a typical tuff consisting of fragments of augite, plagioclase,

leucite, brown volcanic glass and iron-stained fragments of unknown origin. As the rock contains all the components of a leucite-tephrite the name adopted seems adequate for this specimen.

c. Leucitite-tephrites

81. This type of rock differs from the leucite-tephrites in the increasing content of leucite as a phenocryst and the simultaneous decrease in plagioclase. Of the rocks distinguished two specimen of basaltic appearance were collected, Nr. 71882 south-east of the summit of the Moeria on about 1200 feet and one south-west of the G. Tjlering (Nr. 72001 (2)). Of andesitic character were the remaining rocks. They occur near the summit of the Moeria (Nr. 68845 (1)), on the south-east slope near the 1500 feet contour-line (Nrs. 71447 and 71506), west of the summit on about 1500 feet (Nr. 71887) and on the north-east slope on about 500 feet (Nr. 71093 (3)).

1. Rocks of basaltic appearance

82. **Leucitite-tephrite (Nr. 71882).** The hand specimen is a dark grey rock with inconspicuous small prisms of augite and white patches, probably leucite. One large phenocryst of augite of xenolithic appearance was observed, which had a transparent green colour. In the slide abundant augite, some of a distinct yellow colour, numerous leucite in two generations together with subordinate plagioclase and euhedral ore are the porphyritic minerals. The groundmass is rather vitrophyric, isotropic leucite being the main constituent, surrounded by very thin laths of plagioclase and nearly submicroscopic augite. Turbid buff coloured glassy material fills the interstices. Secondary calcite and a few ore pellets are the accessories. The leucite shows only weak birefringence and carries no inclusions. Apatite is a rare constituent.

83. **Leucitite-tephrite (Nr. 72001 (2)).** Porphyritic leucite and augite are macroscopically determinable minerals in this dark grey slightly coarser grained rock. Under the microscope augite of both the green and yellowish variety and conspicuous large euhedral leucite appear to be the predominant phenocrysts next to some crystals of plagioclase. The groundmass consist essentially of leucite euhedral surrounded by augite grains and slender plagioclase prisms. The interstitial material is both plagioclase and orthoclase, the latter

occurring in subordinate quantity. Secondary limonitic ore, calcit and abundant patches of green earthy chlorit are the products c alteration.

2. Rocks of andesitic appearance

84. **Leucitite-tephrite (Nr. 68845 (1)).** This specimen is grey coarse grained rock with conspicuous phenocrysts of augite. I section it is a rock of hypocrystalline appearance in which augite i the very conspicuous phenocryst. It occurs in the diopsidic t aegeritic variety whereas some titaniferous augite is present. Th latter shows the hourglass structure. Corroded biotitic relics also ar observed. The groundmass consists of thin plagioclase laths an augite grains surrounding numerous euhedral leucite crystals. Th mesostasis is xenomorphic leucite, minor orthoclase and some buf coloured glass. Accessory is apatite. Chlorite and tiny ore grain are the secondary products. A xenocryst of quartz was detected rimmed with diopside prismoids and slender prisms of dark green strongly pleochroitic, arfvedsonitic hornblende. Also a brown gree hornblende was encountered in minute prisms; $X : c = +30°$, $Z =$ greenbrown, $X =$ purple brown. This rim of pyriboles was at on end of the phenocryst again surrounded by quartz in two small part of slightly different optical orientation, both differing from that o the xenocryst (fig. 1, plate V). Quartz xenocrysts of the same mod of occurrence are described by HOLMES as a not infrequent componen of the rocks of the Bufumbira area. For a summary of these occur rences see HOLMES & HARWOOD, 1937, III, par. 786.

85. **Leucitite-tephrite (Nr. 71093 (3)).** This rock has abou the same external features as those previously described. The con spicuous phenocryst is again augite. In section, however, it appeare that next to titaniferous and diopsidic augite, plagioclase and leucit both occur as porphyritic minerals (fig. 2, plate V). The plagio clase (An_{83} - An_{72}) occurs in polysomatic clusters. The groundmass consists of abundant leucite of the second generation surrounded b plagioclase laths and ore pellets, augite being very scarce. Interstitia feldspar is the mesostasis. Apatite is rather abundant, whereas secondary chlorite is a common constituent.

86. **Leucitite-tephrite (Nr. 71447).** The hand specimen is a medium grained grey rock in which only few phenocrysts of augite are visible. In the slide augite ranging from the colourless diopsidic

to dark green aegeritic variety is the only phenocryst in a rather coarse groundmass consisting of leucite surrounded by plagioclase laths. The less abundant augite is irregularly distributed. Some orthoclase prismoids are present. The interstices are filled with anhedral leucite and subordinate alkali feldspar. Apatite is very scarce.

87. **Leucitite-tephrite (Nr. 71506).** In the light grey rock with a rough lava-like surface only a few phenocrysts are to be observed. In section augite of the same character as in rock Nr. 71447 is predominant. Also in respect to the other constituents and the general microscopic features the rock is closely alike. It contains, however, xenolithic enclosures which need more exact description. In the first place a very conspicuous biotite crystal of 7 by 4 mm attracts attention. It is strongly pleochroitic X = yellowish brown, Z = red brown and includes green augite and large crystals of apatite (fig. 3, plate V). The second interesting xenolith is a matrix of very small augite grains enclosing two crystals of more or less resorbed olivine the core of which is still unaltered. The contact between the augites and the olivine is very irregular shaped and stained yellowish brown by iron-oxyde. This xenolith resembles the olivine-xenolith described in par. 95. It is probably a fragment of limburgite whereas the biotite may be of biotite-pyroxenitic origin. This is the more likely as large augite crystals occur in close contact with the biotite described.

88. **Leucitite-tephrite (Nr. 71877).** This is the only rock of the leucitite-tephrite group which contains leucite as a macroscopic component (fig. 1, plate VI). The microscope reveals the presence of leucite as the most conspicuous phenocryst. The occurrence of porphyritic plagioclase, however, justifies the classification as a tephrite. The augite is of a diopsidic character and shows a light greenish colour, the extinction angle being Z : c = 40°. The very fine grained groundmass consists of isotropic leucite surrounded by numerous small prisms of augite. In the groundmass the feldspar is sparse. Secondary ore pellets and calcite are present. Apatite is the common accessory. The leucite phenocrysts which measure up to 3.5 mm are typically birefringent. They have remarkable cracks filled up with calcite. Enclosures of small twinned plagioclase crystals occur. There is also a small reaction rim between the leucite crystals and the groundmass consisting of a thin calcite layer and a thin turbid isotropic rim, the first in contact with the leucite.

d. Leucitites

89. The last group of the tephrite-leucitite series includes 7 rocks of the G. Moeria and one of the G. Tjlering. Three of these rocks are of basaltic appearance viz. the numbers 67089 (1), 71372, 71904 and 73213, occurring respectively at 3000 feet south-east of the summit, at 4000 feet near the summit, on the north slope at about 5000 feet and at 700 feet on the east slope. The andesitic rocks are numbers 67092 and 71093 (1) collected at a height of 2500 feet on the south slope and at about 500 feet north-west of the summit. Two rocks of this type contain megascopically conspicuous leucite. These are the numbers 71847 and 72001 (1, 4) found respectively at 700 feet on the west slope of the Moeria and south-west of the G. Tjlering.

1. Rocks of basaltic appearance

90. **Leucitite (Nr. 67089 (1)).** In this dark grey compact rock only a few phenocrysts of augite are megascopically visible. In the slide augite appears to be the only porphyritic mineral. It belongs to the range of varieties normal for the alkaline rocks. A few specimen attract attention on account of their structural features, namely a dark green core of aegerite and a pale green rim of more diopsidic augite. The yellow variety is represented rather abundantly. Next to these augite phenocrysts a few totally corroded relics are present which most likely have been hornblende. One of them, which is totally opaque, includes some opalized and slightly calcified plagioclase crystals. Another shows a remarkable structure being composed of three zones of calcite separated by streaks of opaque ore. The relic reminds of a twinned hornblende (fig. 2, plate VI). The groundmass is fine grained and consists of leucite in euhedral micro-crystals and abundant augite grains. Thin plagioclase needles are present only as rare components. Ore pellets are not very abundant. Secundary calcite occurs in some large patches. Apatite is rare.

91. **Leucitite (Nr. 71372).** A rock of somewhat coarser external features. Some transition to the leucitite-tephrites exists on account of a, be it very subordinate, content of plagioclase in the groundmass as small twinned crystals. The leucite, however, is to such a degree the dominating mineral that the name leucitite is justified. This mineral builds up the rather coarse groundmass, the

numerous euhedra being cemented together by tiny augite and some plagioclase. The phenocryst is augite which occurs as single crystals and in polysomatic clusters. Ore is present as dusty grains in groundmass and as sparse euhedral larger crystals. Apatite is a rare component. The rock encloses a xenolith of a vitrophyric leucite-tephrite consisting of glass with isotropic leucite, plagioclase and augite as the porphyritic minerals.

92. **Leucitite (Nr. 71904).** The hand specimen is a dark grey rock with augite in prisms and clusters and a few round phenocrysts of leucite as the porphyritic minerals. In the slide there appear to be only a few, be it very conspicuous, crystals of leucite and some smaller augite prisms. The leucite shows excellent twinning and birefringence. Some of the euhedral show the beginning of alteration to pseudo-leucitic orthoclase and analcime. The groundmass consists essentially of micro-porphyritic leucite surrounded by small aegerite grains. Ore is subordinate, apatite a rare constituent. Some secondary zeolitic material is present as minute patches filling up the interstices. The identity could not be established.

93. **Leucitite (Nr. 73212).** The specimen of the same general appearance as the former rock contains so many leucite euhedral most of normal phenocrystal size together with a few of micro-porphyritic dimension that a phaneritic brickwork with thin cementing layers of plagioclase and some augite results. Diopsidic augite, mostly in poly-somatic clusters, is abundant. Euhedral ore is present, apatite is the common accessory. The leucite shows the normal birefringence, only a few of the micro-crystals being altered to analcime.

2. Rocks of andesitic appearance

94. **Leucitite (Nr. 67092).** Megascopically the rock has a grey andesitic appearance with pretty large augite and turbid white patches as phenocrystal constituents. In the hand specimen two large apparently xenolithic olivine crystals were detected. In the slide the augite is present in conspicuous single crystals and in polysomatic clusters. Some of the crystals are partly resorbed by the groundmass. Corroded relics occur plentiful, in some cases linked together with augite. In general the relics are of the same character as described by the latites. The ore grains of which they consist, however, are slightly coarser. In one case the arrangement

of the ore pellets after the hornblende cleavage was observed (see also par. 37); in most cases, however, no indication as to their probable origin was found. One more remarkable mineralogical fact may be mentioned. The apatite in this rock occurs abundantly in a brown striped fibrous variety. The termination of the crystals is strongly diverging from that of the common apatite. Its features are not unlike those described from the apatite-rich augite in the latite Nr. 70671 (par. 39), however, in this rock the fibrous habit is the most conspicuous feature. In one augite a single apatite of normal character was enclosed next to numerous brown fibrous specimen. A deuteric origin of the latter is suggested. The groundmass of this rock consists of numerous leucite euhedral with some thin plagioclase laths, augite grains and ore pellets. The sparse interstitial material is both feldspar and xenomorphic leucite.

95. Of the xenocrystal olivine as detected by the megascopic examination of the rock only one specimen was present in the slide. It showed most uncommon features. A rounded nearly colourless crystal is serpentinized along cracks //c, surrounded by a kelyphitic rim of radial orientated diopside and an outer border of ore pellets (fig. 3, plate VI).

One more interesting phenomenon was observed, namely the alteration of a green aegerite-bearing augite to a hornblende of abnormal pleochroism which typically resembled that of hypersthene, being Y = yellowish brown, Z = bluish green. The extinction, however, is Z : c = 9°. The optic sign is negative, 2 V presumably being small.

96. **Leucitite (Nr. 71093 (1)).** The hand specimen has no specific external features. In section it appears to be a rock consisting essentially of augite and leucite, both minerals occurring in two generations. The phenocrystal augite is more conspicuous than the micro-porphyritic euhedral leucite. The groundmass is a fabric of augite grains and subhedral leucite. Ore is not very abundant, apatite rather scarce although some conspicuous brown coloured crystals occur. Plagioclase as subordinate xenomorphic interstitial filling is a rare component. One relic, totally altered to ore and enclosing a typical basal section of apatite, and one probably of deuteric biotite with X = nearly colourless and Z = yellowish brown, are present. The biotite has a more or less rounded habit and is surrounded by a rim of very tiny nearly colourless radial orientated

grains which have straight extinction and form a curious matrix together with tombaque brown fibrous material. In the mineral itself this brown material and the minute grains fill up the thin veins between the cleaved pleochroitic parts of the biotite. If the nearly colourless grains are olivine as is suggested, the alteration of biotite to olivine seems the most probable explanation for the phenomenon described, as with regard to the mode of distribution of the grains the reverse transmutation is considered less likely.

3. Rocks with megascopic conspicuous leucite

97. **Leucitite (Nr. 71847).** Of the two rocks with megascopically conspicuous leucite this number contains more but smaller crystals of the feldspathoid, whereas augite is also rather abundantly present (fig. 4, plate VI). Locally iron-staining can be observed. In the slide this typical leucitite is seen to contain euhedral leucite up to 3.5 mm diameter. On account of alteration no double-refraction of the normal kind is visible but the crystals show irregular patches of slightly brown coloured zeolitic material with fibrous extinction. Probably the same zeolite, but now red brown iron-stained and more distinctly fibrous, fills veinlets and pores in the groundmass. Next to this leucite augite is an abundant phenocryst. The groundmass consists of euhedral micro-phenocrystal zeolitized leucite cemented together by a brownish green turbid substance of chloritic and limonitic material with some submicroscopical birefringent grains, which may be augite. Apatite is the accessory, ore is a common component.

98. **Leucitite (Nr 72001 (1)).** This rock contains the most conspicuous leucite which measures up to 10 mm diameter. In section the leucite appeared to be analcimized as well as altered to another specimen of the zeolite group as described above (par. 97). Next to these macro-porphyritic leucite some aegerite-augite phenocrysts occur. For the rest the rock consists of micro-porphyritic leucite and abundant slender prisms of aegerite. A translucent white secondary product fills caveties and veins throughout the rock. The birefringence thereof is rather low, the refractive index about that of leucite. A treatment with dilute hydrochloric acid caused the gelatinization of this material establishing its zeolitic nature. Apatite occurred as pretty large crystals enclosed in augite and as a component of the groundmass. Euhedral ore is present.

C. LEUCITE-BASANITE SERIES

a. Leucite-basanites

99. Among the rocks of the volcanic area studied only a few olivine-bearing specimen were met with. On account of their content of leucite they are classified as leucite-basanites.

Rocks of leucite-basanitic composition may again be divided into basaltic and andesitic types. The first type includes the numbers 61825, 68789, 70891 and 71513, occurring respectively south-west of the G. Moeria at 800 feet, south-west of the G. Tjlering, on the west slope of the G. Moeria at a height of 600 feet and on the north slope of this mountain at 800 feet. The rocks of andesitic appearance include four numbers of the G. Moeria occurring on the west side of the summit at 2500 feet (Nr. 61772), upstream of the river Sampok on the west slope at about 1000 feet (Nr. 71082), on the south slope at 2500 feet (Nr. 71505 (2)) and at 800 feet (Nr. 71513). Nr. 71940 was collected on the G. Tjlering and a fragment of probably a volcanic bomb was found in the bedding of the Sampok at about 300 feet (Nr. 70938 (2)).

1. Rocks of basaltic appearance

100. **Leucite-basanite (Nr. 61825).** The hand specimen is a dark grey compact rock in which small augite prisms are abundant. In the slide yellowish green augite is the dominating phenocryst. It occurs preferably in polysomatic clots. Leucite is a less conspicuous component, as medium sized euhedral crystals. Some plagioclase is present. The olivine is confined to the groundmass in which it occurs as small rounded crystals mostly altered to chlorite. The groundmass consists essentially of xenomorphic leucite and small euhedral of this mineral, surrounded by thin plagioclase laths and augite grains. A locally conspicuous base of nephelite enclosing poikilitically plagioclase laths and augite grains is frequently observed. Secondary chlorite and calcite are present. Primary subhedral ore next to tiny ore pellets is common. Apatite is the accessory.

101. **Leucite-basanite (Nr. 68789).** Megascopically a dark grey rock with inconspicuous augite and some feldspar. In the slide numerous augite, some very conspicuous polysynthetic twins of plagioclase and rather abundant small olivine crystals are the porphyritic minerals, next to subhedral ore. The rather coarse grained groundmass

consists of micro-phenocrysts of leucite in a holocrystalline fabric of plagioclase laths, interstitial chloritic and nontronitic products of alteration and ore pellets.

Apatite forms a rare inclusion in augite. The olivine has severely suffered alteration to serpentine and iddingsite. Only the large crystals have a nearly fresh core and show the typical mesh-structure of altered olivine. The smaller crystals are mostly totally altered. The leucite still shows the normal features.

102. **Leucite-basanite (Nr. 70891).** The hand specimen is a dark aphanitic rock with abundant augite and feldspar phenocrysts. Under the microscope the augite appears to occur as pale coloured large crystals and polysomatic clusters. The plagioclase is about equally abundant, often with poikilitic intergrowth of augite. Euhedral magnetite is present in conspicuous quantities. The olivine is again partly or totally transformed into serpentine. Cross sections normal to the optic axis are frequently met with. One crystal of biotite was encoutered. These phenocrystal components are embedded in a very fine grained groundmass of tiny rounded leucite, numerous augite grains and ore pellets, plagioclase laths and interstitial feldspar. A remarkable constituent is the apatite in large crystals enclosed in both augite and olivine.

103. **Leucite-basanite (Nr. 71513).** The hand specimen shows a nearly black, rather coarse grained groundmass with megascopic conspicuous leucite and abundant pretty large augite. In the slide much large pale greyish violet augite, some with hourglass structure, often with ragged boundaries and also many large clusters of irregular shaped leucite with resorbed crystal faces are the porphyritic minerals. In one case a rather conspicuous, partly dissolved fragment of augite was found included in leucite. Other crystals have no sharp boundaries but merge vaguely into the groundmass. Small olivine crystals are quite abundant, all of them being corroded and for the greater part altered to a matrix of serpentine and chlorite. Fairly large euhedral magnetite occurs. This primary mineral is in some cases also intensely resorbed and invaded by tongues of groundmass. The groundmass consists of micro-porphyritic plagioclase (An_{75} - An_{58}) prisms, small irregular of augite, ore specks and rather a lot of interstitial chloritic material. Apatite is a common constituent. Secondary calcite occurs plentiful.

2. Rocks of andesitic appearance

104. **Leucite-basanite (Nr. 61772).** A grey rock with conspicuous phenocrysts of augite. In section it appears to be a typical aphanitic dark coloured rock with abundant augite and less olivine as phenocrysts. The augite is pale grey, mostly subhedral, sometimes resorbed and invaded by tongues of groundmass. The olivine is nearly colourless, except for a thin external brown zone of limonitic material. The very fine grained groundmass is essentially composed of subporphyritic rounded leucite, generally without inclusions, surrounded by very abundant grains of pale grey augite, probably more or less corroded and iron-stained olivine, ore pellets and slender twinned plagioclase laths. Very small biotite blebs occur throughout the groundmass. It is of the same variety as the deuteric biotite previously described. One relic of slightly greater dimensions may be corroded biotite. Only one cloudy apatite was detected.

105. **Leucite-basanite (Nr. 71082).** The hand specimen is lighter grey than the foregoing number. It contains conspicuous augite and white patches of feldspathoid. In section the augite occurs in large clusters in combination with ore and apatite. Leucite is very abundant as phenocryst as well as micro-porphyritic material. It is usually double refracting and in one case includes a partly corroded crystal of augite as described in par. 103. The typical clusters of augite are presumable an indication to the xenolithic origin of this mineral. Olivine is present in small rounded crystals of which only a few survived alteration to a mineral which probably belongs to the chlorite group. This alteration product is strongly pleochroitic; X = yellow to yellowish green, Z = olive green; X = // elongation; the extinction is straight, the double refraction of medium order. In a single case the axial figure could be studied. It revealed a nearly uniaxial negative character. After close inspection a hardly perceptible striation // elongation could be detected. These data fit rather close to those of a mineral intermediate between daphnite and amesite. The pleochroism is that of daphnite, which according to LARSEN and BERMAN (1934, p. 84) is Z = pale yellowish, Z = olive green. The refractive index of a very tiny flake isolated out of crushed rock material could be measured and appeared to be about 1.605 which is a value closer to the r.i. of amesite than to that of daphnite. As both, however, are members of an isomorphic serie, daphnite being the ferrous equivalent of amesite, the data obtained are considered to

support sufficiently the assumption under discussion. The occurrence of a flake of the daphnite-amesite enclosed in augite was observed. The cementing material of the leucite is as usual a combination of plagioclase laths, augite grains and ore pellets. Secondary chlorite and calcite are pretty abundant, apatite is a common constituent.

106. **Leucite-basanite (Nr. 71505 (2)).** Megascopically augite and scarce olivine are distributed in a grey groundmass. Under the microscope the rock has the appearance of an augite-rich leucite-tephrite. The augite which is abundantly present in large crystals belongs to the aegerite-rich variety. Next to augite a great many corroded ferromagnesian minerals occur, in some cases with patches of biotite of the type common in rocks of the latite group. Two large and two small very clear olivine phenocrysts are met with. The crystals of both sizes occur mutually in pairs and make the impression to be of xenolithic origin. They are surrounded by a thin rim of iron-oxyde, followed by a border of irregular arranged augite and an outer rim of ore grains and hematite. The fine grained groundmass consists of a lot of small leucite euhedral, plagioclase laths, augite grains, ore pellets and abundant rather cloudy apatite. This constituents are embedded in interstitial anhedral leucite and feldspar.

107. **Leucite-basanite (Nr. 71940).** This specimen of andesitic appearance contains augite and scarce rounded olivine in a grey mass with some feldspathic patches. In the slide the porphyritic minerals are yellowish augite, cloudy plagioclase, large peripherally limonitized olivine, euhedral ore and biotite. The biotite is apparently of deuteric origin. It occurs both as strongly pleochroitic conspicuous crystals and as patches and blebs. In several cases it is present as an inclusion in augite. In one instance a plagioclase crystal has been cleaved, one part being now included in the biotite, the other part of the same optic orientation laying outside the mica (fig. 1, plate VII). The pleochroism is light yellowish green to dark sepia brown. The optical character is uni-axial. In addition to the minerals described porphyritic hornblende is present; Z = pale brown yellow, X = green brown; Z: C = 3°. The groundmass is thickly strewn with leucite-microcrysts surrounded by abundant plagioclase laths and minute augite grains. Ore occurs subordinately as anhedral grains and as pretty large severely resorbed automorphic crystals. Apatite is a common constituent of sometimes rather conspicuous dimensions.

D. AUGITITE-LIMBURGITE SERIES

108. The melanocratic rocks of the G. Moeria include a few specimen of the above named rock-families. All occur on the north slope of the volcano and are interesting on account of their composition. Of the leucite-augitites two specimen have been collected in the lowland (Nr. 71903 and 71188), of the leucite-limburgite only one rock has been sampled at 800 feet (Nr. 71095) and of the limburgites two specimen are present in the collection, both occurring near the summit (Nr. 71361 and 71366). As will follow from the description of the latter rocks a distinct difference between the two exists.

109. **Leucite-augitite (Nr. 71903).** The hand specimen is a rock of basaltic appearance without any megascopically visible phenocrysts. In the slide the rock shows a remarkable habit, the small long prismatic nearly aequigranular augite prisms being orientated in one parallel direction suggesting a nemotablastic structure. Porphyritic minerals are wanting, the rock being composed only of the numerous augite prisms with interstitial leucite among which a few euhedral crystals. Minute thin plagioclase laths are very rare.

110. **Leucite-augitite (Nr. 71188).** Of this rock of the same external features with a few megascopic augite prisms the structure is different. Under the microscope the augite prisms appear to be coarser; they are distributed at random through the slide. A few phenocrysts of augite are present in a groundmass of augite, tiny euhedral leucite, subordinate plagioclase needles and a mesostasis of anhedral leucite. Ore grains and secondary calcite are present, whereas some of the augite is peripherally of sepia brown colour.

111. **Leucite-limburgite (Nr. 71095).** Only one specimen has been collected of this type of rock. Megascopically it is grey andesitic with augite, olivine and turbid white minerals as the porphyritic components. In the slide abundant green, often zoned augite and plentiful olivine in single crystals and polysomatic clusters occur in a hypocrystalline groundmass of very abundant isotropic leucite, numerous augite grains, subordinate olivine, glass and some ore pellets. The mesostasis is a weakly birefringent colourless mineral, which after a chemical test could be identified as nephelite. This nephelite is often present in patches which include poikilitically leucite, augite and rounded glass doubles. Plagioclase is very scarce as thin needle-like prisms.

112. **Limburgite (Nr. 71361 (6)).** A dark aphanitic rock without conspicuous phenocrysts. In section colourless diopsidic augite appears to be the essential component. Of this mineral only a few small phenocrysts are present. The second ferromagnesian mineral is olivine which however, in this rock is only of subordinate importance except for one large clear colourless crystal. The groundmass consists of the same colourless augite, some of submicroscopical dimensions; it is heavely sprinkled with ore. Any possibly present olivine could not be distinguished. Very slender hardly detectable plagioclase needles and some rare patches of biotite were still observed.

113. **Limburgite (Nr. 71366).** In this fine grained rock of andesitic appearance only a few dark components were megascopically visible. In the slide(fig. 2, plate VII) augite of the common pale green variety occurred next to less abundant but more mega-porphyritic olivine in a dark groundmass crowded with augite grains; isotropic glass fills the interstices. Some of the grains in the groundmass are coloured brown by a limonitic film. These may be corroded and limonitized olivine. Rare tiny patches of double refracting colourless interstitial material are detected.

E. SHOSHONITIC-ABSAROKITE-TRACHYTE SERIES

114. The shoshonitic-absarokites are extrusive rocks which contain a conspicuous content of orthoclase next to plagioclase as constituents of the groundmass. The porphyritic minerals are augite and olivine. They are rocks of some importance in the Bufumbira area (HOLMES & HARWOOD, 1937, p. 157) and are also described by IDDINGS & MORLEY as occurring on the Moeria. Only one specimen, apparently closely resembling the Uganda shoshonitic-absarokite M; is in the Moeria collection.

a. Shoshonitic absarokites.

115. **Shoshonitic-absarokite (Nr. 68824 (3)).** The rock occurs north of the G. Tjlering near the coast of the Java Sea; it is rather breccious and has no characteristic external features. In the slide it appears to be a holocrystalline, phaneritic rock of typically doleritic texture. Abundant plagioclase laths (An_{60} - An_{56}), some of nearly porphyritic character and in that case provided with a rim of orthoclase, and equally abundant orthoclase prisms, are the groundmass

minerals. The interstices are filled up with orthoclase mesostasis and minor glass in combination with secondary products of alteration such as chlorite and limonite. The porphyritic minerals are totally altered olivine of intermediate dimensions and greenish augite, the latter occurring in polysomatic clots. As alteration products of the olivine appear chlorite, limonite, and opal. The augite is unaltered except for some resorption of its boundaries. Ore of primary as well as secondary origin occurs plentiful. Some totally corroded relics of unknown origin are present. Apatite is the accessory.

b. Trachytes

116. Of this family several specimen have been collected on the G. Tjlering. They are all leucocratic rocks. One trachyte of grey colour has been found on the G. Moeria and a leucite-bearing variety occurs south of this volcano. As will appear from the description these two rocks are quite other varieties than those of the G. Tjlering, which are typically kali-trachytes. The classification of JOHANNSEN (III, p. 15 and p. 66) has been followed here and in consequence the rocks are divided into leuco-trachyte (Nr. 68818), leuco-kali-trachyte (Nr. 61541 and 71915), leucite-trachyte (Nr. 70803) and hornblende-trachyte (Nr. 71384).

Rock Nr. 68818 occurs on the east slope of the G. Tjlering; Nr. 61541 north of this volcanic hill near the coast of Java; Nr. 71915 is of the same location, whereas Nr. 10803 was collected on the utmost south slope of the G. Moeria near the road from Koedoes to Djapara. The grey coloured trachyte occurred on the summit of the main volcano of the area.

117. **Leuco-trachyte (Nr. 68818).** Megascopically this rock is light greyish white with few sanidine crystals, tiny black spots, ore concentrations and small rather lustreous feldspathic minerals. In section it appears to be a felsic rock without any dark constituents except for a few small ore grains. The felsic minerals are sanidine and plagioclase. The former occurs as subhedral phenocrysts with conspicuous undulose extinction. They are mostly twinned after Carlsbad. The two parts of these twins show a featherlike striping (fig. 3, plate VII). Of the larger crystals some show parts with a slightly higher refractive index, which are presumably soda-feldspathic, some fine twinning lamellae being observable. Minor xenomorphic oligoclase is also present as porphyritic component. The

groundmass consists of a trachytic fabric of plagioclase and sanidine laths with a mesostasis of alkali-feldspar. Parts of the slide are blurred with a slight greenish coating. Worm-like rods of glass occur.

118. **Leuco-kali-trachyte (Nr. 61541).** The hand specimen is a white compact rock with a few phenocrysts of sanidine. In section sanidine appeared to be the only porphyritic mineral. The features of this component are exactly the same as described in the previous paragraph. The groundmass neither contains plagioclase, except perhaps for a few hardly perceptible patches.

119. **Leuco-kali-trachyte (Nr. 71915).** From the same locality a compact rock and a tuffaceous specimen of the same composition are present. The external features of the former are exactly like those described from the previous number. The latter is thoroughly weathered tuff without macroscopically recognizable minerals. In the slide the sanidine seldom reaches macro-porphyritic dimensions. It is of the same undulose and feather-like striped character as already described. The groundmass is a matrix of nearly equally long prismatic sanidines in typical trachytic arrangement (fig. 4, plate VII). Some greenish turbid material is present in the tuff, which is probably argillaceous material. This is in agreement with the occurrence of very tiny, nearly submicroscopical prisms of rutile and rounded grains which may be anatase. Of some of the rutiles even the characteristic geniculated twinning could be observed. A large enclosure consisting of a matrix of a totally chloritized mineral which may have been olivine and ore is present.

120. The appearance of the argillaceous material resembles in no respect the normal lateric clay which is the main soil type in the area. It seems that some older argillaceous sediments has been in contact with this special rock. The occurrence of the rutile also points to this assumption. By ROSENBUSCH-MÜGGE (1927, II, 2, p. 96), the rutile needles are described as the so-called "Tonschiefernädelchen" which according to DE LAPPARANT among others occur in bauxites derived from phyllites. The present author detected the same mineral in the fraction 1 - 5 micron in some Dutch clays (VAN BAREN, 1934, p. 91).

121. **Leucite-trachyte (Nr. 70803).** The hand specimen is a light grey aphanitic rock with few thin and short prismatic dark components, sanidine laths and rounded leucite. One xenolithic augite is present. Microscopically there are still more differences with the

rocks previously described on account of the presence of large crystals of twinned or weakly zoned sanidine and even large leucite in single euhedral crystals and subhedral clusters (fig. 1, plate VIII). Small phenocrysts of aegerite-augite, plagioclase (An_{72} - An_{55}), sparse biotite and hornblende also occur. The groundmass is grey brownish with abundant automorphic leucite, augite prismoids and plagioclase laths embedded in a nearly isotropic glassy mass with very minute feldspar fibres, specked with submicroscopical dusty grains and subordinate ore. Some euhedral ore crystals occur.

122. **Hornblende-trachyte (Nr. 71384 (1)).** Megascopically the rock is a grey pseudo-vitrophyric specimen with conspicuous large crystals of sanidine up to 30 mm length (fig. 2, plate VIII). Long prisms of hornblende and plagioclase are to be recognized. In the slide the phenocrysts are sanidine, plagioclase, hornblende and melanite. The sanidine occurs in large idiomorphic crystals up to 20 mm length. It is marginally zoned with feldspar of slightly higher refractive index (fig. 4, plate VIII). The crystals are clear except for some cracks filled with secondary calcite and a few inclusions of calcified plagioclase crystals and hornblende prisms (fig. 3, plate VIII). The plagioclase is of normal size and provided with a rim of orthoclase. Especially the smaller crystals, however, are calcified and chloritized. The hornblende of which only a few porphyritic crystals are present, is of the arfvedsonitic variety. It is strongly pleochroitic, X = yellowish brown, Z = deep green with the extinction angle $Z : c = 14°$. Some of the micro-porphyritic crystals are altered to calcite and chlorite with some peripherally concentrated ore pellets. The fourth conspicuous component is melanite, occurring in euhedral crystals and subhedral clots. In one case it seemed pseudomorphic after hornblende. however, only a part of this mineral being involved. In another instance patches of pleochroitic hornblende could be detected in the utmost border of the melanite. Some of the larger clusters included partly resorbed hornblende, the holes of which are filled up with groundmass material (fig. 5, plate VIII). The most remarkable features, however, are that the colour of this garnet matches exactly the yellow brown colour //X of the hornblende and that in the cluster parts of the mineral itself shows double refraction. From this observation the metasomatic replacement of the hornblende by the garnet is detucted. The groundmass, containing the porphyritic minerals described, is a turbid opalized fabric of hardly recognizable altered feldspar and

hornblende with abundant secondary calcite and chlorite. The feldspar is probably both plagioclase and sanidine. A small felsic phaneritic enclosure was detected at the border of the section. It consists entirely of plagioclase except for two or three melanite crystals. The texture and composition of this xenolith resembles the plagioclase-rich xenolith described in par. 80, which occurred as an enclosure in leucite-tephrite. The occurrence of the melanite, however, remains an incongruity.

Appendix

123. **Volcanic bomb (Nr. 70938 (2)).** One specimen, whose place among the rocks of the Moeria-area is still obsolete and to which no rock name can be given until a more extensive examination of the type will be possible, still must be described. It is a volcanic bomb of brick red colour, with conspicuous feldspar and olivine in a groundmass of nearly pure iron-oxyde. In the slide this opaque base appears to contain plagioclase and rather fresh olivine, only in some instances partly altered to iddingsite, as phenocrysts. Fibrous plagioclase needles and turbid isotropic material fills small cavities. The plagioclase is also fresh, however, every pore and crack along the cleavage planes are filled up with the omnipresent iron-oxyde. It is a rock which differs in every respect from those described. Although plagioclase and olivine, whose fresh appearance tend to suggest a xenolithic origin are also encountered as xenolithic material in rock Nr. 71361 (3) (par. 56) it seems for the present too far reaching to propose a name based on these scanty data. Referred, however, may be to a possibility as has been argued by HOLMES (1937, par. 383) that diffusion of the constituents of augite into aluminous sediment might lead to the precipitation of anorthite and olivine.

CHAPTER IV

SUMMARY AND CONCLUSIONS

124. Comprising the results of the petrographic data assembled in the previous chapter the following table can be drawn up:

Series	Family	Variety	Number of rocks
Monzonite-latite	Monzonites	Hornblende-monzonite	1
		Augite-biotite-monzonite-porphyry	1
	Latites	Latite	17
		Hornblende-latite	5
		Biotite-hornblende-latite	1
		Biotite-latite	2
		Hypersthene-latite	1
		Leuco-latite	1
Tephrite-leucitite	Tephrites	Tephrite	9
		Tephrite-tuff	1
	Leucite-tephrites	Leucite-tephrite	15
		Biotite-leucite-tephrite	1
		Leucite-tephrite-tuff	1
	Leucitite-tephrites	Leucitite-tephrite	7
	Leucitites	Leucitite	8
Leucite-basanite	Leucite-basanites	Leucite-basanite	9
Augitite-limburgite	Augitites	Leucite-augitite	2
	Limburgites	Limburgite	2
		Leucite-limburgite	1
Shoshonitic-absarokite-trachyte	Shoshonitic-absarokites	Shoshonitic-absarokite	1
	Trachytes	Leuco-trachyte	1
		Leuco-kali-trachyte	2
		Leucite-trachyte	1
		Hornblende-trachyte	1

If we compare our results with those obtained in other alkaline provinces, f.i. those of Bufumbira and Italy, the main differences are:

a. The abundance of latites and members of the tephrite-leucitite series, which respectively comprise 30% and 50% of the examined rocks;
b. The relative paucity of olivine-bearing rocks;
c. The occurrence of trachytes.

In this respect the Moeria rocks show a greater affinity to the rocks of the Vesuvius-Somma complex; a same suite of rocks builds up the G. Ringgit, situated on the north coast of Java (VAN BEMMELEN, 1938b).

125. The distribution of the rocks in the studied area is rather at random. With the exception of the grey vitrophyric hornblende-trachyte collected at the summit of the G. Moeria, which differs in every respect from the leucocratic-trachytes of the G. Tjlering the rocks of the shoshonitic-absarokite series are confined to the G. Tjlering. They represent the main type of rock; however, some other species allied to those of the G. Moeria also were found near this volcanic hill. If we assume furthermore that the latites, which for the greater part build up the latter volcano, are indeed derived from a monzonitic magma, the solidified product of this clan found on the G. Tjlering may be considered to be representative for the magma type seated below the Moeria. The two rocks collected from the G. Patiajam (Nrs. 66996 and 67016) do not ask for further explanation as their relation to the Moeria suite is established beyond doubt.

126. The important point now to discuss is whether any indication as to the origin of these alkaline rocks can be deduced from the petrological facts as revealed by their microscopic examination. As has been stipulated in chapter I, two quite different hypotheses have been developed with regard to this problem viz. the carbonate-syntexis hypothesis (DALY et aliter) and that which may be called the emanation hypothesis (HOLMES). The former theory postulates the assimilation of limestone and the subsequent desilication and relative potash-enrichment of the pre-existing magma; the emanation hypothesis on the other hand assumes the formation of syntectic or diatectic magma as a result of metasomatic processes at a high energy level. HOLMES gives expression to this conception in the following generalizing way (HOLMES & HARWOOD, 1937, p. 253):

a. Incoming emanations (from other "active" magmas or the "substratum")

plus

b. Energy (secular, radioactive, ionic reactions etc.)

plus

c. Crystal rock material, metasomatized, migmatized or more or less magmatized by a) and b)

minus

d. Outgoing emanations and associated energy.

As will be discussed below the emanation-hypothesis is to a satisfying degree in concordance with the results obtained by the investigation of the Moeria rocks whereas the limestone-assimilation theory seems inadequate to offer a conclusive solution to the problem.

127. Reviewing the petrological data as revealed by the microscopic examination the following facts are of actual importance:

a. The corrosion and subsequent biotitization of the hornblende (par. 34, 37, 42, 78 a.o.)
b. The convincing evidence of resorption of early crystallized porphyritic augite, plagioclase and ore (par. 28, 39, 86, 103 a.o.)
c. The occurrence of euhedral leucite surrounding resorbed augite (par. 103) and the presence of deuteric leucite filling a cavity (par. 30)
d. The occurrence of inclusions of biotite-pyroxenite (par. 56, 67, 87).

One of the first questions to be answered is whether there is any causal relation between the petrographical facts observed resp. whether the phenomena under discussion are contemporary or on the other hand originate from independent intra- or extra-magmatic influences. The present author inclines to the first alternative in so far that there exists a positive relation between the different evidences of the action of highly energized emanations either contemporaneous or consecutive.

A systematic discussion of the summarized data will elucidate the conception to which the present author arrived after careful consideration of the phenomena described.

a). The corrosion of the hornblende and the subsequent biotitization has been in most cases sufficiently and in some instances even absolutely convincing. In this respect may be referred to the description of the rocks given in the paragraphs 37 and 78. It is supposed that this hornblende is the early product of crystallization of an original hornblende-augite-andesitic magma which is considered to be the parental magma of the volcanoes of Java in general (RUTTEN, 1927, p. 166 - 167 and own observations).

It is a significant fact that other authors discussing alkaline rocks also mention the more or less conspicuous occurrence of corroded streaks and relics (HOLMES & HARWOOD, 1937, and VAN BEMMELEN (1938b)), which they consider to be relics of corroded biotite. Although the corrosion of this mineral in a few rocks of the G. Moeria also seemed likely and in other instances no definitive conclusions could be drawn, the present author wonders whether a careful re-examination of the rocks at least of the G. Ringgit would not point to the same origin of the relics.

b). The striking symptoms of resorption which in some instances were observed of augite, plagioclase and magmatic ore (par. 28) point to the increase of resorptive energy of the residuum. This increase can be unrestrainedly explained by the enrichment of the liquid by active ingredients, which at the existing temperature are either fluid or gaseous. From the abundance of apatite it may be concluded that the gaseous phase will be the most likely to prevail (NOCKOLDS, 1933).

c). The occurrence of partly solved augite as inclusion in leucite (par. 103) can be taken as evidence that alkalic compounds of probably extraneous origin have been added to the melt causing desilication of the liquid and subsequent crytallization of the feldspathoid and the formation of the yellow pyroxenes, the origin of which in accordance with BROUWER (1913, p. 910) is attributed to pneumatolitic processes.

The crystallization of leucite after resorption of the augite supports the presumption that the potash enrichment owing to the supply of volatiles, acted upon the magma in the first phase of its solidification, when the augite and in some cases also the plagioclase already had been developed. The metasomatic activity of probably highly energized emanations caused the partial remelting of these early phenocrysts and, after subsequent cooling of the liquid, the formation of leucite.

d). The third phase in the processes of solidification is the formation of late magmatic biotite and probably magmatic calcite (par. 22). Also the occurrence of deuteric leucite (par. 30) must, in respect to these late-magmatic processes, be taken into consideration.

In order to explain the occurrence of these potash-bearing deuteric products, again a supply of this element is assumed, as it seems hardly likely that the original magma in itself had a sufficient content of potash. In this respect it is of significance to note that the normal pacific rocks are very poor in biotite. That deuteric calcite may be expected to crystallize under the prevailing chemical conditions is supported in the considerations of BOWEN (1933) regarding the role of volatiles in magmatic liquids. The occurrence of a transfused quartz xenolith is also important as according to HOLMES (l.c. par. 798) this too is a symptom of the association of highly energized emanations with the rocks concerned.

e). The influence of pre-existing potash-bearing rocks is proved by the occurrence of biotite-pyroxenite xenoliths. The presence of xenoliths of this type has been deduced in some instances by combining the minerals of which the xenolithic character was obvious. A direct proof, however, may probably be seen in the occurrence of biotite-pyroxenite xenoliths in rocks of the G. Ringgit, which are consanguineous with those of the Moeria (VAN BEMMELEN, 1938b, p. 177). That in the Bufumbira suite biotite-pyroxenite also plays an important part is considered to be in favour of the conception that the formation of the alkaline clan of Java is also connected with pre-existing biotite pyroxenite. The same holds presumably true for the alkaline rocks of Celebes as the batukite described by IDDINGS (1915) chemically exactly matches biotite-pyroxenite (HOLMES & HARWOOD, 1937, p. 11). The diversity of rocks which varies from monzonite-latites to augitites and trachytes may probably be explained by normal differentiation of the alkalinic magma. A more conclusive answer with regard to this problem, however, depends on a chemical investigation of the studied rocks. The present author hopes to be able to discuss this side of the problem in a forthcoming paper when the results of the chemical analyses which are in progress, will be known.

128. Summarizing the foregoing considerations the following general conception crystallizes:

A primary magma of hornblende-augite-andesitic composition is acted upon by incoming emanations. The subsequent change in chemical composition of magmatic liquid, in which some early minerals already had been crystallized, i.e. ore, augite, plagioclase and hornblende, causes the resorption of the first three mentioned minerals, while the plagioclase consequently is provided with a rim of orthoclase. The hornblende being the least stable is corroded and subsequently biotitized. In the course of the crystallization of the residual magma further enrichment and subsequent desilication takes place. The formation of leucite phenocrysts and, in a later phase of solidification, of a leucitic base results. In the last phase of crystallization the deuteric biotite and the late-magmatic leucite are developed. Sodium was for the greater part already consumed for the transformation of augite into an aegeritic variety. The rest remains in the residual aqueous solution and will contribute to the composition of the rock by forming nephelite and eventually primary or secondary zeolites such as natrolite and analcime. The biotite-pyroxenite has contributed to the processes of desilication and potash enrichment. It may furthermore be beared in mind that magmas from which biotite crystallizes in depth give olivine and leucite at lower pressure (HOLMES, 1937, p. 28, also WASHINGTON, 1906, p. 158). Whether the lime bearing rocks which underlay the volcano have had any influence on these processes remains obscure. The quoted facts have, however, be convincingly proved that any whole-sale assimilation of limestone is out of question. In this respect attention may be drawn to the observation that the desilication of the residuum and the formation of the leucite have started after previous resorption of early minerals. This involves that the temperature of the residual liquid was very near the point of solification of the rock. It seems highly improbable that sufficient superheat would be available to account for the assimilation of limestone on such a large scale as is supposed to be necessary for the formation of alkaline rocks.

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Text of plate I

Fig. 1. Hornblende-monzonite [× ¾].
Polished surface showing white feldspathic base and hornblende.
Described in par. 15.

Fig. 2. Section of the same rock. Crossed nicols [× 10].
The colourless base is orthoclase, poikilitically enclosing barkevikitic hornblende and plagioclase.
Described in par. 15.

Fig. 3. Augite-biotite-monzonite-porphyry, (Nr. 70939) [× ¾].
Polished surface of hand specimen. The dark minerals are mainly augite.
Described in par. 16.

Fig. 4. Section of the same rock. Parallel nicols [× 10].
The photograph shows a conspicuous augite, common for this rock.
Described in par. 16.

PLATE I.

Fig. 1

Fig. 2

Fig. 4

Fig. 3

Text of plate II

Fig. 1. Slide of rock Nr. 70939. Parallel nicols [× 50].
Conspicuous abundant apatite as inclusions in augite and as constituent of the groundmass. Note basal section in centre of photograph.
Described in par. 16.

Fig. 2. Biotite-latite (Nr. 61485). Crossed nicols [× 20].
Photograph shows radial arranged calcite filling.
Described in par. 20.

Fig. 3. Latite (Nr. 70938 [1]). Crossed nicols [× 25].
Typical latite, showing labradorite phenocrysts in a slightly trachytic groundmass.
Described in par. 26.

Fig. 4. Biotite-hornblende-latite (Nr. 71361 [4]). Crossed nicols [× 9]. Filling of cavity consisting of core of calcite, with rim of deuteric leucite. In centre natrolite. Note sharp termination of leucitoëder in contact with calcite. Double refraction of leucite is visible.
Described in par. 30.

Fig. 5. Biotite-hornblende-latite (Nr. 71361 [1]). Natural size. Polished surface shows enclosure as of fig. 4 at 1 cm to the right of number. The white core of calcite and the greyish border of leucite may be recognized.
Described in par. 30.

PLATE II.

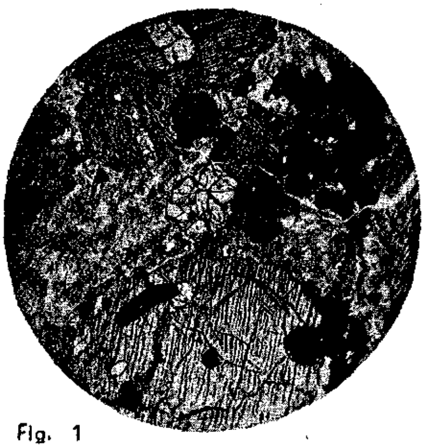
Fig. 1


Fig. 2

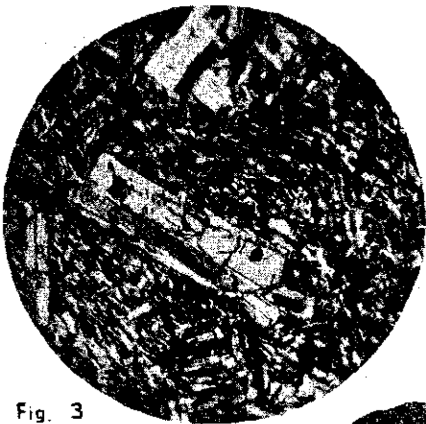
Fig. 3


Fig. 4

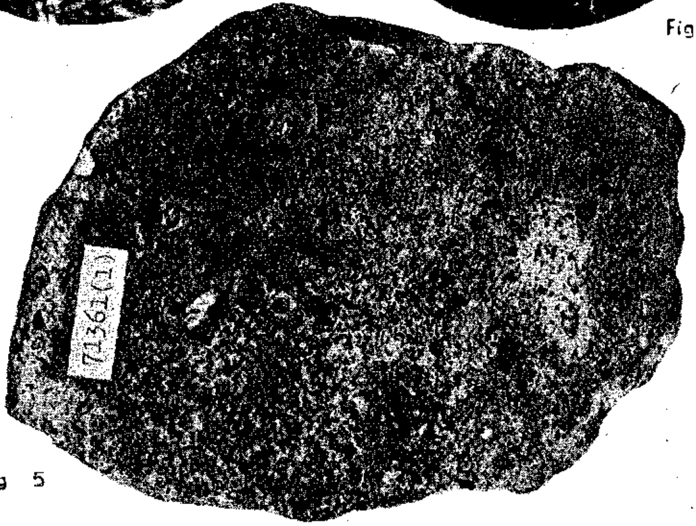

Fig. 5

Text of plate III

Fig. 1. Latite (Nr. 70660). Parallel nicols [× 90].
The photograph shows relic of hornblende. The ore pellets are arranged after the hornblende cleavage normally visible in a basal section.
Described in par. 37.

Fig. 2. Latite (Nr. 70671). Parallel nicols [× 20].
Augite shot through with apatite, of which mineral 22 are included in the one augite crystal.
Described in par. 39.

Fig. 3. Hornblende-latite (Nr. 70949). Crossed nicols [× 25].
Enclosure of xenolithic cluster of plagioclase and hornblende.
Described in par. 41.

Fig. 4. Hornblende-latite (Nr. 71933). Parallel nicols [× 25].
Typical hornblende with corrosion rim of ore pellets and invaded groundmass.
Described in par. 46.

Fig. 5. The same hornblende now with crossed nicols.
The alteration of the hornblende into two parts of different optical orientation is clearly visible. The lower part has a straight extinction, the upper part oblique extinction X : c = 16. Described in par. 46.

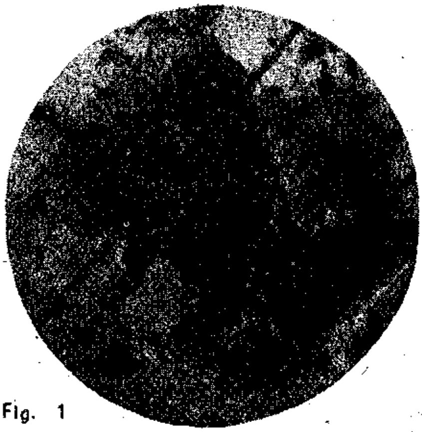

Fig. 1

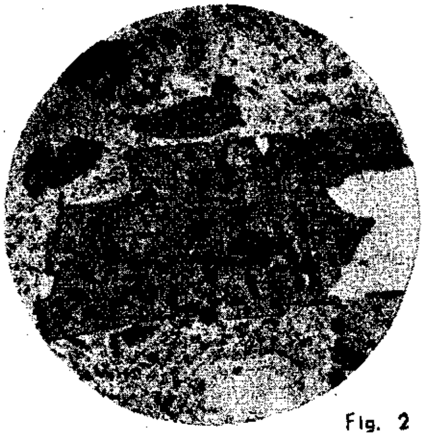

Fig. 2

Fig. 3

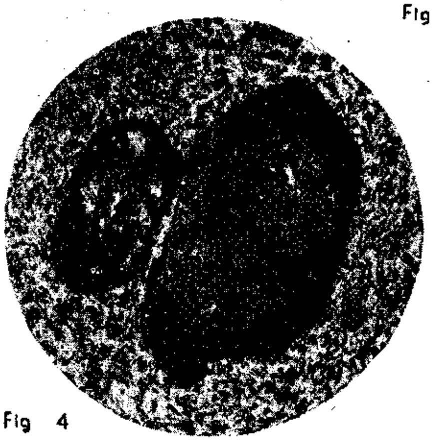

Fig 4

Fig 5

Text of plate IV

Fig. 1. Tephrite (Nr. 71862). Crossed nicols [× 13].
Typical shaped plagioclase consisting of two congruent parts viz. a core with thin orthoclase rim and a large border again provided with a thin rim of potash plagioclase.
Described in par. 53.

Fig. 2. Tephrite (Nr. 71361 [3]). Parallel nicols [× 15].
Conspicuous basal section of apatite.
Described in par. 56.

Fig. 3. Leucite-tephrite (Nr. 61784). Crossed nicols [× 50].
Typical section of leucite-tephrite with numerous small rounded leucite euhedra (isotropic), augite (left and centre), plagioclase (right) and ore (deep black).
Described in par. 65.

Fig. 4. Leucite-tephrite (Nr. 61818). Crossed nicols [× 25].
Polysynthetic twinning in plagioclase (An_{80} - An_{72}). The anorthite content of only two parts could be messured sufficiently accurate owing to undulose extinction.
Described in par. 71.

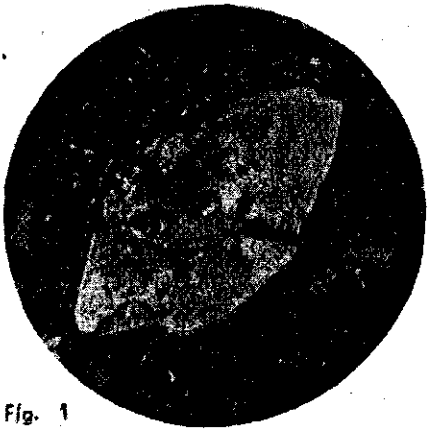

Fig. 1

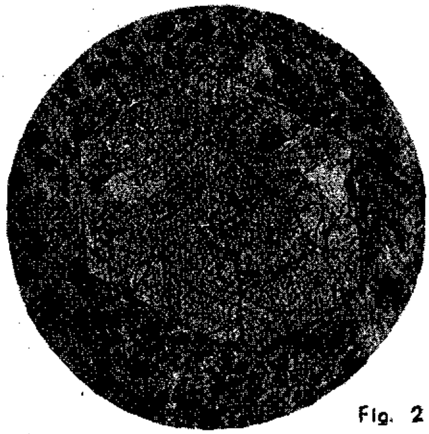

Fig. 2

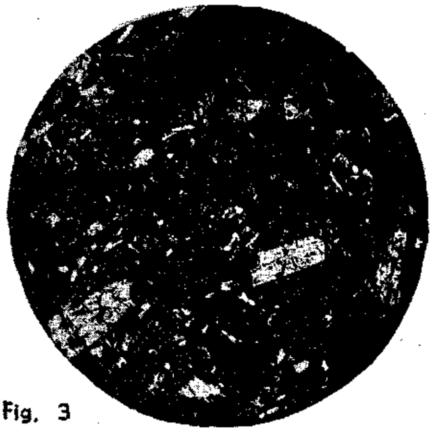

Fig. 3

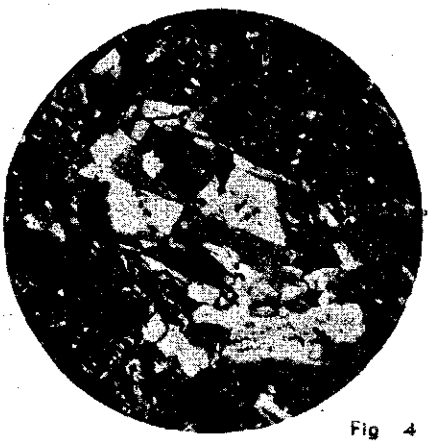

Fig 4

Text of plate V

Fig. 1. Leucitite-tephrite (Nr. 68845 [1]). Parallel nicols [× 80].
Quartz xenolith with rim of diopsidic augite and some arfvedsonitic hornblende.
Described in par. 84.

Fig. 2. Leucitite-tephrite (Nr. 71093 [3]). Crossed nicols [× 25].
Typical section showing macro- and micro-porphyritic leucite and plagioclase phenocrysts.
Described in par. 85.

Fig. 3. Leucitite-tephrite (Nr. 71506). Parallel nicols [× 10].
Biotite crystal (7 × 4 mm) enclosing augite and conspicuous apatite.
Described in par. 87.

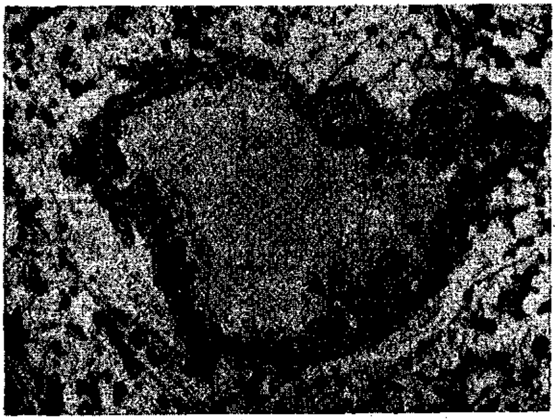

Fig. 1

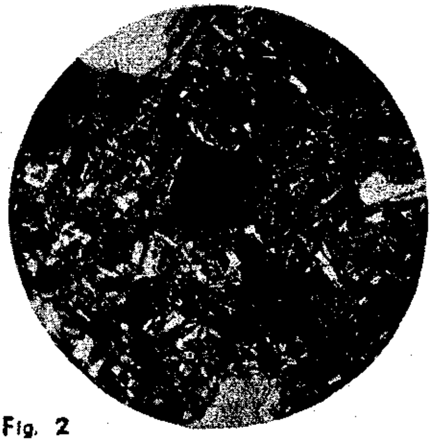

Fig. 2

Fig. 3

Text of plate VI

Fig. 1. Leucitite-tephrite (Nr. 71877) [× ¾].
Polished surface clearly showing conspicuous leucite euhedra. Described in par. 88.

Fig. 2. Leucitite (Nr. 67089 [1]). Parallel nicols [× 50].
Typical corroded previously twinned hornblende now consisting of calcite and hornblende. Note abundance of tiny leucite euhedra in the section.
Described in par. 90.

Fig. 3. Leucitite (Nr. 67092). Parallel nicols [× 45].
Olivine xenocryst provided with kelyphitic rim of augite and ore pellets.
Described in par. 95.

Fig. 4. Leucitite (Nr. 71847). Natural size.
Polished surface showing abundance of leucite.
Described in par. 97.

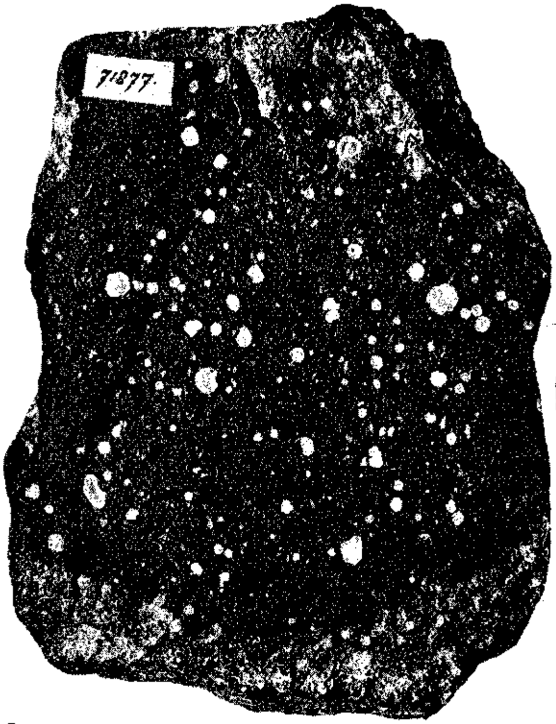

Fig. 1

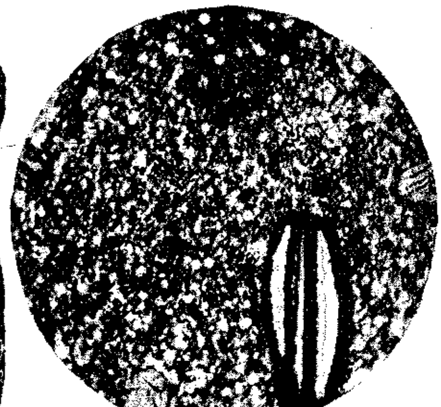

Fig. 2

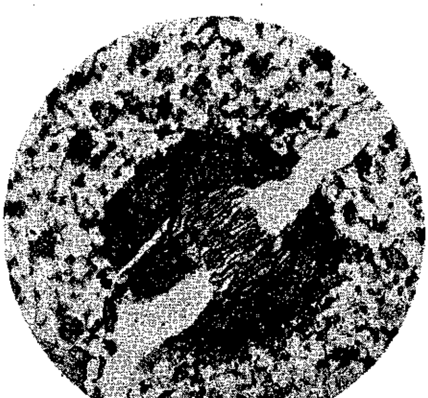

Fig. 3

Fig. 4

Text of plate VII

Fig. 1. Leucite-basanite (Nr. 71940). Crossed nicols [× 45].
Cleaved plagioclase enclosed in deutric biotite. The parts of the plagioclase have the same optical orientation.
Described in par. 107.

Fig. 2. Limburgite (Nr. 71366). Parallel nicols [× 25].
Typical section showing olivine and augite in augite-rich groundmass.
Described in par. 113.

Fig. 3. Leuco-kali-trachyte (Nr. 61541). Crossed nicols [× 45].
Featherlike striping of twinned sanidine phenocryst.
Described in par. 117 - 118.

Fig. 4. Leuco-kali-trachyte (Nr. 71915). Crossed nicols [× 25].
Typical section showing trachytic arrangement of sanidine laths.
Described in par. 119.

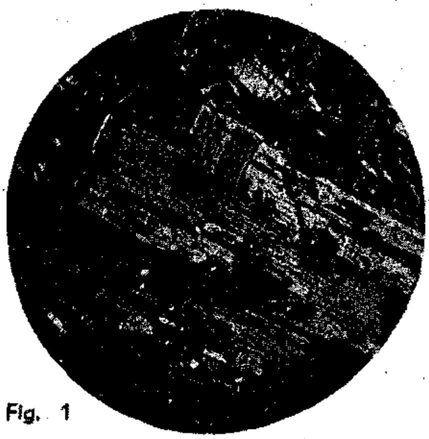

Fig. 1

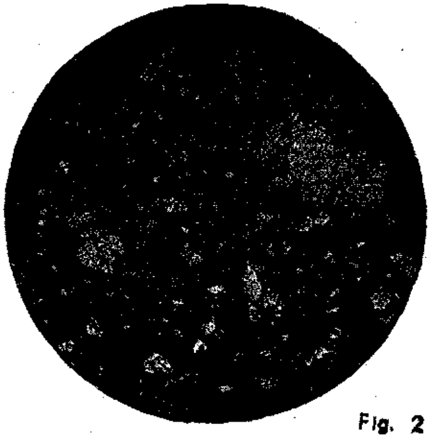

Fig. 2

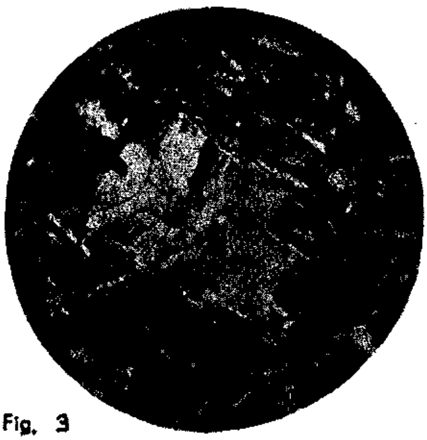

Fig. 3

Fig. 4

Text of plate VIII

Fig. 1. Leucite-trachyte (Nr. 70803). Crossed nicols [× 25].
Leucite euhedra showing typical twinning.
Described in par. 121.

Fig. 2. Hornblende-trachyte (Nr. 71384 [2]). Natural size.
Polished hand specimen showing conspicuous sanidine and a few hornblende crystals.
Described in par. 122.

Fig. 3. Section of the same rock showing sanidine crystals with cracks ⊥ c. Crossed nicols [× 10].

Fig. 4. Section of the same rock showing sanidine with thin rim of higher r. i. Crossed nicols [× 25].
In lower part of photograph a hornblende crystal.

Fig. 5. Section of the same rock showing melanite with enclosed hornblende. Parallel nicols [× 25].

PLATE VIII.

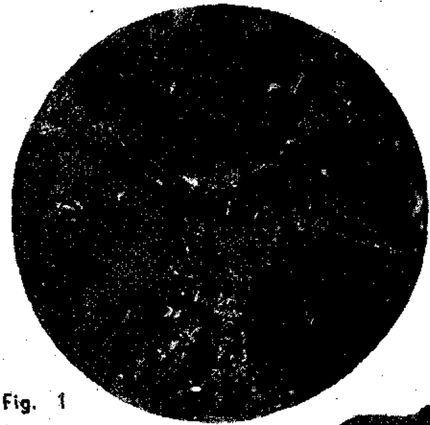

Fig. 1

Fig. 2

Fig. 3

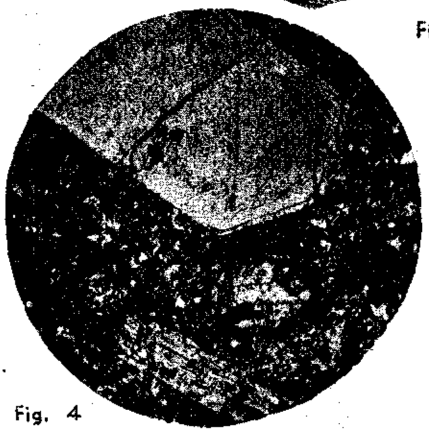

Fig. 4

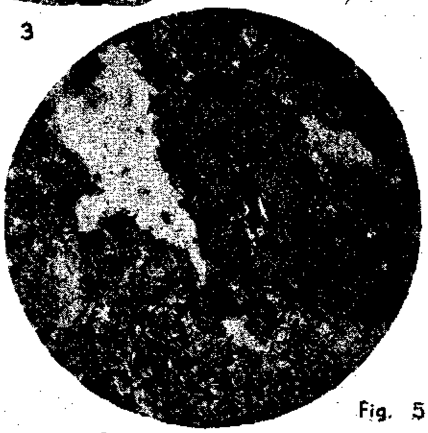

Fig. 5