
(Communicated at the meeting of June 28, 1924).

INTRODUCTION.

At the boundary between the Transvaal and the Orange Free State an approximately circular granite area (fig. 1) occurs, which

Fig. 1.
Geological sketch of a portion of the Vredefort Mountainland.
Scale ± 1 : 250,000.
Ga = Gatsrand or Pretoria Series \{ Transvaal System.
D = Dolomite Series
V. S. = Ventersdorp System.
W. S. = Witwatersrand System.
B. Gr. = Biotite Granite of Vredefort.
I, II and III = Bosses of Alkali Granite.
1—8 = Dykes of Nepheline Syenite.

The Black Reef Series, the lowermost division of the Transvaal System, between the Ventersdorp System and the dolomite, is very poorly developed in this area and has been omitted in the figures 1 and 2.

1) Shaler Memorial Series.
is intersected by the Vaal River. In this area the villages of Vredefort and Parys are situated; hence this granite is often called the granite of Vredefort or of Parys. The diameter of the area amounts to 41 km. The granite is surrounded on all sides by a girdle of sharp-crested hills composed of highly tilted or even overtilted sediments. Both the granite and the belt of sediments, which form together the Vredefort Mountainland are partly hidden from view by later deposits of Karroo age. This belt has a thickness of about 15000 m. and comprises from the granite in ascending order of succession the Witwatersrand System, the Ventersdorp System and the Transvaal System (Fig. 1 and 2). The uppermost portion of the last system

![Diagram](image)

**Fig. 2.**

Schematical section showing the geological position of the intrusions of alkali-granite in the girdle of tilted sediments around the Vredefort granite boss.

- Ga = Gatsrand Series
- D = Dolomite Series
- V = Ventersdorp System
- W = Witwatersrand System
- Vr. Gr. = Vredefort Granite
- A. G. = Alkali granite
- S. S. = Hinge plane

only occurs outside of the zone affected by the movements which caused the tilting of all the underlying beds. The exact age of this thick complex of very old rocks is not known; its age is at least pre-Devonian and may be pre-Cambrian.

Within this girdle of highly tilted sediments three comparatively small bosses of granite are intruded (Fig. 1). The largest occupies an area of about 5 square km. Two of these bosses are situated at the Vaal River in the Witwatersrand System on the farms Witbank, Koedoeslaagte and Schurvedraai; the third occurs in the dolomite,
the middle division of the Transvaal System, on the two farms Rietfontein.

The authors, one of whom was a member of the Shaler Memorial Expedition organised by Professor Daly of Harvard University, discovered in the year 1922 that these three bosses consist of alkali-granite, and that dykes of nepheline-syenite occur in or near these bosses, which are intimately connected with the alkali-granites.

**Alkali Granite.**

The alkali-granites in the three bosses are composed of medium- to fine-grained rocks and they show a great uniformity and marked petrographical family likeness. In specimens there is just enough difference to enable one to distinguish the rocks of any one boss from those of the others with certainty. In contradistinction to the much older biotite-granite or Vredefort-granite the alkali-granites nowhere show a streaky or gneissic structure, nor rapid alteration in grain.

The alkali-granites are light-coloured rather leucocratic acid rocks containing a fair amount of visible quartz, and this general character is reflected in the results of three analyses carried out by H. G. Weall, Government Laboratories, Johannesburg, which are given in the columns I, II and III of the table I on page 472.

During its intrusion the magma of these bosses made room for itself, partly by pushing aside the strata of the tilted sediments, partly by incorporating and assimilating material from the sediments.

The first phenomenon, the pushing aside of the pre-existing strata during their intrusion, can be best studied at the two bosses on the Vaal River (I and II in fig. 1) and is well marked by the disturbed position and the bending of the line of strike of the bars of hard quartzite near the bosses. A number of faults are combined with these disturbances and on Witbank, as well as on Koedoeslaagte and Schurvedraai, the intrusion of the two bosses of alkali-granite has given rise to very complicated tectonical relations, which have more or less affected the entire lower division of the Witwatersrand System.

The second phenomenon, the incorporation and assimilation of material from the sediments, is excellently illustrated at the first boss on Witbank and Koedoeslaagte, where a range of hills, consisting of gritty quartzites of the so-called Government Reef Series has been invaded and locally completely destroyed by the uptruding magma. In fact on both sides of the river the ridge, in which the strata of quartzite stand nearly vertical, is clean cut off against the
boss of alkali-granite. Its continuation can be followed for a small distance into the granite in the form of a rapidly fading trail of blocks of quartzite which appear to float in it. The selvedge of the alkali-granite against this quartzite is composed of a very acid hybrid rock full of xenoliths of quartzite. The first boss of alkali-granite appears to have been acidified throughout by the assimilation of all this quartzitic material, as is shown by the analysis made by H. G. Wealit, Government Laboratories, Johannesburg of an average sample of fresh rock from the centre of the boss, given in the first column of table I on page 472. The figure for silica is not less than 7 1/2% higher than in the rock of Koedoeslaagte which in all other respects is closely allied. The analysis of the latter is given in the second column of the same table.

On Rietfontein the intrusion of the alkali-granite of the third boss has probably also been accompanied both by pushing aside of the strata of dolomite and intercalated chert and by assimilation of material from these rocks. The unsatisfactory exposure of this boss, however, prohibited to study the mode of emplacement of this granite well.

Contact-metamorphism is well developed around the bosses of alkali-granite. This phenomenon, however, is not much in evidence around those bosses which are intruded in the strata of the Witwatersrand System, because these had before the intrusion of the alkali-granites already been affected by strong thermal metamorphism; in fact in these strata the pre-existing effects of metamorphism have only been intensified at the contact with the intrusive alkali-granite.

At Rietfontein, where the boss of alkali-granite is intruded in highly tilted strata, composed of alternating layers of dolomite and chert, which had not yet suffered from any previous alteration, the contact-metamorphism is intense. In places the dolomite is altered into a beautiful, medium-grained white marble, in other places where the metamorphism is stronger it is completely converted into a very tough kind of rock, composed chiefly of a felty aggregate of needles of tremolite.

In handspecimens the alkali-granites of the Vredefort area are less trachytic than is the case with the majority of such rocks elsewhere, especially with those of Scandinavia. It is only in the alkali-granite on the two farms Rietfontein that the felspar crystals by their shape and arrangement more or less determine the general habit of the rock. The alkali-granites of the two bosses on the Vaal River could macroscopically be taken very well for ordinary biotite- and amphibole-granites.
Mineralogical composition.

The two bosses on the Vaal River consist of arfvedsonite-soda-granite. The rock which composes the bulk of the boss on Witbank (1 on fig. 1) may be described here in some detail.

The leucocratic rock is chiefly composed of felspar and quartz. Microcline is the predominating felspar, generally showing lamellae after the two twin laws; where these are wanting or not seen, it is scarcely possible to distinguish the microcline from orthoclase, which may also be present in moderate proportions. Next to microcline albite is much in evidence; it forms both larger crystals with many twin lamellae and also aggregates of smaller crystals which as a rule only show a small number of twin lamellae or are simple twins. Parallel intergrowths of microcline and albite of different types are frequent; in the most common type the albite is found as a microperthitic intergrowth within the microcline; less often the latter forms microperthitic intergrowths in albite. Not seldom the albite is found in well-defined individuals in larger crystals of microcline; sometimes again this mineral is found in patches intergrown in larger crystals of albite. In several of the slides crystals of microcline or of microcline-microperthite are surrounded by a rim of albite and sometimes sinuous offshoots of the latter can be seen penetrating from the rim into the kernels of microcline. In other cases such kernels of microcline or microcline-microperthite are more or less cut up by a system of nearly parallel narrow streaks of albite. Quartz is present both in larger grains filling the interspaces left between the crystals of the other minerals, and as smaller grains forming aggregates together with small crystals of albite and microcline.

The femic minerals are all clustered together and thus appear macroscopically as dark specks fairly wide apart. Each cluster is composed mainly of arfvedsonite and aegyrine together with ore in small grains, and biotite in much varying quantities. Titanite occurs in all and zircon in the majority of the slides, confined to these clusters; apatite is present only here and there as long slender prisms.

Arfvedsonite takes the dominant place among the femic minerals. It occurs in the form of elongated prisms which show distinct faces of the prism (110), whereas in the direction of the vertical axis they are not well terminated. At both ends of this axis the crystals often run out into thin needles. Separate small sheaf-like clusters of needles and also separate needles of arfvedsonite are found scattered in small quantities, and are not seldom enclosed in the felspars.

The arfvedsonite shows the familiar strong dispersion of the
bisectrices very well and is characterized by its pleochroism:

a deep blue  
b deep grayish blue  
c gray

Examined in ordinary light the different sections offer an exquisite variety of tints, bright lavender blue being most conspicuous under such conditions.

Among the femic minerals aegyrine takes the second place; it occurs in grains of about the same size as those of the arfvedsonite, rarely showing well defined crystal outlines. Seen in ordinary light the aegyrine in certain sections is very conspicuous by its bright emerald-green colour. In polarised light the strong pleochroism is as follows:

a yellow to greenish yellow  
b bright green  
c deep green.

Arfvedsonite and aegyrine are often intergrown in the ordinary way, with the vertical axes and the orthopinacoidal planes parallel. These intergrowths are not seldom very intricate, a veritable mosaic being visible especially in sections parallel to the plane of symmetry.

Biotite is always present but as a rule only in small quantities. The crystals show very strong pleochroism: for rays swinging parallel to the cleavage dark olive-green to opaque, and for rays swinging at right angles to the cleavage golden-yellow.

Specks of ore are rarely wanting in any of the clusters, and also titanite in quite irregularly shaped grains is frequently found wedged in between the other femic minerals.

Plump short prisms of zircon bounded by the faces (111), (100), (010) and (110) are present in varying amounts. The crystals show a most perfect zonal structure.

The effects of the assimilation of great quantities of quartz are well seen in the mineralogical composition of the somewhat finer-grained acidified varieties of alkali-granite found in the selvedge of this boss at and near the contact with the lower quartzites of the Government Reef Series (compare page 468). There is a great increase in the amount of quartz in this selvedge rock, and numerous more or less corroded fragments of quartzite are incorporated in it as xenoliths. The felspars do not differ from those of other parts of the rock. Aegyrine and arfvedsonite are very scantily represented, whereas biotite is present in larger quantities
than in samples taken nearer the centre of the boss. In places the rock of the selvedge carries epidote in considerable quantities.

The alkali-granite of the second boss (II in fig. 1) on Schurvedraai and Koedoeslaagte differs in minor points only from that of the first boss. The main difference is that besides arfvedsonite also another amphibole of the riebeckite-type occurs, whereas aegyrine is little represented. On Schurvedraai in the north-western portion of the boss, however, the granite differs more from that of the first boss. Biotite is there the predominant felsic mineral. Arfvedsonite though present in fairly large quantities is always intergrown with and included in the larger flakes of biotite. Consequently in handspecimens biotite appears to be well-nigh the only felsic mineral. Calcite occurs in the majority of the clusters of felsic minerals of early consolidation in such a way that it more suggests a primary constituent than a product of decomposition.

The microscopic character of the alkali-granite of the third boss on Rietfontein (III in fig. 1) reveals certain features distinct from those of the rocks making up the other bosses. It is a soda-granite. The felspars form the bulk of the rock. Most of their crystals are somewhat tabular parallel to (010) and are twinned after the Carlsbad law and these twins by their arrangement determine the character of the rock, by which it is individualized from the alkali-granites of the other bosses. Each of the components of the Carlsbad twins consist of parallel intergrowths of orthoclase, microcline, microcline-microperthite and albite, which show a great variability. The rims of the crystals generally consist of albite. The components of the Carlsbad twins as a rule meet along an irregular composition plane.

Besides felspar, quartz, amphibole, biotite, zircon and ore are always present, and pyroxene and titanite are observed here and there.

The felsic minerals are clustered together. The amphibole is idiomorphic and well crystallized, the main crystalform being a somewhat stout prism. Twins after the orthopinacoid are of common occurrence. The pleochroism is strong:

- a light yellowish green
- b deep olive-green
- c deep olive-green with a shade of blue.

The amphibole belongs to a type between common hornblende and arfvedsonite. Pyroxene is wanting in many of the slides and in others appears to represent a type between aegyrine and diopside.

The biotite, which occurs in good-sized flakes, is a strongly pleochroic lepidomelane. The colours shown for rays swinging at
right angles to the cleavage are golden yellow to brownish yellow, and for these swinging parallel to the cleavage, deep brown to opaque; smaller flakes of biotite are frequently enclosed in the amphibole and these form not seldom parallel intergrowths with their host. Ore, probably magnetite, as black specks is found scattered in the rock and also enclosed both in the crystals of biotite and of amphibole. Zircon here and there joins the clusters of feric minerals and so does sphene. Quartz which is much in evidence fills the interspaces between the other minerals of the rock.

Chemical composition.

The chemical composition of the alkali-granites of the Vredefort Mountainland and also of some allied rocks, is shown in the following table.

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
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VII. Arfvedsonite-granite, Ampasibitika, Madagascar. Analyst M. F. Pisani.

The analysed rocks of the Vredefort area all represent types in which amphibole is the dominant felsic mineral. They are soda-granites, soda occurring much in excess over potash. Iron is present in small quantities only, and magnesia and lime in very small quantities.

Such leucocratic soda-granites are uncommon rocks. They have a great similarity to the soda-granites described by Brögger 1) which occur intimately connected with the Nordmarkites in the Christiania area. They are further closely related to the arfvedsonite-granite of Ilimausak (IV in table) and the soda-granite of Iviangusat, (V in table) both described by Usning 2) and the soda-granite of Hougnatten (VI in table), described by Brögger 3). The arfvedsonite-granite of Ampasibitika in Madagascar (VII in table) described by Lacroix 4) is much richer in iron than the soda-granites of the Vredefort-area.

The abundance of microcline among the felspars approaches these rocks also to the riebeckite-soda-granite of San Peter's Dome, Colorado, described by Lacroix 5).

Nepheline Syenite.

Dykes of nepheline-syenite occur in intimate connection with the bosses of alkali-granite described in the previous pages.

4) A. Lacroix, Matériaux pour la minéralogie de Madagascar. Nouvelles Archives du Muséum (4) I, p. 82, Paris 1902.

The dykes of nepheline-syenite either cut through the bosses of alkali-granite, whence they may extend into the surrounding sedimentary strata, as is the case at the second boss on Koedoeslaagte and the boss on Rietfontein, or they may occur in the immediate vicinity of those bosses, as is the case with the dyke between the bosses I and II both on Witbank (Locality 3) and on Koedoeslaagte (Locality 4). The dykes have a varying width, in the case of the Canadites not exceeding 16 m. (Dyke Locality 7 on Koedoeslaagte). They stand vertical, as far as this could be proved with certainty, and their strike corresponds on the average (not on Rietfontein) with the general strike of the invaded sediments. The dykes of nepheline-syenite though genetically connected with the bosses of alkali-granite are younger than those and must have been injected after the emplacement of the masses of alkali-granite; consequently they are also younger than the phenomenon of up-doming of the Vredefort granite boss. They are, just as well as the alkali-granites, much altered by pressure and crushed and consequently in many places converted into mylonites and ultimately in pseudo-tachylytes or flinty crush-rocks. Numerous veins composed of these latter rocks cut through the alkali rocks in various directions; on Plate I in fig. 1 such a vein is shown occurring is a canadite of Locality 5 (see fig. 1).

Just as in the alkali-granites two groups could be distinguished, on the one hand the typical arfvedsonite-soda-granites of the bosses I and II and on the other hand the soda-granite of boss III, so the nepheline-syenites connected with the first two bosses are as a group distinct from those which are found connected with the third boss.

The dykes of the first group on Witbank, Koedoeslaagte and Schurvedraai notwithstanding considerable variety in external appearance all consist of Canadites, whereas the dyke on Rietfontein must be classed amongst the Foyaites.

The Canadites at the Vaal River.

Although the nepheline-syenites of the different dykes on Witbank, Schurvedraai and Koedoeslaagte show in many places rapid variations of grain, structure and mineralogical composition yet they all have a strong family likeness. They belong to the group of the Canadites, defined by QUENSEL and SHAND as nepheline-syenites with nepheline and albite as principal salic minerals. QUENSEL \(^1\) first proposed the

\(^1\) P. QUENSEL, The alkaline rocks of Almunge, Bull. Geol. Inst. of Upsala XII, p. 177, Upsala 1914.
name Canadite for such rocks, but in defining the group he emphasizes the abundance of felsic minerals, whereas Shand calls the canadites „rather leucocratic rocks“. In this respect the rocks of the Witbank area best correspond to the type as it is defined by Shand 1), for on the average they are decidedly leucocratic rocks.

The general characteristics given by Adams and Barlow 2) of the nepheline-syenites of the Haliburton and Bancroft areas on pp. 228—232 of their memoir can to a great extent be applied to the majority of the nepheline-syenites of the Witbank area. The canadites of this area, however, do not contain calcite and in places are free from aegyrine and rich in lepidomelane, when they correspond to the litchfieldite-type, as described by Bailey 3).

The mineralogical composition is varying, but all the varieties observed pass one into the other, generally rather abruptly. Although each of the dykes shows one or more characteristics of its own, by which it can be singled out, such characteristics mostly apply to the way in which the different varieties of the canadite-type are represented.

The rocks are usually massive, but in some places they possess a more or less perfect banded or even schistose structure reminding of that of lujaurites, (Pl. I, fig. 2). Massive and banded streaks may alternate repeatedly. They vary in texture from fine-to coarse-grained or even porphyritic (Pl. I fig. 1) while in pegmatitic phases nepheline and anorthoclase occur as individuals as much as 20 cm. in diameter.

The coarse-grained and porphyritic phases may occur as more or less parallel streaks intercalated in finer-grained rock, especially where the latter is more or less banded (localities 4 and 7), in other places the pegmatite may occur in irregular patches (localities 1, 4 and 7) and also the rock may present quite a massive development over a good distance, which at once is interrupted by the appearence of clusters or phenocrysts of large dimensions (locality 3).

The rocks, as a rule, are quite fresh and unaltered and only show a thin weathered coating.

Mineralogical composition.

The canadites of Witbank and Koedoeslaagte are made up essen-

2) F. D. Adams en A. E. Barlow, Geology of the Haliburton and Bancroft areas, Geol. Survey Canada, Memoir Nr. 6, Ottawa 1910.
tially of albite and closely allied plagioclases, anorthoclase, nepheline, cancrinite, aegyrine and biotite; also microcline, orthoclase, amphibole, titanite, apatite and magnetite enter into the composition of the rocks.

The order of crystallization is not quite definite. Magnetite, apatite and sphene were the first minerals to crystallize, and after those aegyrine and biotite were formed; albite and allied felspars came next in order; nepheline as a rule is crystallized somewhat later than the felspars and cancrinite is the last mineral to crystallize.

Numerous exceptions, however, have been observed to this general order of crystallization; thus nepheline may be found included in felspar, and lepidomelane may poikilitically embrace such salic minerals as albite and nepheline.

Among the minerals of which the canadites are composed rank as main constituents felspars, nepheline, cancrinite, aegyrine, biotite; and as accessory constituents amphibole, muscovite, titanite, apatite and magnetite.

Main constituents. Felspars. The felspars as a rule form the bulk of the rocks, although locally nepheline may preponderate over felspar. The crystals are fresh and transparent even at a small distance from the weathered surface.

Albite, with allied acid plagioclases, is by far the ruling felspar in the massive portions of the rocks. The crystals of albite are more or less tabular after the brachypinacoid; the smaller crystals are as a rule simply twinned, the larger ones show repeated twinning and then the lamellae are often so close together, that they become difficult to distinguish. The anorthoclase occurs in rather large more irregular plates with either no albite lamellation or only a very shadowy indication, or with a patchy form of extinction resembling quartz with undulatory extinction. Anorthoclase is the dominant if not the only felspar amongst the phenocrysts. Its crystals often attain large dimensions, and diameters of about 15 cm. are not rare. The dyke 3 (see Fig. 1) carries such phenocrysts in abundance.

Both in the massive portions and in the groundmass of the porphyritic portions of the rock anorthoclase plays an unimportant role compared with albite. In its somewhat tabular crystals the albite lamellation is only faintly indicated. Microperthite is always present intergrown with albite but never as abundant as in the soda-granites. Microcline is erratic, wanting in many of the rocks and rather abundant in some of them. Orthoclase is rarely observed with certainty and is doubtless a subordinate mineral in these rocks.

Nepheline. The nepheline is quite fresh; under the microscope it is colourless and transparent. Macroscopically on fresh fractures of
the rock it is recognisable by its greasy lustre; its colour is gray to faint greenish. In the porphyritic varieties nepheline occurs both in the groundmass and as phenocrysts (Pl. I, fig. 1). The latter have the shape of short plump prisms, bounded by the faces of the basal pinacoid and the prism (1010); they may attain a diameter of about 10 cm. as e.g. in the dyke at locality 4.

On the weathered surface of the rock the crystals of nepheline by their relatively rapid weathering are invariably indicated and easily discernible by pits or depressions surrounded by rims composed of minerals such as felspar or aegyrine. The shape of these pits or depressions is either hexagonal or quadratic. The surface of the nepheline in these depressions is often shagreened and coated by a thin film of a bluish gray enamel.

The crystals of nepheline in the groundmass may be idiomorphic and then they often show a perfect zonal arrangement of their inclusions which as a rule chiefly consist of needles of aegyrine. The figure 4 in Pl. I represents a section of a crystal of nepheline cut at right angles to the optical axis showing this zonal arrangement. In other rocks the crystals of nepheline are hypidiomorphic and are bounded by crystal faces in the zone of the prism only, but bluntly terminated in the direction of the optical axis. As a rule such crystals have fairly large dimensions and the enclosed needles of aegyrine are then arranged exclusively parallel to the optical axis. In other rocks again the nepheline is perfectly allotriomorphic and is found wedged in between the crystals of felspar in a similar way as quartz in granites. Besides aegyrine all the other minerals, cancrinite excepted, may be found enclosed in nepheline, but never in abundance.

Cancrinite. This mineral although present in notable quantities in several nepheline-syenites of the Witbank area can only be distinguished by the aid of the microscope. It occurs in irregular perfectly allotriomorphic grains of about the same size as those of albite and nepheline in the non-porphyritic portions of the rocks. It also occurs as thin beady rims surrounding crystals of felspar or nepheline, and again it may enter into cracks or fissures, especially in felspars. This may explain, why it is sometimes found apparently enclosed in felspar.

Under the microscope the cancrinite is transparent and colourless, free from inclusions, quite fresh and consequently free from alteration products. It always occurs somewhat concentrated in streaks and

1) A similar coating is described by Adams and Barlow, l.c. p. 236.
patches and in some of the dykes streaks are found, where the cancrinite occurs in quantities great enough to make it one of the dominant minerals. Where this occurs the name cancrinite-canadite would be appropriate. An exceptionally fine variety of this type is found in the banded portion of the big dyke (locality 7 in fig. 1) on Koedoeslaagte, which is a granular rock made of grains of about equal dimensions of albite, nepheline and cancrinite without femic minerals (Pl. I, fig. 3). Albite is the preponderating mineral, next comes cancrinite and nepheline takes the third place. Nepheline is scarce or even wanting in some portions of this rock. This cancrinite-canadite sometimes contains as the sole femic constituent lepidomelane in such quantities that the name cancrinite-litchfieldite would be justified.

The cancrinite is a primary constituent, and even where it occurs in very small grains, arranged as beady rims bordering such minerals as nepheline and felspar it does not make the impression of a secondary element.

Aegyrine and biotite. These minerals are never met with in equal quantities, either one or the other dominating. In much of the occurrences pyroxene is the ruling femic constituent. The pyroxene as to its optical characteristics conforms to aegyrine but the pleochroism is much less strong than is usually observed in aegyrine. In the kernels of the crystals the pleochroism, although faint is well discernable

\[ \begin{align*}
    a & \text{ bright green} \\
    b & \text{ light green} \\
    c & \text{ pale yellow}
\end{align*} \]

whereas the rims show hardly any pleochroism. The pyroxene occurs chiefly in the form of long and slender prisms which may take the shape of needles; not rarely, however, the prisms are stouter and less elongated, and sometimes they are more or less tabular after the orthopinacoid.

Biotite is an important mineral only in those varieties, which belong to the litchfieldite-type chiefly found in the dyke at locality 7. This rock carries biotite in abundance both in the porphyritic portions as flakes which may attain a diameter of 14 cm., and in smaller crystals scattered through the rock. The phenocrysts show on their cleavage planes the traces of the three systems of gliding planes well. The mineral is a lepidomelane with very strong pleochroism from straw-yellow to opaque. It not rarely poikilitically encloses crystals and grains of all the other minerals, with the exception of the cancrinite.
Accessory constituents. Hornblende. This mineral is rare and found in notable quantities only in a dyke on Koedoeslaagte (Locality 6) as small prisms together with and in between prisms of aegyrite. Its pleochroism is strong

\begin{itemize}
\item [a] deep bluish green to opaque
\item [b] dark olive-green
\item [c] yellowish green.
\end{itemize}

This amphibole shows the optical properties of arfvedsonite, only the pleochroism does not conform to that of arfvedsonite.

Muscovite. This mica is exclusively found in some rocks of the litchfieldite type, which are rich in cancrinite. It is possible, but not certain that this muscovite is a product of decomposition.

Titanite. This mineral is on the average well represented amongst the accessory minerals, in microscopic crystals only. It is erratic in its occurrence, sometimes much in evidence and sometimes very scarce or absent. It is generally found in irregular grains and with aegyrite.

Apatite is rare and only observed in some of the dykes. It is well crystallized either in slender or plump prisms, only visible under the microscope.

Magnetite. This mineral is always present in specks or more frequently in well-defined microscopical crystals with triangular, quadratic or hexagonal outlines. Sometimes the crystals are scattered all through the rock but more often they are clustered together with or enclosed in flakes of lepidomelane or aegyrite.

Zircon is present in the majority of the rocks. The colour of this mineral is yellowish and it is conspicuous by the beautiful zonar structure of the crystals, which are bounded by the faces of prism and pyramid.

Chemical composition.

The chemical composition of the canadites on the Vaal River is given in the columns I and II of the following table.


### TABLE 2.

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
</tr>
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<tbody>
<tr>
<td>SiO₂</td>
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<td>48.60</td>
<td>51.58</td>
<td>60.39</td>
<td>57.78</td>
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<td>TiO₂</td>
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<td>—</td>
<td>1.83</td>
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<tr>
<td>ZrO₂</td>
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<td>nil</td>
<td>trace</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<tr>
<td>Al₂O₃</td>
<td>22.3</td>
<td>20.5</td>
<td>19.89</td>
<td>19.40</td>
<td>22.57</td>
<td>15.45</td>
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<td>Fe₂O₃</td>
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<td>3.5</td>
<td>2.97</td>
<td>4.26</td>
<td>0.42</td>
<td>3.06</td>
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<td>FeO</td>
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<td>5.76</td>
<td>5.25</td>
<td>2.26</td>
<td>3.11</td>
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<td>MnO</td>
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<td>trace</td>
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<td>0.20</td>
<td>0.08</td>
<td>0.98</td>
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<td>2.75</td>
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<td>3.64</td>
<td>0.32</td>
<td>1.72</td>
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<td>MgO</td>
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<td>0.49</td>
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<td>1.13</td>
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<tr>
<td>Na₂O</td>
<td>9.1</td>
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<td>8.74</td>
<td>7.49</td>
<td>8.44</td>
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</tr>
<tr>
<td>K₂O</td>
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<td>4.23</td>
<td>4.77</td>
<td>2.89</td>
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<tr>
<td>P₂O₅</td>
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<td>nil</td>
<td>0.56</td>
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<td>—</td>
<td>—</td>
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<tr>
<td>CO₂</td>
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<td>nil</td>
<td>1.10</td>
<td>1.53</td>
<td>trace</td>
<td>—</td>
</tr>
<tr>
<td>H₂O, at 110°</td>
<td>0.2</td>
<td>0.15</td>
<td>0.21</td>
<td>—</td>
<td>—</td>
<td>0.94</td>
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<td>H₂O, loss on ignition</td>
<td>0.45</td>
<td>0.5</td>
<td>1.73</td>
<td>1.02</td>
<td>0.57</td>
<td>0.94</td>
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<tr>
<td></td>
<td>99.8</td>
<td>99.95</td>
<td>99.27</td>
<td>99.59</td>
<td>99.95</td>
<td>99.92</td>
</tr>
</tbody>
</table>

1) Including SO₂ 0.10; F 0.06; S 0.01; BaO 0.05; Ce₂O₃ 0.59.

IV. Nepheline-syenite (canadite), Monmouth Co., Ontario, Canada. Analyst M. F. Connor.


VI. Nepheline-syenite (arfvedsonite-canadite), Tuoljubucht, Finland. Analyst H. Bergell.

The great preponderance of soda over potash, combined with the fairly low percentage of calcium, explains the scarcity of orthoclase and the abundance of albite, and of plagioclase poor in anorthite. The absence of carbon-dioxide in the analyses, notwithstanding the common occurrence of cancrinite in these canadites, can only be explained by the fact that this mineral is somewhat erratic in its occurrence. The analyses are evidently made from fragments in which cancrinite is absent or nearly so.

Comparing the analyses of these rocks with those of other localities, besides the above mentioned strong preponderance of soda.
over potash, the relatively high percentage of silica and the scarcity of iron also attract attention. The latter features explain the pronounced leucocratic character of the rocks.

The chemical composition has a similarity, but not a close one, to those of the canadites of Almunge and of Monmouth County which served Quensel \(^1\) as types in distinguishing his special group of canadites. The composition of these rocks is given for comparison in columns III and IV. The chemical composition of the variety of canadite containing lepidomelane as the sole femic constituent, to which Bayley \(^2\) has given the name *litchfieldite* is added in column V.

The canadites of the Vaal River contain more silica, and less iron and calcium than the canadites of Almunge and Monmouth County. One has, however, to take into account that in the case of the Almunge-rock only the dark-coloured commonest type is analysed.

The Almunge-rock, however, shows a great diversity of types, and the dark-coloured varieties, rich in femic minerals, may grade rapidly into white or pink rocks devoid of dark minerals; these latter leucocratic varieties are not analysed. From the descriptions it appears that in the Almunge-district and in Monmouth Co. melanocratic rocks greatly preponderate, whereas in the Witbank area by far the bulk of the nepheline-syenites is decidedly leucocratic, the melanocratic varieties being restricted to a few bands and streaks only.

Thus the nepheline-syenites of the Witbank area appear to represent one of the purest leucocratic types, hitherto found, of the canadite group, i.e. of a nepheline-syenite composed chiefly of nepheline and albite. As far as can be judged from the description and the analysis the nepheline-syenite of Tuolj-bucht on the peninsula of Kola \(^3\) offers another excellent example of a leucocratic canadite. This rock is poorer in nepheline than the canadites of the Witbank area and contains as femic minerals arfvedsonite and some aegyrine. Its chemical composition is given in column VI.

Amongst the nepheline-syenites found elsewhere in Transvaal, in the Bushveld, no canadites have been recorded.

**The Foyaite on Rietfontein.**

The foyaite on the farms Rietfontein N°. 555 and N°. 664 occurs

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\(^1\) P. Quensel, l.c. p. 180.

\(^2\) W. S. Bayley, l.c. p. 241.

\(^3\) W. Ramsay und V. Hackman, Das Nephelinsyenitgebiet auf der Halbinsel Kola I, Fennia II, p. 139, 1894.
as a powerful dyke 1) cutting through the boss of alkali-granite described above and the surrounding dolomite. Its strike is N8E., its dip about 90°. The thickness is 28 metres. It can be followed for about 2 km. from near the boundary between Rietfontein 555 and 664 in a north-northeasterly direction to the central portion of the first farm along a series of outcrops well marked by accumulations of large rounded blocks.

The dyke of weathered foyaite which occurs 6 k.m. more to the South on Buffelshoek probably is the continuation of this dyke on Rietfontein.

The foyaite is a pale-pink medium-grained slightly porphyritic rock. The handspecimens show pale-pink orthoclase, often white by decomposition and many irregular waxy-grey to dark-red patches of nepheline. The dark minerals aegyrine, aegyrine-diopside and biotite are scattered freely through the rock in small irregular clusters.

Mineralogical composition.

Thin sections show the following minerals in order of abundance: orthoclase, nepheline, pyroxene, and biotite.

Orthoclase. This is the chief component; some crystals are larger than the others and appear as phenocrysts. They are all tabular after (010). The phenocrysts are perfectly euhedral and reach a length of 15 mm, parallel to the c-axis, whereas the thickness of the platy crystals in the direction of the b-axis does not exceed 1 mm. Carlsbad twins are frequent. Both the phenocrysts and the smaller crystals of orthoclase have their rims generally composed of albite, while is the kernels the orthoclase is intergrown in small quantities with microperthite and albite. The orthoclase is more or less decomposed and cloudy but the albite is quite transparent and fresh.

Nepheline. Under the microscope the nepheline is more idiomorphic than the handspecimens suggest. Although the crystals appear to be wedged in between the tabular felspars they are often euhedral and bounded by faces of the prism and of the basal pinacoid. The bulk of the nepheline is fresh and transparent, though in part turbid with the properties of elaeolite; inclusions are few.

Pyroxene. The pyroxenes are represented by diopside and aegyrine.

1) This dyke has been discovered and described as a dyke of elaeolite-syenite by E. T. MELLOR in: The geology of the central portion of the Potchefstroom District, Report of the Geol. Survey for the year 1907, p. 26. Pretoria, 1908.
The former mineral occurs in plump prisms bounded by the faces of the two pinacoids (100) and (010) truncated by small faces of the prism (110). The aegyrine occurs in well defined tabular crystals flattened parallel to the orthopinacoid. In the vertical zone the crystals are bounded by the faces of the orthopinacoid and the prism (110). The diopside shows a maximum angle of extinction with the axis c of 42° in sections parallel to the plane of symmetry; those of aegyrine in corresponding sections have a nearly straight extinction.

In the crystals of diopside the pleochroism is weak:

- a yellowish grey
- b greenish grey
- c greenish to bluish grey.

In the crystals of aegyrine the pleochroism is strong:

- a dark bluish green
- b emerald green
- c greenish yellow.

The crystals of diopside often have broad rims composed of aegyrine, the two minerals forming together parallel intergrowths.

Biotite is always clustered together with the other fermen constituents. It is a dark brown variety showing pleochroism from orange-brown to opaque. Magnetite is always found in the rock, but apatite is very scarce, and sphene has not been observed.

The order of crystallization is not well marked in these rocks and the separation of all the component minerals appears to have continued up to the moment of final consolidation. Although the felspar is more euhedral than any of the other minerals yet in places its tabular crystals are influenced in their position by pre-existing faces of nepheline. Pyroxene is largely idiomorphic and yet felspar laths penetrate into pyroxene and biotite, and locally the spots where the fermen minerals are clustered together then show an ophitic structure. Biotite is in places found with good crystal faces, but in many of the clusters it embraces poikilitically all the other constituents.

**Chemical composition.**

The nepheline-syenite of Rietfontein belongs to the group of the foyaites.

Its chemical composition is given in column I of the following table.
### TABLE 3.

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
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<tbody>
<tr>
<td>SiO₂</td>
<td>55.3</td>
<td>56.12</td>
<td>56.44</td>
</tr>
<tr>
<td>TiO₂</td>
<td>0.8</td>
<td>0.46</td>
<td>1.16</td>
</tr>
<tr>
<td>ZrO₂</td>
<td>0.15</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>18.25</td>
<td>19.62</td>
<td>15.54</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>3.55</td>
<td>2.32</td>
<td>3.27</td>
</tr>
<tr>
<td>FeO</td>
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<td>0.90</td>
<td>3.67</td>
</tr>
<tr>
<td>MnO</td>
<td>0.6</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>CaO</td>
<td>3.15</td>
<td>2.07</td>
<td>4.16</td>
</tr>
<tr>
<td>MgO</td>
<td>0.55</td>
<td>0.13</td>
<td>1.73</td>
</tr>
<tr>
<td>Na₂O</td>
<td>5.6</td>
<td>9.50</td>
<td>5.81</td>
</tr>
<tr>
<td>K₂O</td>
<td>4.65</td>
<td>4.17</td>
<td>4.27</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>0.15</td>
<td>—</td>
<td>0.83</td>
</tr>
<tr>
<td>CO₂</td>
<td>nil</td>
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<td>0.97</td>
</tr>
<tr>
<td>H₂O, at 110° C.</td>
<td>0.6</td>
<td>—</td>
<td>0.44</td>
</tr>
<tr>
<td>H₂O, loss on ignition</td>
<td>3.00</td>
<td>3.50</td>
<td>2.06</td>
</tr>
</tbody>
</table>

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>99.80</td>
<td>100.39</td>
</tr>
</tbody>
</table>


In the columns II and III the composition of two chemically analogous nepheline-syenites is given, viz. a Foyaite of Leeuwfontein described by Brouwer¹) and an analcite-syenite of Mauchline described by Tyrrell ²).

#### Relationship between the Alkali-Granites and the Nepheline-Syenites.

A close analogy in chemical composition exists between the alkini-


granite and the nepheline-syenite of the dykes, which are connected with the bosses of alkali-granite. This analogy becomes obvious as soon as one applies the so-called triangular method of projection of Osann \(^1\), which makes independent of the content of silica. The projection of all the analyses, made of the alkali-granites and nepheline-syenites of the Vredefort Montainland, with exception of the foyaite of Rietfontein, lie closely together in Osann’s triangle and partly even coincide. The somewhat distant position of the foyaite of Rietfontein is caused by the fairly great amount of iron contained in that rock. It is allowed to infer from these facts, that the magma, which has been injected in the dykes of nepheline-syenite, probably has been a part of the magma of the alkali-granite which had lost a portion of its silica.

The authors intend to describe these alkaline rocks more in detail in a memoir on the Vredefort Mountainland, and then to discuss also briefly their probable mode of origin in connection with other rocks in that area. They will confine themselves now to call the attention to the fact that the soda-granite and the foyaite on Rietfontein have been intruded into rocks of the dolomite formation. Daly’s \(^2\) theory on the genesis of alkaline rocks would be readily acceptable here, as soon as one admits, that the acid magma rich in soda — probably a soda-rich and acid differentiate or residue of a much larger hidden magma of more basic composition — which has been intruded into the dolomite and is found now solidified in the boss of soda-granite, has absorbed in the depth a certain quantity of the dolomitic rock, causing it to become locally desilicated. From these desilicated portions then originated the dykes of foyaite.

A similar explanation would appear to be untenable in the case of the nepheline-syenites on the Vaal River, because these are injected in the Witwatersrand System, of which no limestones or dolomites form part. Yet one has to take into account, that the tilting and overtilting of the belt of sediments round the Vredefort granite-mass has been accompanied by strong tectonic disturbances and dislocations. It is not quite impossible that along the hinge plane SS (fig. 2) disturbances caused by faulting and shearing were great enough to allow masses derived from the dolomite to come

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1) A. Osann, Versuch einer chemischen Classification der Eruptivgesteine T. M. P. M. Bd. XIX, p. 351, 1900.
in contact with and to get incorporated into the ascending magma. It certainly would be difficult to explain the presence of notable quantities of cancrinite in the nepheline-syenites on the Vaal River, in case the possibility of rocks containing carbonates being absorbed in the alkaline magma were considered to be absolutely non-existent.

The authors feel greatly indebted to Mr. H. J. Wraill of the Government Laboratories at Johannesburg, who made the analyses of the rocks and to Dr. P. Krüzinga at Delft, who carefully prepared the microphotographs.

Delft, June 1924. Geological Laboratory.

Fig. 1.
Porphyritic type of canadite, cut by a vein of pseudo-tachylite; n. nepheline, enclosing crystals of albite. Koedoeslaagte, dyke 5 in fig. 1. Magn. $25 \times . + \text{ nicols.}$

Fig. 2.
Canadite with parallel arrangement of crystals of a. albite, ae. aegyrine, n. nepheline. Koedoeslaagte, dyke 7 in fig. 1. Magn. $42 \times . + \text{ nicols.}$

Fig. 3.
Cancrinite-canadite, c. cancrrinite, n. nepheline. Koedoeslaagte, dyke 7 in fig. 1. Magn. $70 \times . + \text{ nicols.}$

Fig. 4.
Section of a crystal of nepheline parallel to the basal pinacoid; needles of aegyine arranged parallel to the faces of the prism. Koedoeslaagte, dyke 4 in fig. 1. Magn. $148 \times$, ordinary light.