LEUCITE, POTASH NEPHELINE, AND CLINOPYROXENE FROM VOLCANIC LAVAS FROM SOUTHWESTERN UGANDA AND ADJOINING BELGIAN CONGO

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Chemical analyses by H. B. Wiik

ABSTRACT. Four specimens of rocks from the young volcanic belt of southwestern Uganda and adjoining Belgian Congo have been investigated. Leucite, nepheline, and clinopyroxene (diopside), extracted from the rocks by means of heavy liquids, have been analyzed chemically. Optical properties are also given. Chemical compositions of the analyzed minerals are discussed.

INTRODUCTION

A feature in the geology of the Western Rift of Equatorial East Africa is the occurrence of a series of young volcanic lavas and near-surface plugs and sheets accompanied by tuffs and other ejectamenta along a belt extending from the Fort Portal area northeast of Mt. Ruwenzori in southwestern Uganda to Lake Kivu in Belgian Congo. The petrology of these lavas and pyroclasts has been described in a series of papers by Holmes and Harwood (1932, 1937), Holmes (1942), Combe and Holmes (1945), Friedlaender (1949), Holmes (1950), and others. These volcanics exhibit a rather unique series of undersaturated alkaline rocks from extremely potassic to comparatively sodic. As has been specially emphasized by Friedlaender (1949), the soda-to-potash ratio shows certain regional variations. On the other hand, Holmes (1950) has produced evidence indicating that this ratio varies considerably also within a single flow, the nose of a flow sometimes being richer in potash then the lava nearer its source.

The general undersaturated character and the relatively high potash content are reflected in the mineralogical composition of the rocks for which new rock names are introduced. The potash-rich rock suite of the area has been classified by Holmes according to a triangular scheme in which the following rock species with their critical minerals serve as end members:

Ugandite: leucite, augite, olivine.
Mafurite: kalsilite, augite, olivine.
Katungite: melilite, olivine, potash-rich glass.
Between these rocks, all intermediate types occur. Olivine is mostly very abundant. Potash ankaratrites, conspicuously rich in augite and relatively poor in olivine, represent a parallel with the ugandite-mafurite series. The potash ankaratrites vary from typical leucite-ankaratrite with predominantly leucite among the leucocratic constituents to kalsilite-ankaratrite in which kalsilite preponderates over leucite. The intermediate types of potash ankaratrites contain very potash-rich nepheline in association with leucite. Feldspars and amphiboles are not essential constituents of these rocks.

Most of the lavas in question are very fine grained, only larger phenocrysts of olivine, augite, and occasional melilite being commonly detectable with the naked eye. In rarer instances, phenocrysts of leucite, and, exceptionally, nepheline aggregates and phenocrysts are of sufficient size to be identified in hand specimen. The leucocratic minerals usually occur only in the ground mass. It is therefore understood that the variation of the chemical composition of leucite and nepheline in these rocks has been very little investigated. Not only large phenocrysts should be studied but also nephelines and leucites of the fine-grained ground mass. The ground mass nepheline and leucite certainly are not easily extracted from the rocks for chemical analysis. However, the authors had the privilege of receiving five specimens specially selected for the purpose by Professor Arthur Holmes of Edinburgh from his excellent collection of the Uganda volcanic rocks. Four of these rocks have been subjected to mineral separation and subsequent chemical analysis, the results of which are presented below.

**Specimens Investigated**

The rock specimens were crushed and ground down to a grain size of 10-20 microns. The powdered material was centrifuged several times in Clerici's solution using relatively high speed on the centrifuge. In this way, leucite and nepheline could be separated out of the fairly fine-grained rock material. The purity of the final material to be analyzed was tested under the microscope by counting a large number of grains. On doing the grain counting, it is important to immerse the material in a liquid that shows approximately the same index of refraction as the mineral. The mineral to be tested thus almost disappears and the impurities, usually having different
index, become easily detectable. The analyzed materials of leucite and nepheline were sent to Dr. F. A. Bannister, of the British Museum, London, for powder pattern test. According to a personal communication received from him, no foreign lines in any of the separated fractions of leucite and nepheline were detected. The specimens investigated are described below.

**Specimen C. 9956.** Aggregates of phenocrysts of potash nepheline and leucite in a dark gray ground mass. Southern slope of Mt. Ninagongo at a height of ca. 2900 meters, Lake Kivu National Park Area, Belgian Congo.

The aggregates of phenocrysts are fairly large, up to 5 mm. or more in diameter. They consist of well developed idiomorphic crystals of potash nepheline and leucite with some additional augite. Separate phenocrysts of these minerals and melilite are scattered in the ground mass between the large aggregates. Some few phenocrysts of opaque ore also occur. The vesicular ground mass, partly glassy, contains the same minerals as tiny crystals. No sign of any flow structure was detectable in the specimen. For mineral separation, 113 g. of the rock were available.

The potash nepheline of the aggregates is clear and shows no zoning $\epsilon = 1.539, \omega = 1.543$. The product of separation, amounting to 5.5 g., was analyzed chemically. The analysis is given in table 1. Grain counting of the analyzed material gave the following result:

<table>
<thead>
<tr>
<th>Description</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1952 water clear nepheline grains</td>
<td>91.4</td>
</tr>
<tr>
<td>182 nepheline grains with some inclusions</td>
<td>8.5</td>
</tr>
<tr>
<td>2 leucite grains</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Assuming that the grains with inclusions contain 5 per cent impurities on the average, the total amount of impurities in the analyzed fraction will be ca. 0.6 per cent. This figure is considered a maximum value.

The very high purity of the analyzed material suggests that the content of ferric and ferrous iron and of lime is not caused by impurities but belongs to the nepheline itself. The analysis shows a slight deficiency in alcalis with respect to silica.

The very high potash content of the nepheline C. 9956 from Mt. Ninagongo is specially noteworthy. The weight per cent of potash is even higher than that of soda, yet the mineral is
nepheline, and not kalsilite (X-ray test; personal communication from Dr. Bannister). The molecular soda-to-potash ratio amounts to \( \text{Na}: \text{K} = 57.4: 42.6 \). Thus, the nepheline from Mt. Ninagongo represents the most potash-rich nepheline analyzed so far. As compared with the data given by Bannister and Hey (1931), the refractive indices of this nepheline are relatively low. Evidently the refractive indices of nephelines cannot be simply predicted on the basis of the soda-to-potash ratio and vice versa.

The leucite of the aggregates is almost free from inclusions, beautifully twinned, and shows no rims around the crystals. \( n = 1.510 \). The amount of the mineral in the specimen is considerably smaller than that of nepheline. Accordingly, the fraction extracted out of the rock was too small (0.49) to allow a complete chemical analysis to be made. No grains of foreign minerals were detected in the analyzed material. An alkali determination on leucite gave:

\[
\begin{align*}
\text{Na}_2\text{O} & \quad 0.98 \text{ per cent} \\
\text{K}_2\text{O} & \quad 19.44
\end{align*}
\]

As might be expected from the chemical composition of the nepheline (table 1) coexistent with this leucite, the soda content of the leucite is relatively low, as compared with leucites from other petrographic provinces.

*Specimen C. 2912 (=C. 2911).* Mikenite (leucite of Mikeno
Clinopyroxene from S.W. Uganda and Belgian Congo

type). Flow from Mt. Mikenno, 1 mile S. of Rulenga Mission, Lake Kivu National Park Area, Belgian Congo.

The specimen (C. 2911) has been fully described by Holmes and Harwood (1937). They also give a bulk analysis of the rock. The rock contains numerous phenocrysts of leucite, titanian augite, and opaque ore. The leucite crystals are very fresh, containing only tiny prisms of augite and apatite as inclusions. They are beautifully twinned and show outer rims of pseudoleucite. About 219 g. of rock was crushed, ground, and subjected to mineral separation. The leucite fraction, tested under the microscope by grain counting, shows the following purity:

1790 completely clear leucite grains ........... 92.6 per cent
142 leucite grains with very little pigment .... 7.3
2 foreign grains ......................... 0.1

No grains having refractive indices lower than that of leucite were detected. The amount of impurities in the grains with pigment is estimated to be less than 5 per cent (probably much less). Thus, the total amount of impurities would be less than 0.5 per cent. An analysis of the bulk rock reproduced from Holmes and Harwood (1937) and of leucite is given in table 2. The index of refraction of leucite was determined to \( n = 1.509 \). The material available for chemical analysis amounted to 5 g.

As is shown by the analysis, the leucite from specimen C. 2912 is unusually pure and very low in soda. The norm of the corresponding rock (C. 2911) given by Holmes and Harwood (1937) is, for the main salic constituents, as follows: orthoclase 36.56, anorthite 4.23, leucite 1.22, nepheline 23.86 or, if priority is given to leucite: leucite 29.87, nepheline 14.52, anorthite 4.23, albite 17.21. The occurrence of the rims of pseudoleucite around the leucite phenocrysts indicate instability of leucite in its present environment. The composition of mikenite is interpreted by Holmes and Harwood as a result of assimilation of highly silicic material by nilgongite magma. If this interpretation is correct, the leucite phenocrysts may have originally crystallized in an environment chemically different from the present ground mass of the rock. The discrepancy between the modal and normative composition would thus become understandable. An example of the occurrence of
leucite in a rock in which it is chemically not anticipated, has
been given by Wade and Prider (1940) from the leucite-bearing
rocks of the West Kimberley area, Western Australia. These
rocks are not undersaturated, yet the most striking feature
in their mineralogy is the abundant occurrence of leucite, mostly
completely altered.

Specimens C. 5549 and C. 5550. Potash ankaratrite. Ejected
blocks from the W. side of crater slope near top, Nyamunuka
Crater, Katwe-Kikorongo field, southwestern Uganda.

These two specimens are virtually identical with each other
and with the specimen C. 1000 fully described by Holmes and
Harwood (1932). Therefore, they are given here together.
The constituents are: clinopyroxene, olivine (with brown re-
action rims), nepheline, leucite, biotite, opaque ore, apatite,
perovskite. In addition, analcite and sodalite have been men-
tioned by Holmes and Harwood (1932). Clinopyroxene forms
most of the rock and shows numerous tiny crystals of perovskite
as inclusions along the margins. Nepheline is more abundant
than leucite. Both occur in the space between large pyroxene
crystals. Nepheline is rarely idiomorphic, very clear, free from
turbidity and without sign of zoning. The grains measure up to

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Table 2

Chemical Composition of Leucite from Mikenite C. 2912 and of
Mikenite C. 2911. Rulenga Mission, Belgian Congo

<table>
<thead>
<tr>
<th></th>
<th>Leucite (from specimen C. 2912)</th>
<th>Mikenite (bulk rock) (specimen C. 2911)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weight per cent found</td>
<td>Molecular ratio multiplied by 1000</td>
</tr>
<tr>
<td>SiO₂</td>
<td>54.62</td>
<td>909</td>
</tr>
<tr>
<td>TiO₂</td>
<td>0.00</td>
<td>---</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>22.93</td>
<td>225</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>0.26</td>
<td>2</td>
</tr>
<tr>
<td>FeO</td>
<td>0.26</td>
<td>4</td>
</tr>
<tr>
<td>MnO</td>
<td>0.00</td>
<td>---</td>
</tr>
<tr>
<td>MgO</td>
<td>0.00</td>
<td>---</td>
</tr>
<tr>
<td>CaO</td>
<td>0.08</td>
<td>1</td>
</tr>
<tr>
<td>Na₂O</td>
<td>0.66</td>
<td>11</td>
</tr>
<tr>
<td>K₂O</td>
<td>21.02</td>
<td>223</td>
</tr>
<tr>
<td>H₂O⁺</td>
<td>0.12</td>
<td>7</td>
</tr>
<tr>
<td>H₂O⁻</td>
<td>0.00</td>
<td>---</td>
</tr>
<tr>
<td>Total</td>
<td>99.95</td>
<td>---</td>
</tr>
</tbody>
</table>

* The sum includes: Co₂, 0.02, ZrO₂ none, P₂O₅ 0.77, Cl 0.14, F 0.08, S 0.01,
Cr₂O₃ none, V₂O₅ 0.03, NiO none, BaO 0.22, SrO 0.10, Li₂O trace, ---O. 0.06.
0.2 mm. Leucite occurs as clear rounded grains, up to 0.05 mm. in size. Alkali determinations carried out on the bulk rocks gave:

<table>
<thead>
<tr>
<th></th>
<th>Specimen C. 5549</th>
<th>Specimen C. 5550</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na₂O</td>
<td>1.43 per cent</td>
<td>1.65 per cent</td>
</tr>
<tr>
<td>K₂O</td>
<td>2.28</td>
<td>2.40</td>
</tr>
</tbody>
</table>

Of specimen C. 5549, ca. 500 g. were available for mineral separation. Nepheline and leucite were extracted from the rock. Of specimen C. 5550, ca. 760 g. were available. In addition to nepheline and leucite, clinopyroxene was also extracted for analysis. The following amounts of nepheline and leucite were obtained: specimen C. 5549, 2.6 g. leucite and 1.7 g. nepheline; specimen C. 5550, 1.4 g. leucite and 2.9 g. nepheline. The optical properties are:

<table>
<thead>
<tr>
<th></th>
<th>Specimen C. 5549</th>
<th>Specimen C. 5550</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leucite</td>
<td>n = 1.511</td>
<td>n = 1.511</td>
</tr>
<tr>
<td>Nepheline</td>
<td>ε = 1.542</td>
<td>ε = 1.543</td>
</tr>
<tr>
<td></td>
<td>ω = 1.548</td>
<td>ω = 1.548</td>
</tr>
</tbody>
</table>

Of nepheline C. 5549 and of leucite C. 5550 only alkali determinations were made with following results:

<table>
<thead>
<tr>
<th></th>
<th>Specimen C. 5549</th>
<th>Specimen C. 5550</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nepheline</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leucite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Na₂O</td>
<td>13.23 per cent</td>
<td>0.60 per cent</td>
</tr>
<tr>
<td>K₂O₅</td>
<td>8.78</td>
<td>18.50</td>
</tr>
</tbody>
</table>

Complete analyses of leucite from specimen C. 5549 and of nepheline from specimen C. 5550 are given in table 3. A bulk analysis of specimen C. 1000, reproduced from Holmes and Harwood (1932), is added to the table.

According to microscopic estimation, the analyzed samples of leucite C. 5549 and of nepheline C. 5550 are slightly more impure than leucite C. 2912 and nepheline C. 9956. The amount of impurities in the sample of leucite C. 5549 and nepheline C. 5550 is about 1 per cent. The contents of minor oxides in these two samples apparently are only in small part caused by foreign contamination.
TABLE 3
Chemical Composition of Leucite from Specimen C. 5549, of Nepheline from Specimen C. 5550, and of Potash Ankaratrite C. 1000. Nyamunuka Crater, Katwe-Kikorongo Field, Southwestern Uganda

<table>
<thead>
<tr>
<th></th>
<th>Leucite Specimen C. 5549</th>
<th>Nepheline Specimen C. 5550</th>
<th>Potash ankaratrite Specimen C. 1000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weight per cent found</td>
<td>Molecular ratio multiplied by 1000</td>
<td>Weight per cent found</td>
</tr>
<tr>
<td>SiO₂</td>
<td>54.80</td>
<td>904</td>
<td>40.78</td>
</tr>
<tr>
<td>TiO₂</td>
<td>0.26</td>
<td>3</td>
<td>0.07</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>20.08</td>
<td>197</td>
<td>30.95</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>1.44</td>
<td>9</td>
<td>2.41</td>
</tr>
<tr>
<td>FeO</td>
<td>0.22</td>
<td>3</td>
<td>0.57</td>
</tr>
<tr>
<td>MnO</td>
<td>n.d.</td>
<td>—</td>
<td>n.d.</td>
</tr>
<tr>
<td>MgO</td>
<td>0.00</td>
<td>—</td>
<td>0.07</td>
</tr>
<tr>
<td>CaO</td>
<td>1.84</td>
<td>33</td>
<td>0.78</td>
</tr>
<tr>
<td>Na₂O</td>
<td>1.88</td>
<td>30</td>
<td>13.93</td>
</tr>
<tr>
<td>K₂O</td>
<td>19.02</td>
<td>202</td>
<td>9.78</td>
</tr>
<tr>
<td>H₂O+</td>
<td>0.75</td>
<td>42</td>
<td>0.32</td>
</tr>
<tr>
<td>H₂O—</td>
<td>0.00</td>
<td>0.00</td>
<td>—</td>
</tr>
<tr>
<td>Total</td>
<td>99.79</td>
<td>99.66</td>
<td></td>
</tr>
</tbody>
</table>

*The sum includes: CO₂ 0.06, ZrO₂ 0.04, P₂O₅ 0.53, Cl, F trace, S none, Cr₂O₃ 0.02, V₂O₅ 0.02, NiO trace, BaO 0.10, SrO 0.10, Li₂O none.
Clinopyroxene from S.W. Uganda and Belgian Congo

The analyses of leucite and nepheline and of the bulk rock of table 3 are all made on different specimens. These three specimens are, however, very similar and evidently justify a comparison of the corresponding analyses with each other as if they were made on materials derived from the same specimen. In addition to general microscopic evidence, the similarity of specimens C. 5549 and C. 5550 is shown by the alkali determinations on nepheline extracted out of these specimens. The alkali determinations on the bulk rocks given above yield values not far from the corresponding figures of the seventh column of table 3.

A comparison of the analyses of the leucites C. 2912 and C. 5549 with each other shows that the latter corresponds less closely to the ideal leucite composition. The soda-to-potash ratio of nepheline C. 5550 amounts to Na: K = 68.4: 31.6. The norms for specimen C. 1000 calculated by Holmes and Harwood (op. cit.) show ca. 8 per cent leucite and ca. 6 per cent soda nepheline. The high potash content of the modal nepheline is thus a consequence of the composition of the bulk rock.

The clinopyroxene of specimen C. 5550 was also extracted out of the rock and analyzed. The optical properties of this pyroxene are:

\[ a = 1.695^1 \]
\[ \beta = 1.701 \]
\[ \gamma = 1.721 \]
\[ 2V_\gamma = 60^\circ \pm 2^\circ \]
\[ c_{\alpha\gamma} = 46^\circ \]

Frequent twinning on (100).

The chemical composition of this pyroxene is shown in table 4. Grain counting made on the analyzed sample gave:

1117 clear pyroxene grains .................56.5 per cent
817 pyroxene grains with some inclusions .... 41.3
42 pyroxene grains with many inclusions .... 2.1

The inclusions are mostly perovskite. Assuming that the grains with some inclusions contain 5 per cent impurities on the average, and the grains with many inclusions ca. 30 per cent, the total amount of impurities will be 3 per cent.

1 Owing to slight zoning, the indices of refraction vary up to \pm 0.002.
Table 4
Chemical Composition of Clinopyroxene from Potash Ankaratrite C. 5550. Nyamunuka Crater, Katwe-Kikorongo Field, Southwestern Uganda

<table>
<thead>
<tr>
<th></th>
<th>Weight per cent found</th>
<th>Atomic ratios (multiplied by 1000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>49.23</td>
<td>Si 820</td>
</tr>
<tr>
<td>TiO₂</td>
<td>2.25</td>
<td>Ti 28</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>2.01</td>
<td>Al 39</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>2.87</td>
<td>Fe³⁺ 36</td>
</tr>
<tr>
<td>FeO</td>
<td>3.53</td>
<td>Fe²⁺ 49</td>
</tr>
<tr>
<td>MnO</td>
<td>0.09</td>
<td>Mn 1</td>
</tr>
<tr>
<td>MgO</td>
<td>14.69</td>
<td>Mg 364</td>
</tr>
<tr>
<td>CaO</td>
<td>24.23</td>
<td>Ca 432</td>
</tr>
<tr>
<td>Na₂O</td>
<td>0.46</td>
<td>Na 15</td>
</tr>
<tr>
<td>K₂O</td>
<td>0.15</td>
<td>K 3</td>
</tr>
<tr>
<td>H₂O⁺</td>
<td>0.38</td>
<td>OH 42</td>
</tr>
<tr>
<td>H₂O⁻</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>99.89</strong></td>
<td></td>
</tr>
</tbody>
</table>

A part of the titania shown by the analysis of table 4 is probably contained in the perovskite inclusions. Adding titania and alumina to silica, ferric iron, ferrous iron, and manganese to magnesia, and the alkalis to lime, the analysis corresponds closely to a metasilicate composition. The molecular ratio \((\text{Fe}^{3+} + \text{Fe}^{2+}) : \text{Mg} : \text{Ca} = 9.7 : 41.3 : 49.0\). Thus, according to the nomenclature presented by Hess (1941), the clinopyroxene from specimen C. 5550 is no augite proper but has to be classified as a diopside close to salite. The refractive indices are, however, somewhat higher than those indicated by the diagrams of Tomita (1934), Deer and Wager (1938), and Hess (1949). The reason for this discrepancy might be the relatively high ferric iron and titania content of the mineral. Although a part of the titania content apparently is caused by the perovskite inclusions, some part of it very probably belongs to the pyroxene.

Discussion

The data given above are too scattered to allow any more general conclusions about the mineralogy of the potash rich rock suite of southwestern Uganda and adjoining Belgian Congo. The results of this preliminary investigation are given only to show that, in addition to considerable petrological interest, the rocks in question offer excellent material for
studying the general mineralogy of leucite, nepheline, etc. On a later occasion, the authors hope to study these rocks in more detail. Therefore, only a few remarks are added in the following.

The diopside from specimen C. 5550 so far being the only analyzed pyroxene from the rock suite in question, no further comments are possible at present.

In connection with the study of the formation of pseudoleucite, Bowen and Ellestad (1937) published an analysis of leucite occurring as phenocrysts in leucite theralite on Mt. Nyamalagira. This leucite, like those given in this paper, is relatively poor in soda. The average molecular soda-to-potash ratio for the leucites from Mt. Nyamalagira and from the specimens C. 9956, C. 2912, C. 5549, and C. 5550 amounts to Na: K = 8.5: 91.5. An average of fourteen analyses of leucites from Vesuvius calculated by Chirwinsky (1931) amounts to Na: K = 15.4: 84.6. No indication of the existence of the compound K₂O·MgO·5SiO₂ in the rocks in question has been found so far. According to Roedder (1951), this compound forms a complete series of solid solutions with leucite and might well be expected to occur in nature.

As to nepheline, the occurrence of a more or less continuous rock series from ugandite to mafurite and of the corresponding potash ankaratrites and, on the other hand, the variation of the soda-to-potash ratio in these rocks, offer a rather unique opportunity for studying the mineralogy of the nepheline-kalsilite series. The extremely potassic character of the nephelines in these rocks, very rare elsewhere, was noted by Bowen and Ellestad (1936). Their analysis of a nepheline occurring in a relatively coarse-grained, melilite-leucite nepheline from Ngoma Crater on Lake Kivu shows it to be the most potash-rich nepheline analyzed up to that time. The molecular soda-to-potash ratio of the Ngoma Crater nepheline amounts to Na: K = 63.1: 36.9. Later, the mineral kalsilite (KAlSiO₄) was discovered by Bannister and Hey (1942) from a certain type of mafurite in which the mineral occurs as pegmatoidal aggregates associated with diopside, calcite, zeolite, etc. The existence of a relatively pure potash analogue to nepheline in these rocks was suggested by Holmes (1942). According to Bannister and Hey (1942), kalsilite represents a polymorph of kaliophilite with a smaller unit cell and forms an incomplete
series of solid solutions with nepheline proper. Another analysis of nepheline from a phonolite on the Nairobi-Nyeri road in Kenya in the Eastern Rift of Equatorial East Africa, also published by Bowen and Ellestad (1936), shows a molecular soda-to-potash ratio of Na: K = 86.3: 13.7, in accordance with the generally sodic character of the volcanics of the Eastern Rift. However, on the basis of microscopic observations, the occurrence of comparatively potash-rich nephelines in the Eastern Rift lavas was suggested by Ödman (1930) and by King (1948). An analysis of a very potash-rich nepheline from ijolite from Homa Bay, Kenya, has been given by Pulfrey (1949), showing Na: K = 67.0: 33.0.

In this connection, Buerger, Klein, and Hamburger (1946, 1947) concluded that two of the eight alkali atoms in the unit cell occupy positions structurally different from those of the remaining six. On the basis of the chemical composition of natural nepheline, they suggest that these two positions, representing larger holes produced by collapse of voids in the tridymite structure, are occupied by larger potassium atoms. Thus, the ideal formula of nepheline would be KNa₃Al₄Si₂O₁₆. The data referred to above for nephelines from the East African volcanics may suffice to show that, as was emphasized already by Bowen and Ellestad (1936), the composition of nepheline largely depends on the composition of the bulk rock. Potash-rich rocks show more potassic nephelines, provided, of course, that the silica content is low enough for the formation of nepheline. That the common range of variation of the soda-to-potash ratio appears to be comparatively narrow and that only a few examples of very potash-rich nephelines are known, may be attributed to the relative rarity of rocks in which the more potassic nephelines may be anticipated. Therefore, even if the two alkali sites of the nepheline unit cell are preferred by the potassium atoms, the nepheline formula suggested by Buerger, Klein, and Hamburger (1946, 1947) represents an idealization of the actual nepheline composition that neglects the existence of the nepheline-kalsilite solid solution series. In this series, the nepheline C. 9956 from Mt. Ninagongo, given above, represents the most potash-rich member known so far that still shows the nepheline structure. On the other hand, the only analysis of natural kalsilite, derived from Uganda mafurite, has been published by Bannister and
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Hey (1942). Accordingly, the width of the probable gap in
the solid solution series between natural nepheline and kalsilite
cannot be considered known. It is entirely possible that more
potash-rich nephelines and more soda-rich kalsilites will be
found. High temperature synthetic studies made by Bowen
(1917) and Schairer and Bowen (1935) have revealed a com-
plete mutual solid solubility between NaAlSiO₄ and KAlSiO₄.
Recently, a review of the existing data for the composition of
natural nephelines has been given by Miyashiro (1951). He
argues that the physical conditions under which a nepheline
crystallizes are largely responsible for its composition.

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REFERENCES

Bannister, F. A., and Hey, M. H., 1931. A chemical, optical, and X-ray
569-608.
-----, -----, 1942. Kalsilite, a polymorph of KAlSiO₄, from Uganda:
-----, and Ellestad, R. B., 1936. Nepheline contrasts: Am. Mineralogist,
vol. 21, pp. 363-368.
22, pp. 409-415.
Buerger, M. J., Klein, G. E., and Hamburger, Gabrielle, 1946. The structure
of nepheline. Complete structure determination (abst.): Geol. Soc.
-----, -----, -----, 1947. The structure of nepheline (abst.):
Chirwinsky (Tschirwinsky), Peter, 1931. Durchschnittliche chemische
Zusammensetzung der wichtigen Mineralien der Eruptivgesteine und
der Meteorite (summary by the author): Neues Jahrb., Referate, II.
Combe, A. D., and Holmes, Arthur, 1945. The kalsilite-bearing lavas of
Kabirenge and Lyakauli, southwest Uganda: Royal Soc. Edinburgh
Trans., vol. 61, part 2, pp. 359-379.


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