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PHASE RELATIONS IN THE SYSTEM NEPHELINE - LEUCITE - ANORTHITE AT 1 ATMOSPHERE

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Leucite and nepheline are the most commonly occurring feldspathoids in potassium-rich basic and ultrabasic rocks. Whenever present in leucite-bearing rocks, plagioclase feldspars are always anorthite-rich (Shand 1947). The system nepheline (Ne)-leucite (Lc)-anorthite (An) was investigated at one atmosphere pressure to determine the mutual phase relations of these minerals. Natural nepheline contains $CaAl_2Si_2O_8$, $KAlSiO_4$ and silica in solid solution (Miyashiro 1951; Donnay *et al.* 1959). Similarly, leucite incorporates sodium as the $NaAlSi_2O_6$ molecule in solid solution (Fudali 1963). The determination of the extents of these solid solutions may have important petrological implications.

The systems nepheline-anorthite (Gummer 1943) and leucite-anorthite (Schairer & Bowen 1947) have been published. The third join, nepheline-leucite, has been extrapolated from the system nepheline-kalsilite-silica (Schairer 1950).

Experimental techniques, were the same as given by Gupta *et al.* (1973). Twenty-six mixtures were homogenized to glasses and crystallized at 1000°C for use as starting materials. Temperatures were measured with calibrated thermocouples with estimated precision of ±5°C.

Results are given in Table 1 and summarized in Figure 1, which shows that the Ne—Lc—An join cuts the primary phase volumes of β-alumi-

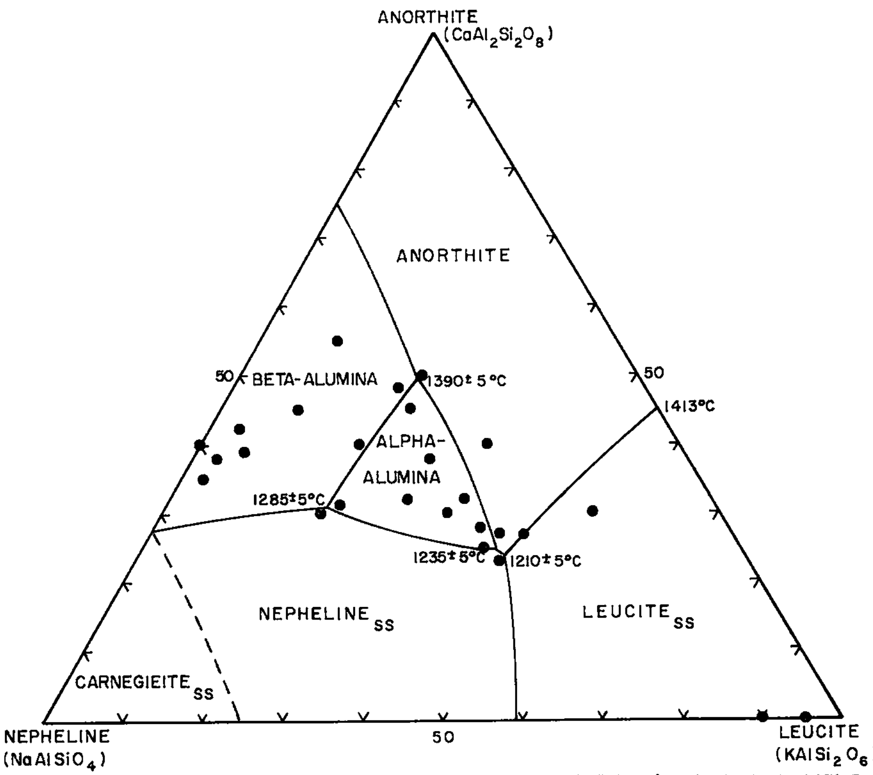

FIG. 1. Liquidus phase relations for the system $NaAlSiO_4$ (nepheline) - $KAlSi_2O_6$ (leucite) - $CaAl_2Si_2O_8$ (anorthite) at atmospheric pressure.

na, corundum (α-Al_2O_3), carnegieite, nepheline, leucite and anorthite and is thus a join of the five-component system Na_2O—K_2O—CaO—Al_2O_3—SiO_2. Four, four-phase points occur at the following temperatures and compositions: 1) 1390°±5°C, $Ne_{26}Lc_{22}An_{52}$ where β-alumina, corundum, anorthite and liquid coexist; 2) 1285°±5°C, $Ne_{49}Lc_{20}An_{31}$ where nepheline, β-alumina, corundum and liquid are in equilibrium; 3) 1235±5°C, $Ne_{31}Lc_{44}An_{25}$ where corundum, nepheline and anorthite coexist with liquid; 4) 1210±5°C, $Ne_{31}Lc_{44}An_{25}$ where leucite, nepheline, anorthite and liquid are in equilibrium. The five-phase assemblage of nepheline, leucite, anorthite, corundum and liquids occurs at 1205±5°C.

With the exception of corundum, all phases are solid solutions. Schairer & Bowen (1955) and Winchell & Winchell (1964) suggested that β-alumina is unstable in the absence of Na_2O and K_2O and may exist as $Na_2O.6Al_2O_3$. Semiquantitative electron microprobe analysis of β-alumina crystals (5-15μ) indicate that they contain approximately 80 weight per cent Al_2O_3. This suggests that β-alumina exists as $(K_2O.Na_2O).6Al_2O_3$. β-alumina has a reaction relationship with liquid at temperatures ranging from 1340°C for $Ne_{31}Lc_{21}An_{48}$ and $Ne_{27}Lc_{23}An_{50}$ to 1255°C for $Ne_{50}Lc_{20}An_{30}$.

As a check that corundum was not a result of metastability or loss of alkalis, two mixtures ($Ne_{32}An_{38}Lc_{30}$) and ($Ne_{34}An_{30}Lc_{36}$) lying within the primary phase field of corundum were heated in sealed platinum capsules at 1300°C for a week, and showed no change in result.

The tiny crystals and high alkali content of the feldspathoids did not permit quantitative determination of the compositions of the silicates by microprobe. However, a reasonable estimate of their compositions could be inferred from optical and *x*-ray diffraction methods.

In the system nepheline-anorthite, nepheline containing 23 weight per cent $CaAl_2Si_2O_8$ is isotropic (Bowen 1912). In the studied portion of the system nepheline—anorthite—leucite, nepheline is nearly isotropic, suggesting that it contains comparable amounts of anorthite. In all the mixtures with less than 20 weight per cent $KAlSi_2O_6$, the final assemblage is nepheline + corundum + anorthite + liquid. Absence of leucite in these mixtures suggests that nepheline contains $KAlSiO_4$ and SiO_2 (in the combined form of leucite) in solid solution. Edgar (unpublished data) showed that $CaAl_2Si_2O_8$ does not affect the interplanar spacings of nepheline. The amounts of $KAlSiO_4$ and SiO_2 in nephelines were determined from three mixtures ($Ne_{47}An_{31}Lc_{22}$, $Ne_{31}An_{23}Lc_{46}$ and $Ne_{16}An_{30}Lc_{54}$) using the methods of Hamilton & Mackenzie (1960). All contained 21.5±1% of $KAlSiO_4$ and 3.91±0.5% of silica in solid solution. The present study therefore suggests that both potassium and calcium are equally favored in the nepheline structure. The composition of nepheline is thus controlled by the bulk composition of the melt from which it crystallizes, as suggested by Bowen & Ellestad (1936). High amounts of calcium in natural nephelines have been reported by Bannister & Hey 1931 (4%) and Barth 1963 (2%). Becke & Hibsch (1926) reported isotropic nepheline.

TABLE 1. QUENCHING RUNS IN THE SYSTEM $NaAlSiO_4$-$CaAl_2O_8$-$KAlSi_2O_6$

Composition wt. % Ne	An	Lc	Phases (Temp. °C)
31	23	46	Ne in 1221, An in 1215, Lc in 1213, Cor in 1205. (Ne+An+Lc+Cor)*
32	25	43	Cor in 1245, Ne in 1240, An in 1235, Lc in 1205. (Ne+An+Lc+Cor).
29	27	44	An in 1245, Cor in 1240, Lc in 1215, Ne in 1205.
26	27	47	An+Lc in 1260, Ne in 1205, Cor in 1205 (?).
50	30	20	Ne in 1305, β-Al_2O_3 in 1290, Cor in 1285, β-Al_2O_3 out 1255, Ne in 1240, Lc in 1210.(Ne+An+Cor).
34	30	36	Cor in 1275, An in 1261, ** Cor+An present at 1250. (Lc+Ne+An+Cor).
32	38	30	**Cor+An present at 1300.
31	45	24	Cor in 1385, β-Al_2O_3 in 1370, An in 1342, β-Al_2O_3 out 1315.
31	48	21	β-Al_2O_3 in 1385, Cor in 1370, An in 1345, β-Al_2O_3 out 1340. (Ne+An+Cor).
27	50	23	Cor in 1395, β-Al_2O_3 in 1391, An in 1390, β-Al_2O_3 out 1340. (Ne+An+Cor).

*Assemblages shown within brackets are the phases in the starting materials crystallized at 1000°C.

**Runs heated in sealed platinum capsules for 1 week.

Optical and *x*-ray study of two mixtures, $Lc_{95}Ne_5$ and $Lc_{90}Ne_{10}$, showed that below 1350°C, leucite contains more than 5 but less than 10 weight per cent of nepheline.

The amount of anorthite incorporated by leucite in solid solution is very small as suggested by the system leucite-anorthite (Schairer & Bowen 1947).

The association of corundum with nepheline and plagioclase is usually found in metamorphic rocks and attributed to complex metamorphic reactions (Moyd 1949; Carlson 1957) or metasomatism (Gummer 1943). Thus the liquidus relations have little relevance to these rocks. However, the presence of corundum in diabase dikes in the Glen Riddle area of Pennsylvania (Tomilson 1939) may have a primary origin and may have been produced by the type of reactions present in the synthetic system.

Leucite is normally absent in corundum-bearing undersaturated rocks. Under conditions of low to moderate water vapour pressures and in the presence of small amounts of MgO and FeO, leucite would react to form mica, a common accessory in such rocks. In leucite tephrites and basanites in which leucite, Ca-rich plagioclase and nepheline occur with ferromagnesian minerals, corundum is absent. In these rocks any excess alumina may combine with MgO and FeO to produce spinel ($MgAl_2O_4$) or hercynite ($FeAl_2O_4$).

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