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CRYSTALLIZATION OF LEUCITE-NEPHELINE-SANIDINE IN BASIC DIFFERENTIATES FROM A PERIDOTITE-DUNITE MASS IN SALEM, MADRAS STATE, INDIA

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ABSTRACT

The potassic rocks of Salem occur as dikes and sheets within or marginal to a dunite-peridotite mass that has intruded into Archean Peninsular gneisses, charnockite series, pyroxenites and dolerites. The rocks are porphyritic with euhedral crystals of olivine and augite set in a ground mass consisting of (1) leucite-pseudoleucite-sanidine, (2) nepheline, sanidine and nepheline-sanidine intergrowths, (3) sanidine laths or massive sanidine and (4) sanidine or orthoclase cryptoperthites. The texture resembles that of lamprophyres. Both the rocks and the residua have been chemically analysed, and interpreted on the SiO_2-$NaAlSiO_4$-$KalSiO_4$ diagram of Schairer and Bowen (1935). It is held that the magma crystallized under high water vapor pressure and that the field of leucite was restricted. Consequently, the pseudoleucite reaction was restricted to a narrow range in time, and the crystallization of nepheline and sanidine, and nepheline-sanidine intergrowths was the end product of the differentiation of these potassic rocks.

INTRODUCTION

Basic plutonic potassic rocks have been reported by W. H. Weed and L. V. Pirsson (1901) from the Shonkin Sag laccolith. The shonkinite reported from there consists of augite, olivine, biotite, apatite, and magnetite in a matrix of potash feldspar, zeolites and carbonates, with pseudoleucite appearing conspicuously in a chilled marginal phase. A somewhat similar series of rocks was noticed by the author and S. Ramanathan in Salem, Madras State, India, in 1953, and the rocks were described, under the author's guidance, by S. Ramanathan (1954). In these rocks, zeolites and carbonates are absent. Leucite and sporadic pseudoleucite occur in some dike phases. Nevertheless, on account of their close resemblance, mineralogically and chemically, to the shonkinites and missourites, they have been described as the "shonkinite series" of Salem.

A map of the area, prepared for the present paper by N. L. Rao, is presented in Fig. 1. The country consists of Archean Peninsular gneisses, charnockite series, pyroxenites and dolerites, which have been intruded by a dunite-peridotite mass. The potassic rocks occur in this mass as marginal sheets or dikes. The dunite-peridotite mass is now largely converted to magnesite, serpentine, mica, asbestos and other hydrous minerals. The magnesite is the largest deposit of its kind in India.

DESCRIPTION

The potassic rocks are black to dark gray and look like lamprophyres. Under the microscope they show a panidiomorphic texture with euhedral to subhedral crystals of olivine and augite, set in a groundmass, which may consist of, (1) leucite, pseudoleucite and sanidine, (2) nepheline, sanidine and intergrowths of nepheline-sanidine, (3) sanidine laths or massive sanidine and (4) sanidine, or orthoclase cryptoperthites (Figs. 2–8). Of these four types of matrices, the first two occur in small dykes and the last two in the main mass. Their distribution is indicated in Fig. 1. The percentages of the area occupied by the four varieties of rocks is:- 1.3(1):0.2(2):3.0(3):95.5(4). In the bulk of the mass, therefore, the matrix consists of sanidine or orthoclase cryptoperthites.

The olivine is both fayalitic and forsteritic and shows optic axial angles ranging from $2V(+)=72°$–$85°$ to $2V(-)=78°$–$82°$. In some crystals inclusions are arranged zonally. The augite is diopsidic and gives Optic axial angles ranging from $2V(+)=55°$–$60°$, to $2V(+)=65°$–$78°$, and $Z \wedge C=42°$–$57°$. The crystals are zoned, some having as many as thirty-five zones that show a small variation in extinction angles. Twinning parallel to {100}, lamellar twins, herring-bone twins and staurolite-like twins are common. Rimmed crystals give varying optic axial angles, the core has $2V(+)=59°$, and the rim $2V(+)=61°$. They have sometimes inclusions parallel to all the pinacoids or irrational faces. They are poikilitic with olivine. At contacts with sanidine, both olivine and augite are altered to phlogopite, which may cut across and along the cleavages. Both olivine and augite may occur sparingly as tiny grains in the various matrices. When there is micaisation in the rocks, the iron oxides are also rimmed by phlogopite.

The potash feldspars give optic axial angles ranging from 0° to 44°(−) or 50°(−) to 66°(−). As it

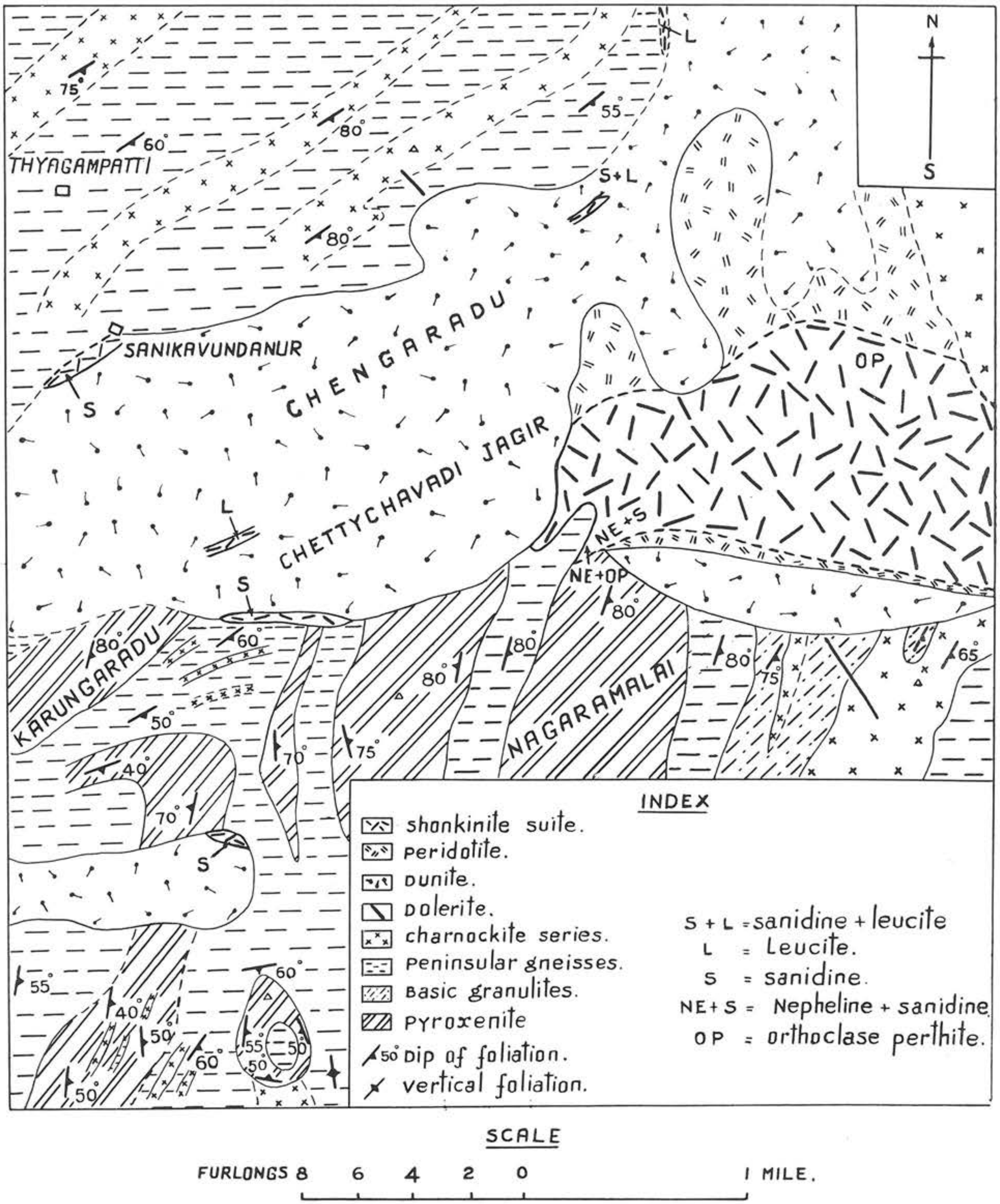

FIG. 1. Geological map of Nagaramalai, Salem, Madras State, India.

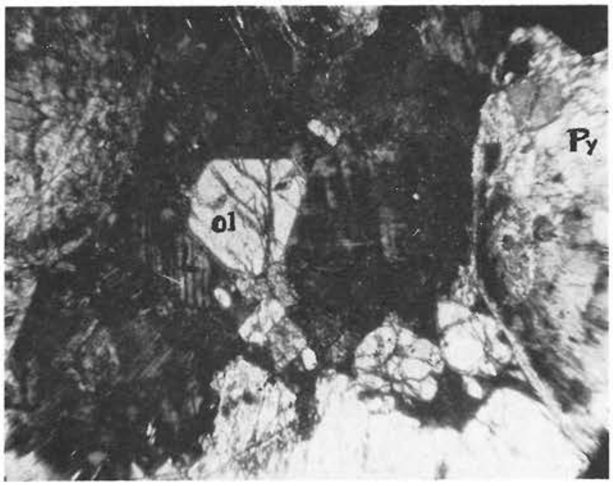

FIG. 2. Interstitial leucite with lamellae, L=Leucite, Ol=Olivine, Py=Pyroxene. Nicols crossed, ×26

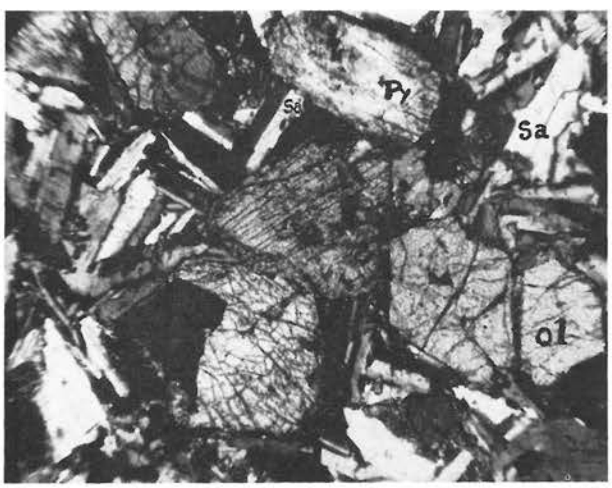

FIG. 3. Interstitial sanidine laths, Sa=Sanidine, Ol=Olivine, Py=Pyroxene. Nicols crossed, ×26

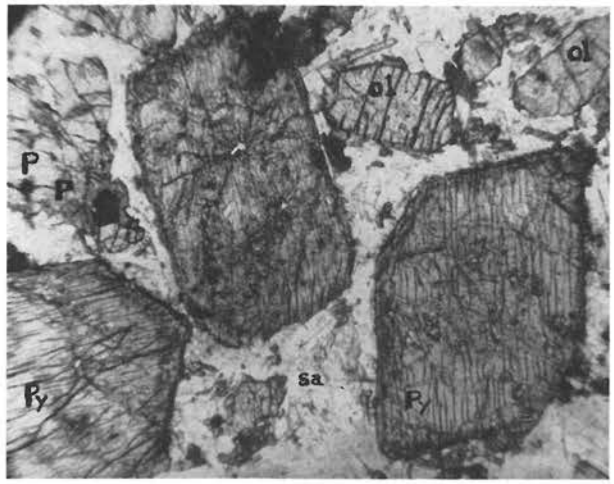

FIG. 4. Interstitial massive sanidine, Sa=Sanidine, Py=Pyrox ene with reaction rims, Ol=Olvine, P=Phlogopite. Nicols not crossed, ×26.

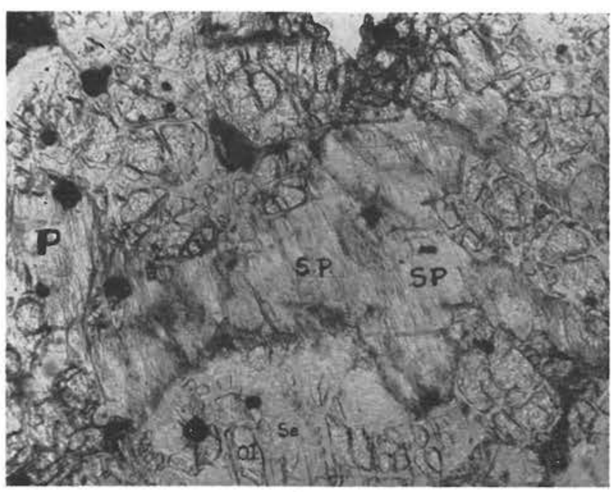

FIG. 5. Interstitial sanidine perthites S.P.=Sanidine perthites, Ol=Unaltered olivine, Se=Serpentine; P=Phlogopite. Nicols not crossed, ×70.

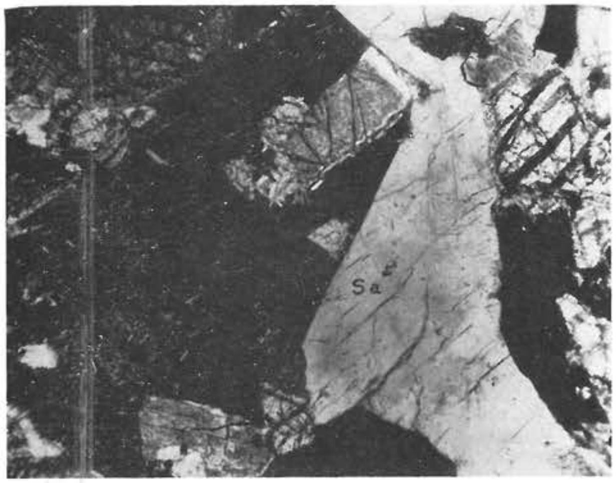

FIG. 6. Symplectitic intergrowths of nepheline and sanidine, (100) of sanidine parallel to prism of nepheline Y=E, Sa=Sanidine. Dark portion with crystallites=Nepheline. Nicols crossed, ×70.

FIG. 8. Interstitial massive sanidine with brown pleochroic patches and faint lamellae. Nicols crossed, ×70

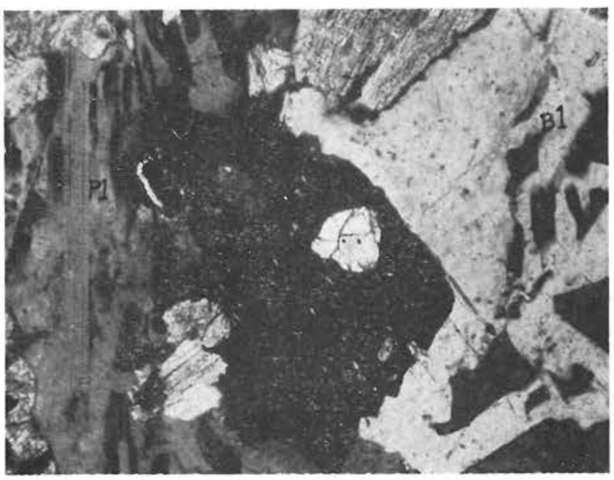

FIG. 7. Intergrowths of nepheline and sanidine, plumose or dactylic and bleb type, Bl=Bleb type; Pl=Plumose type. Dark portion with crystallites=discrete grain of nepheline. Nicols crossed, ×70.

TABLE I. MODES OF THE POTASSIC ROCKS OF SALEM

	1	2	3	4	5	6	7	8	9	10	11	12
Sanidine including sanidine cryptoperthite	44.2	44.0	29.8	—	49.2	44.3	17.9	16.4	11.2	2.2	2.5	0.7
Orthoclase including orthoclase cryptoperthite	—	—	—	34.6	—	—	—	—	—	—	—	—
Pseudoleucite	—	—	—	—	—	—	—	—	—	2.4	2.4	—
Nepheline	—	—	6.1	—	—	—	—	—	—	—	—	—
Nepheline-sanidine intergrowth	—	—	11.8	—	—	—	—	—	—	—	—	—
Leucite	—	—	—	—	—	—	—	—	—	13.5	17.2	—
Olivine	12.7	13.5	16.8	20.7	15.6	10.9	26.1	74.7	75.4	43.0	37.1	24.5
Augite	36.8	37.2	22.0	34.7	29.7	42.4	53.6	4.5	3.4	36.9	37.1	71.8
Mica	5.2	4.1	12.4	6.8	4.2	1.1	1.4	4.2	6.9	1.8	3.5	0.9
Accessories (Apatite, iron ore)	1.1	1.2	1.1	3.2	1.3	1.3	1.0	0.2	3.1	0.2	0.2	2.1

TABLE II. ANALYSES OF THE BASIC POTASSIC ROCKS OF SALEM

	Analyses				Niggli Basis				
	A	B	C	D					
SiO_2	50.55	48.87	50.10	48.31	Kp	14.58	16.10	13.77	35.35
TiO_2	1.52	1.29	0.41	0.11	Ne	7.95	13.94	14.26	11.23
Al_2O_3	6.97	9.44	13.81	18.73	Ns	1.27	—	—	—
Fe_2O_3	0.29	2.33	0.35	1.79	Cal	—	0.33	7.94	6.94
FeO	7.93	7.57	4.91	6.16	Cs	18.06	14.05	12.58	8.37
MnO	0.43	0.42	0.15	Tr	Sp	—	—	—	—
MgO	13.11	12.15	11.66	4.56	Fs	0.33	2.43	0.43	1.82
CaO	12.22	9.57	11.45	8.14	Fo	26.95	25.00	23.43	9.42
Na_2O	1.97	2.61	2.74	2.11	Fa	9.55	9.13	5.67	6.88
K_2O	4.13	4.56	3.99	10.12	Ru	1.05	0.88	0.27	0.05
P_2O_5	Tr	Tr	—	—	Cm	—	—	—	—
H_2O	0.33	0.44	0.22	0.03	Q	20.26	18.14	21.65	19.94
H_2O^-	0.06	0.16	0.10	0.10	L	22.53	30.57	35.97	53.52
Total	99.51	99.41	99.89	100.16	M	57.21	51.49	42.38	27.54

A. B, C Analyst: S. Ramanathan, Oil and Natural Gas Commission, Government of India.
D Analyst: S. Saravanan, Analytical Chemist, Department of Geology and Geophysics, University of Madras.
A Rock with a matrix of sanidine.
B Rock with a matrix of nepheline, sanidine and nepheline-sanidine intergrowths.
C Rock with a matrix of sanidine and orthoclase perthites.
D Rock with a matrix of leucite and pseudolecuite.

Q, Kp, Ne recalculated to 100

	A	B	C	D
Q	45	39	43	30
Kp	35	33	28	53
Ne	20	28	29	17

is not possible to determine on the Fedorow stage optic axial angles below 20°, only angles above this value are recorded. The rest are inferred to be uniaxial when they answer the uniaxial test. The optic axial plane, whenever it is possible of determination, is perpendicular to (010). These feldspars are sanidine and orthoclase (Tuttle, 1952) and are classified as follows: Grains showing $2V(-)=0°–40°$ and lath-shaped as sanidine laths; when not lath-like as massive sanidine; when perthitic as sanidine cryptoperthites, grains showing $2V(-)=50°–66°$ as orthoclase; and when perthitic, as orthoclase cryptoperthites. Intergrowths of nepheline and sanidine, occurring in leucite-bearing rocks, are described as pseudoleucites. When there is no leucite present, but the nepheline-sanidine intergrowths occur along with discrete grains of nepheline and sanidine, they are not regarded as pseudoleucites.

Leucite, being interstitial, rarely has its common crystal shape, but, it shows the characteristic lamellar twinning. Some of the lamellae give optic axial

TABLE III. ANALYSES OF THE MATRICES OF POTASSIC ROCKS OF SALEM.

	Leucite, pseudo-leucite & sanidine (1)	Sanidine laths (2)	Massive sanidine (3)	Sanidine perthites (4)	Nepheline and sanidine (5)
SiO_2	55.08	64.68	64.92	66.30	59.01
Al_2O_3	24.01	18.10	18.05	18.41	22.69
K_2O	20.71	16.30	16.21	14.38	12.72
Na_2O	0.99	0.25	0.33	1.67	5.37
Total	100.79	99.33	99.51	100.76	99.79

Analyses calculated to molecules SiO_2 (O), $NaAlSiO_4$ (Ne) and $KAlSiO_4$ (Kp).

	1	2	3	4	5
Q	26.60	43.39	43.80	44.41	32.48
Kp	68.90	55.47	54.76	47.96	42.85
Ne	4.50	1.14	1.53	7.63	24.67

Analyst: S. Saravanan, Analytical Chemist, Department of Geology and Geophysics, University of Madras.

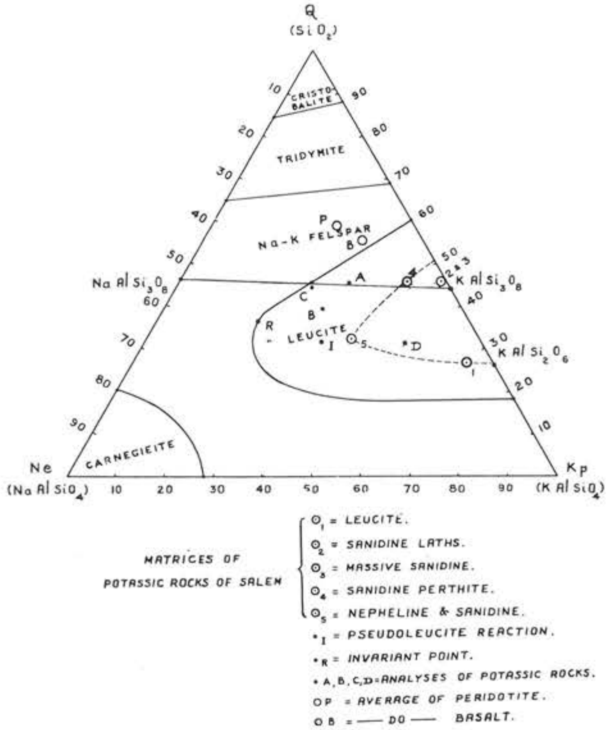

FIG. 9. Phase diagram of the system $SiO_2(Q)$, $NaAlSiO_4(Ne)-KAlSiO_4(Kp)$.

angles of 0° to 44°(−). They have reacted with the liquid to form sanidine. In other instances they have formed pseudoleucite.

MODES

The modes of the basic potassic rocks are shown in Table I.

The modes show the relative variation of the mafic and felsic minerals indicating the role of crystallization-differentiation in the formation of these rocks. The presence of olivine and augite, in all the rocks, relates them to the peridotites and the dunites. The larger proportion of felsic constituents is generally parallel with the increase of augite. The early abundant crystallization of olivine and later of diopside-augite had rendered the residuum siliceous and alkalic (Bowen 1956).

CHEMICAL DATA

Four of these rock types have been analyzed. The analyses are given in Table II along with their Niggli basis molecules.

The matrices of these rocks, after separating the mafics from them, were also analysed and the results are given in Table III.

The Q, Kp, Ne values of the analyzed rocks and the matrices are plotted in Fig. 9 which is the SiO_2-$KAlSiO_4$-$NaAlSiO_4$ phase diagram of Schairer and Bowen (1935).

DISCUSSION

Treating the points, as lying in the system investigated, at one bar, all the rock analyses are seen to lie within the leucite field. They may all, therefore be regarded as crystallizing leucite, which reacted with the liquid and formed orthoclase and pseudoleucite in succession. The course of the magma was from D towards A, B and C, by the crystallization of residuum No. 1. At about C, residua Nos. 2, 3 and 4 crystallized. When the magma reached the invariant point R, residuum No. 5 crystallized. But, it may reasonably be assumed that, since the potassic rocks of Salem crystallized under plutonic conditions and high water vapor pressure, the field of leucite was restricted. (Bowen and Tuttle, 1950). The assumed restriction is indicated in dotted lines. Rock No. D is the only fraction that lies in the leucite field. It is regarded that D, by crystallizing fraction 1, moved on to A, where, by crystallization of fractions 2 and 3, the magma moved on to C, when fraction 4 crystallized. By this time, the magma was desilicated and moved on to B, where, it crystallized fraction 5, with the independent crystallization of nepheline and intergrowths of sanidine and nepheline. This fraction is therefore not regarded as pseudoleucite.

TABLE IV. MODES OF DISCRETE GRAINS OF NEPHELINE AND SANIDINE AND NEPHELINE-SANIDINE INTERGROWTHS

	Discrete grains		Nepheline-sanidine intergrowth	Percentage of nepheline to sanidine in the intergrowth		App. proportion of discrete grains of nepheline and sanidine	App. proportion of nepheline to sanidine in the intergrowth	App. proportion of nepheline to sanidine in the whole rock
	Nepheline %	Sanidine %						
Slide 1	12.90	62.03	25.07	42.06	57.94	1:5	2:3	1:3
Slide 2	8.59	67.13	24.10	32.96	67.04	1:8	1:2	1:5
Slide 3	13.61	37.04	49.35	37.89	62.11	1:3	2:3	1:2

The proportion of discrete grains of nepheline and sanidine to nepheline-sanidine intergrowths and the proportion of nepheline to sanidine in the intergrowths themselves, was estimated in three slides by point-counter, and the results are tabulated in Table IV.

If all the intergrowths of nepheline and sanidine were pseudoleucites, the proportion of nepheline to sanidine in residuum 5, Fig. 9, would be 1:3. This proportion is not born out by all the estimated modal proportion in the slides.

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