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Some chemical data on members of the shoshonite association

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SUMMARY. A number of minerals and residual glasses from absarokites, shoshonites, and latites have been analysed by electron probe.

Clinopyroxenes show very little iron-enrichment and these rocks are thus distinguished from tholeiites and alkali basalts.

Glasses from this group are also distinct from tholeiites and alkali basalts and occupy a separate field on a CaO–Na_2O–K_2O diagram.

WHEN attention (Joplin, 1965) was drawn to the close resemblance between certain lavas on the south coast of New South Wales, the absarokite–shoshonite–banakite series of Wyoming (Iddings, 1895), and the latites of Sierra Nevada (Ransome, 1898), it was suggested that these rocks might be related to the alkali basalts or might even represent a distinct magma-type.

A review of world occurrences of shoshonitic rocks (Joplin, 1968) has shown that compositions may range from ultramafic absarokites to felsic toscanites and liparites and that there is little iron enrichment. Thus, the shoshonitic rocks have some affinities with the calcalkaline andesitic suite and the suggestion that they may be related to the alkali basalts is wrong.

The range in composition from absarokites to liparites suggests that they belong to a differentiation series, but the andesite suite also shows a considerable range in composition and many petrologists consider that members of this suite arise by a complex process involving partial melting rather than by fractional crystallization or by contamination of a basaltic magma (Green and Ringwood, 1968; Taylor *et al.*, 1969). The shoshonitic rocks may have a somewhat similar origin (Jakeš and White, 1969). As the word 'series' seems to imply a differentiation series and it is unlikely that the shoshonitic rocks are the differentiates of a single magma, it is preferable to refer to them as members of the shoshonite association.

In 1965 it was also pointed out that shoshonitic lavas are associated with regions that were incompletely stabilized or only recently stabilized at the time of their extrusion. This is in harmony with their geographical distribution with regard to the andesites in the island arcs.

Shoshonites and monzonites have a very similar composition and because many monzonites are associated with nepheline- and melanite-bearing rocks, with or without leucite, it was thought that they might be the undersaturated members of the shoshonite association (Joplin, 1964, 1965). Monzonites found with nepheline- and melanite-bearing types, however, appear to be confined to carbonatite complexes. The relation between shoshonites and carbonatites is not known.

In Wyoming, in Italy, and in Indonesia undersaturated shoshonitic rocks may contain leucite, so it would appear that the true undersaturated members of the association are leucite-bearing and not nepheline- or melanite-bearing as formerly suggested.

Like the alkali basalts, shoshonites may trend towards trachytes, and this is probably a differentiation process that takes place at high levels in the crust.

After re-examining the absarokite–shoshonite–banakite series from the type area, Yellowstone National Park, Wyoming, Nicholls and Carmichael (1969) concluded that these rocks had a tholeiitic aspect because some contained a siliceous glassy residuum. However, from the present study we conclude that there is a range in the composition of the glasses, that siliceous glasses are found only in the more felsic rocks and that they are more lime-rich than tholeiitic glasses. We have also shown that the clinopyroxenes exhibit almost no iron enrichment, and thus differ from those of the tholeiites and alkali basalts. During the course of this work several other minerals were analysed by electron-probe analysis.

Rocks from which chemical data were obtained. As most of the specimens available were very small, it was possible to make only a polished section for electron-probe analysis, and no chemical analysis of the whole rock was carried out. Where possible, small chips were obtained from type specimens that had been previously analysed and these analyses are shown in Table I together with one new analysis.

In only three rocks have all the principal mineral components been analysed. These rocks are a shoshonite and latite from Indonesia and a latite (vulsinite) from Italy. Glasses, clinopyroxenes, and several other minerals have been examined in a number of rocks from other localities.

Clinopyroxene occurs as phenocrysts in absarokites, shoshonites, and latites and is present in the groundmass of all members of the shoshonite association. In the latites, toscanites, and liparites orthopyroxene also occurs, commonly as phenocrysts and also in the groundmass. Only one orthopyroxene has been analysed. This occurs in a latite from the Lesser Sunda Islands (Table I, Anal. 6), and has the composition $En_{72}Fs_{25}Di_3$.

Table II shows that all the clinopyroxenes are rich in calcium and magnesium and relatively poor in iron. On fig. 1 it may be seen that, irrespective of the composition of the rocks in which they occur, the clinopyroxenes tend to cluster and are not strung out along a differentiation curve as are those in tholeiites and alkali basalts. Boesen (1964) found this same lack of differentiation trend among the clinopyroxenes of the monzonitic complex of Mount Dromedary.

Plagioclase. Absarokites contain plagioclase only in the groundmass, but all other members of the shoshonite association contain phenocrysts of this mineral. Phenocrysts are commonly rimmed with potassium feldspars.

Table III shows the composition of the feldspars in a shoshonite and two latites and it is obvious that very calcic plagioclase persists even in the groundmass of the latites, though a latite from the Lesser Sunda Islands contains calcic phenocrysts with a narrow rim of andesine. No toscanite was available for electron-probe analysis, but Washington (1897) has reported that andesine occurs in the groundmass of these rocks.

TABLE I. *Some of the rocks from which mineral data have been obtained*

	1	2	3	4	5	6
SiO_2	48·95	50·83	55·62	55·91	58·21	60·06
Al_2O_3	12·98	16·66	19·32	18·64	19·90	18·52
Fe_2O_3	3·63	1·52	2·20	2·06	4·07	2·21
FeO	4·68	6·64	4·37	4·32	0·87	2·57
MgO	11·73	6·08	2·60	2·71	0·98	1·55
CaO	7·66	10·99	6·91	6·87	3·58	5·30
Na_2O	2·31	2·66	3·76	3·81	2·57	3·63
K_2O	3·96	2·05	3·33	3·49	9·17	4·06
H_2O+	3·16	0·36	0·65	0·36	0·74	1·08
H_2O-			0·11	0·08	0·74	0·12
TiO_2	0·49	0·81	0·71	0·78	—	0·53
P_2O_5	0·67	1·61	0·52	0·43	—	0·39
MnO	0·13	0·12	0·13	0·18	—	0·09
CO_2	—	—	—	0·08	—	—
	100·35	100·33	100·23	99·72	100·09	100·11

1. Absarokite, Lamar River, Yellowstone National Park, U.S.A. Anal. L. G. Elkins (Iddings, 1899, p. 329, Spec. No. 1306).
2. Shoshonite (basalt) scoria, Stromboli, Italy, erupted Aug. 1914. Anal. H. S. Washington (Kozu and Washington, 1918).
3. Shoshonite (olivine basalt to trachybasalt), Lewololo, Lomben, Lesser Sunda Islands, Indonesia. Anal. E. F. Bouman (Brouwer, 1940, p. 48, Spec. NO. nr. 53).
4. Another part of the same specimen as analysis 3 and from which electron probe data was obtained. Anal. E. Kiss.
5. Latite (vulsinite), Bolsena, Italy. Anal. H. S. Washington (Washington, 1896, p. 565, Spec. No. 665)
6. Latite (amphibole–pyroxene andesite to trachyandesite), between Tokodjain and Lamawolo, Lesser Sunda Islands, Indonesia. Anal. E. F. Bouman (Brouwer, 1940, pp. 34 and 53, Spec. No. 52).

Other ferromagnesian minerals. Magnesian olivine occurs as phenocrysts and in the groundmass of absarokites and shoshonites and as rare phenocrysts in some latites. No iron-rich olivine has been noted in any member of the shoshonite association. Table IV shows that olivine in the shoshonite is a little less rich in magnesium than that of the absarokite.

Biotite may occur in the groundmass of absarokites and as phenocrysts, micro-phenocrysts and in the groundmass of all other members of the shoshonite association. Only two analyses of biotite have been made (Table V) and both appear to be a phlogopitic variety.

Amphibole phenocrysts are common in many latites and the one analysed (Table V) has the composition of a pargasite/ferrohastingsite.

TABLE II. *Clinopyroxenes*

	1	2	3	4	5	6	7	8	9	10
SiO_2	51·94	52·78	54·07	50·04	51·97	51·16	49·79	49·10	50·52	50·88
TiO_2	0·69	0·25	0·43	0·96	0·87	0·99	0·69	0·95	0·35	1·02
Al_2O_3	2·60	2·24	1·67	3·37	2·52	3·53	3·46	4·76	2·48	5·36
Fe_2O_3	—	—	—	2·05	—	0·46	—	—	—	1·21
FeO*	6·59	5·00	3·54	7·41	9·65	8·97	9·27	9·62	7·97	4·67
MnO	0·18	0·14	< 0·03	0·10	0·25	0·23	0·46	0·28	0·48	abs
MgO	15·20	15·67	16·75	14·59	15·10	14·88	16·04	13·07	16·18	13·78
CaO	22·49	23·56	23·14	20·34	19·57	19·17	20·01	21·47	20·60	22·96
Na_2O	0·33	0·22	0·22	0·61	0·40	0·41	0·32	0·27	0·54	0·50
K_2O	< 0·02	0·02	< 0·30	0·18	< 0·02	0·06	abs.	0·05	abs.	abs.
Sum	100·02	99·88	99·92	100·55	100·33	99·86	100·04	99·57	99·12	100·38
Analyses of pyroxenes recalculated on basis of six oxygen atoms:										
Si	1·92	1·94	1·97	1·88	1·93	1·90	1·86	1·85	1·90	1·86
Al^{iv}	0·08	0·06	0·03	0·12	0·07	0·10	0·14	0·15	0·10	0·14
Al^{vi}	0·03	0·04	0·04	0·03	0·04	0·06	0·01	0·06	0·01	0·10
Ti	0·02	0·01	0·01	0·03	0·02	0·03	0·02	0·03	0·01	0·03
Fe^{3+}	—	—	—	0·06	—	0·01	—	—	—	0·03
Fe^{2+}	0·20	0·15	0·11	0·23	0·30	0·28	0·29	0·30	0·25	0·14
Mn	0·01	—	—	—	0·01	0·01	0·01	0·01	0·02	—
Mg	0·84	0·86	0·91	0·80	0·84	0·82	0·89	0·73	0·91	0·75
Ca	0·89	0·93	0·90	0·81	0·78	0·76	0·80	0·87	0·83	0·90
Na	0·02	0·02	0·01	0·04	0·03	0·03	0·02	0·02	0·04	0·04
K	—	—	—	0·01	—	—	—	—	—	—
WXY	2·01	2·01	1·98	2·01	2·01	2·00	2·04	2·02	2·07	1·99
Composition, atomic percent:										
Ca	45·9	47·7	47·0	42·4	40·5	40·5	40·1	45·3	41·5	49·2
Mg	43·2	44·1	47·4	42·3	43·4	43·7	44·7	38·4	45·2	41·1
Fe	10·9	8·2	5·6	15·3	16·1	15·8	15·2	16·3	13·3	9·7

1. From absarokite, Lamar River, Yellowstone National Park, U.S.A. Anal. N. G. Ware (see Table I, Anal. 1).
2. From absarokite between Orangie Bay and Milne Bay, East Papua, T.P.N.G. Anal. N. G. Ware.
3. From absarokite between Orangie Bay and Milne Bay, East Papua, T.P.N.G. Anal. N. G. Ware.
4. From shoshonite (basalt) scoria, Stromboli, erupted Aug. 1914. Anal. H. S. Washington (see Table I, Anal. 2).
5. From shoshonite, south of Opal Creek, Yellowstone National Park, U.S.A. Anal. N. G. Ware (Iddings, 1899, p. 341, Spec. No. 1143).
6. From shoshonite, Port Kembla, N.S.W. Anal. T. G. Vallance.
7. From shoshonite (olivine basalt to trachybasalt), Lewololo, Lomben, Lesser Sunda Islands, Indonesia. Anal. J. R. Widdowson (see Table I, Anal. 4).
8. From latite (vulsinite), Bolsena, Italy. Anal. J. R. Widdowson (see Table I, Anal. 5).
9. From latite (amphibole-pyroxene andesite to trachyandesite), between Tokodjain and Lamawolo, Lesser Sunda Islands, Indonesia. Anal. J. R. Widdowson (see Table I, Anal. 6).
10. From toscanite breccia, Monterano, near Bracciano, Italy. Anal. H. S. Washington (Washington, 1897; Kozu and Washington, 1918).

* Electron-probe analyses, total iron as FeO (except nos. 4, 6, and 10).

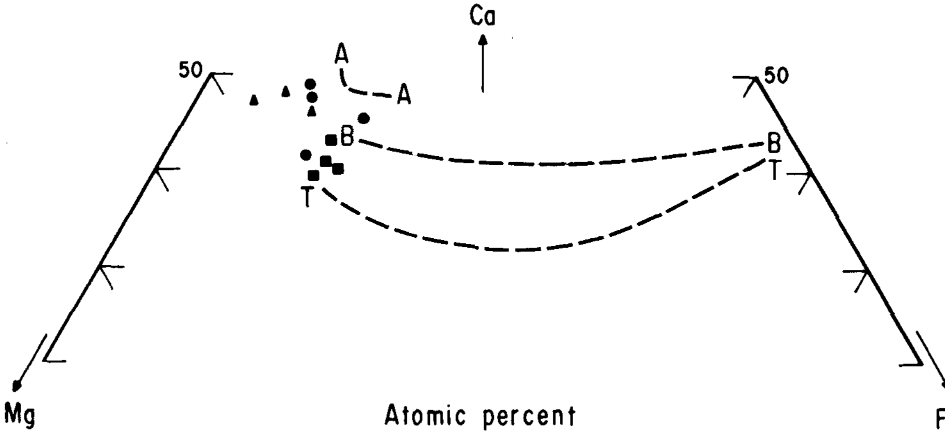

FIG. 1. Plot of analyses of clinopyroxene on a Ca–Mg–Fe atomic % diagram. Triangles are plots of pyroxene from absarokites, dots from shoshonities, and squares from latites. A–A (dashed line) is the differentiation trend of clinopyroxene in the undersaturated alkali basalt magma from Square Top, N.S.W. (Wilkinson, 1966b). B–B (dashed line) is the differentiation trend of clinopyroxene in the near-saturated alkali basalt magma in the Nandewar Mountains, N.S.W. (Abbott, 1969). T–T (dashed line) is the differentiation trend of clinopyroxenes in the Tasmanian theoleiites (McDougall, 1961).

TABLE III. *Plagioclase phenocrysts, microphenocrysts, and groundmass*

	1		2			3				
	a	b	a	b	c	a	b	c	d	e
SiO_2	47·34	53·18	48·45	48·23	51·10	47·12	48·77	58·51	53·30	54·66
Al_2O_3	33·19	29·35	32·72	31·80	29·66	33·03	32·70	25·76	29·67	27·30
Fe_2O_3	—	—	—	—	—	—	—	—	—	0·39
FeO*	0·75	0·83	0·63	0·72	0·79	0·70	0·74	0·70	0·87	0·25
MgO	0·04	0·04	0·01	0·01	0·01	0·04	0·04	0·04	0·04	< 0·01
CaO	16·75	11·49	17·11	15·66	13·06	15·93	13·83	8·49	12·77	12·72
Na_2O	1·41	4·22	1·97	2·77	3·96	1·94	3·30	5·84	3·93	2·96
K_2O	0·20	0·61	0·07	0·21	0·48	0·30	0·34	0·86	0·42	0·32
TiO_2	< 0·05	< 0·05	< 0·01	< 0·01	< 0·01	< 0·05	< 0·05	< 0·05	< 0·05	< 0·01
MnO	< 0·05	< 0·05	< 0·01	—	< 0·01	< 0·05	< 0·05	< 0·05	< 0·05	< 0·03
Sum	99·64	99·68	100·95	99·39	99·05	99·02	99·68	100·16	100·96	98·63

1. Plagioclase in shoshonite, Lomben, Lesser Sunda Islands, Indonesia. Anal. J. R. Widdowson (see Table I, Anal. 4).
   a: Bytownite ($Ab_{12.6}An_{86.3}Or_{1.1}$) phenocryst; b: Labradorite ($Ab_{37.1}An_{59.6}Or_{3.3}$) in groundmass.
2. Plagioclase in latite (vulsinite), Bolsena, Italy. Anal. J. R. Widdowson (see Table I, Anal. 5).
   a: Bytownite ($Ab_{16.5}An_{83.1}Or_{0.4}$) phenocryst; b: Labradorite ($Ab_{24}An_{74.9}Or_{1.1}$) core of microphenocryst; c: Labradorite ($Ab_{33.6}An_{63.6}Or_{2.8}$) margin or microphenocryst.
3. Plagioclase in latite (amphibole–pyroxene andesite to trachyandesite) between Tokodjain and Lamawolo, Lesser Sunda Islands, Indonesia (see Table I, Anal. 6). Anals. J. R. Widdowson (a–d) and E. Kiss (e).
   a: Bytownite ($Ab_{16.9}An_{81.3}Or_{1.8}$) inclusion in outer margin of zoned phenocryst; b: Labradorite ($Ab_{28.2}An_{69.6}Or_{2.2}$) core and greatest part of slightly zoned phenocryst; c: Basic andesine ($Ab_{50.7}An_{43.5}Or_{2.2}$) outer zone of phenocryst; d: Labradorite ($Ab_{33.4}An_{64.4}Or_{2.2}$) in groundmass; e: Labradorite ($Ab_{28.4}An_{67.7}Or_{1.9}$) phenocrysts and microphenocrysts (bulk composition).

* Electron-probe analyses, total iron as FeO (except 3e).

Opaques. Table IV also includes analyses of two titanomagnetites from each of three different rocks. Only the latite (vulsinite) from Italy shows any marked variation in composition between different grains. Pyrrhotine occurs as well as titanomagnetite in the latite from the Lesser Sunda Islands. These opaque minerals are present as microphenocrysts and as small grains in the groundmass.

TABLE IV. *Olivine and opaques*

	1	2	3		4		5	
			a	b	a	b	a	b
SiO_2	40·36	36·95	< 0·05	nd	< 0·05	nd	0·10	0·10
TiO_2	< 0·03	< 0·05	10·65	10·65	7·20	7·52	11·52	25·59
Al_2O_3	< 0·03	< 0·05	nd	4·49	nd	5·54	2·21	2·56
Cr_2O_3	nd	nd	nd	0·10	nd	0·06	—	—
FeO*	15·32	25·84	83·50	79·59	86·58	83·87	84·16	63·83
MnO	0·30	0·91	< 0·05	0·89	< 0·05	0·94	0·52	0·23
MgO	44·02	35·77	3·35	3·44	2·66	2·72	0·06	1·07
CaO	0·32	0·22	< 0·05	nd	< 0·04	nd	—	—
Na_2O	< 0·04	< 0·05	—	—	—	—	—	—
K_2O	< 0·02	< 0·04	—	—	—	—	—	—
Sum	100·32	99·67	97·50	99·16	96·44	100·65	98·57	93·38
	Fo = 77	Fo = 62						

1. Olivine from absarokite, between Orangie Bay and Milne Bay, East Papua, T.P.N.G. Anal. N. G. Ware.
2. Olivine from shoshonite (olivine basalt to trachybasalt), Lewololo, Lomben, Lesser Sunda Islands, Indonesia. Anal. J. R. Widdowson (see Table I, Anal. 4).

3 to 5. Opaques:

3. From shoshonite (olivine basalt to trachybasalt), Lewololo, Lomben, Lesser Sunda Islands, Indonesia. Anal. J. R. Widdowson (see Table I, Anal. 3).
4. From latite (amphibole-pyroxene andesite to trachyandesite), between Tokodjain and Lamawolo, Lesser Sunda Islands, Indonesia. Anal. J. R. Widdowson (see Table I, Anal. 6).
5. From latite (vulsinite), Bolsena, Italy. Anal. J. R. Widdowson (see Table I, Anal. 5).

* Electron-probe analyses, total iron as FeO.

Residual glass has been noted in all members of the shoshonite association, but in the absarokites it is rarely fresh. Iddings (1895) reported interstitial glass in a number of rocks from Yellowstone Park, and through the kindness of Dr. H. H. Banks, *Jr.*, we were able to examine a number of chips from type rocks described by Iddings and now housed in the Smithsonian Institution, Washington, U.S.A. High magnification showed most of the interstitial material in the absarokites was either devitrified glass, very fine potassium feldspar, or zeolites. One Cainozoic absarokite from Papua contained fresh glass, but in other Papuan absarokites the interstitial material showed devitrification, opalization, or zeolitization (Table VI).

Table VI gives analyses of five glasses from rocks ranging from absarokites to latites. These are plotted on a $CaO–Na_2O–K_2O$ diagram (fig. 2). It is customary to plot the composition of residual glasses on a Qtz–Ab–Or diagram, but this was not used for three reasons. In the first place, analyses in Table VI were made by electron probe, thus Fe_2O_3 was not estimated, so normative quartz is low as the whole of FeO is calculated as a silicate. A valid comparison therefore could not be made between glasses that have been analysed by electron probe and those analysed by other methods.

TABLE V. *Micas, an amphibole, and various interstitial materials*

	1	2	3
SiO_2	40·73	37·22	42·24
TiO_2	3·18	3·77	2·61
Al_2O_3	12·70	15·23	11·16
FeO*	6·61	11·69	12·14
MnO	0·33	0·14	0·29
MgO	23·12	17·42	14·32
CaO	—	—	11·39
Na_2O	0·47	1·28	2·21
K_2O	9·59	9·17	1·21
Sum*	96·73	95·92	97·57
Atomic ratios:†			
Si	5·76	5·46	6·27
Al^{iv}	2·12	2·54	1·73
Ti	0·12	—	—
Σ(iv)	8	8	8
Al^{vi}	—	0·09	0·22
Ti	0·21	0·42	0·29
Fe	0·78	1·43	1·51
Mn	0·04	0·02	0·04
Mg	4·87	3·81	3·17
Σ(vi)	5·90	5·77	5·23
Ca	—	—	1·81
Na	0·13	0·36	0·64
K	1·73	1·72	0·23
Σ	1·86	2·08	2·68

	4	5	6	7	8
SiO_2	65·74	63·89	66·10	51·77	62·89
TiO_2	0·26	—	0·61	0·91	0·03
Al_2O_3	19·00	19·71	19·21	17·17	21·30
FeO*	0·32	0·49	0·77	9·73	0·04
MnO	0·03	—	0·03	0·04	0·03
MgO	0·03	—	0·34	2·72	0·03
CaO	1·01	1·13	0·68	6·27	0·35
Na_2O	3·69	3·38	4·75	1·35	6·62
K_2O	10·24	10·22	7·44	2·04	0·02
Sum*	100·29	98·82	99·90	92·00	91·16
Quartz	2·46	2·04	8·70	11·58	23·76
Orthoclase	60·60	60·60	43·92	11·68	—
Albite	31·44	28·82	39·82	11·00	56·07
Anorthite	5·56	5·56	3·61	31·41	1·39
Corundum	—	0·92	1·02	1·43	9·89
Hypersthene	—	0·92	—	23·04	—
Ilmenite	0·46	—	1·22	1·67	—

* Electron-probe analyses, total iron as FeO, H_2O not determined.

† Atomic ratios of micas on a basis of 22 oxygen, of the amphibole on a basis of 23.

1. Phlogopite from latite (vulsinite), Bolsena, Italy. Anal. J. R. Widdowson (see Table I, Anal. 5).
2. Phlogopite from latite (amphibole–pyroxene andesite to trachy-andesite) between Tokodjain and Lamawolo, Lesser Sunda Islands, Indonesia. Anal. J. R. Widdowson (see Table I, Anal. 6).
3. Pargasite–ferrohastingsite from same rock as 2. Anal. J. R. Widdowson.
4. K-feldspar ($Or_{62\cdot1}Ab_{32\cdot2}An_{5\cdot7}$) from absarokite, Lamar River, Yellowstone National Park, U.S.A. Anal. N. G. Ware (see Table I, Anal. 1).
5. K-feldspar ($Or_{63\cdot9}Ab_{30\cdot3}An_{5\cdot8}$) from latite (vulsinite), Bolsena, Italy. Anal. J. R. Widdowson (see Table I, Anal. 5).
6. (?) Devitrified glass from shoshonite, Yellowstone National Park, U.S.A. Anal. N. G. Ware (Type Spec. 1143, Iddings, 1899, p. 1143).
7. (?) Devitrified and zeolitized glass from absarokite, between Orangie Bay and Milne Bay, East Papua, T. P. N. G. Anal. N. G. Ware.
8. (?) Zeolitized, opalized and kaolinized glass from absarokite, between Orangie Bay and Milne Bay, East Papua, T.P.N.G. Anal. N. G. Ware.

Secondly, pantellerite glasses cannot be plotted accurately on a Qtz–Ab–Or diagram because Na_2O is so high that there is an excess over both Al_2O_3 and Fe_3O_3 and this is calculated as sodium metasilicate and not taken into account in the diagram. Finally, it is obvious that calcium is an important constituent of the shoshonitic glasses and should be taken into account.

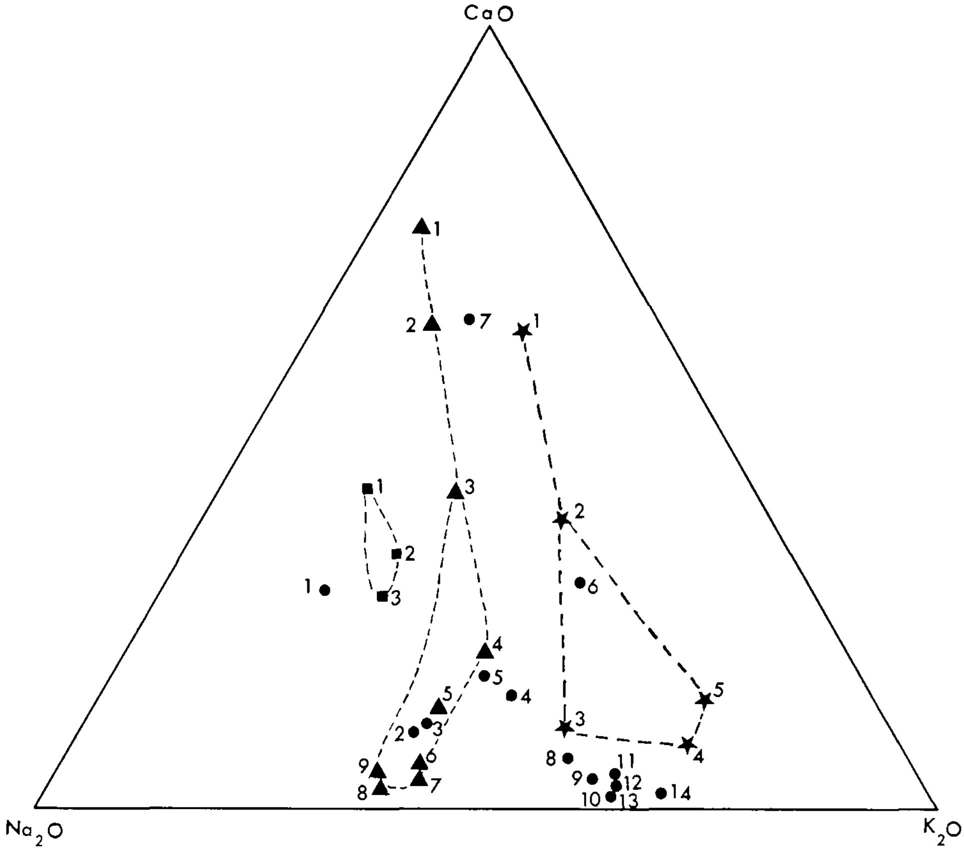

FIG. 2. Plot of residual glasses on a CaO–Na_2O–K_2O diagram. Stars are the plots of glasses from rocks of the shoshonite association and numbers refer to analyses in Table VI. Triangles are plots of glasses in alkali basalts. 1 = average of three tachylytes, Macquarie Island (Mawson, 1943), 2 – glass from olivine basalt, Cooktown, Queensland (Morgan, 1968), 3 – mugearite glass, Nandewar Mountains, N.S.W. (Abbott, 1968), 4 – glass from alkali basalt, Guyra, N.S.W. (Wilkinson, 1966a), 5 = glass from nepheline basanite, Inverell, N.S.W. (Wilkinson, 1966a), 6–9 = glasses from pantellerites (Carmichael, 1962). Squares are plots of glasses from normal andesites in the Hunter River Valley, N.S.W. 1 and 3 – glasses from pyroxene andesites, Stanhope, N.S.W., 2 = glass from andesitic ignimbrite, Port Stephens, N.S.W. (Wilkinson and Whitten, 1964). Circles are plots of glasses from tholeiitic rocks. 1–4 = from Iceland (Carmichael, 1963), 5 – from Eskdalemuir, Scotland (Elliott, 1956), 6 = from Kap Daussy, Greenland (Vincent, 1950), 8–14 = from Makaopuhi, Hawaii (Evans and Moore, 1968).

Fig. 2 shows that the normal andesite and alkali-basalt glasses contain less potassium than the shoshonitic glasses and that each group occupies a somewhat restricted field. On the other hand, tholeiitic glasses show a good deal of scatter, some occupying the fields of the alkali basalts and of the shoshonites. Some tholeiite glasses contain as much potassium as those of the shoshonite association, but are distinct from them in containing less calcium.

Other interstitial materials. In all members of the shoshonite association the most important interstitial material is potassium feldspar. Table V gives analyses of two potassium feldspars from rocks of different composition and from different parts of the world, yet there is little difference in the composition of the two feldspars.

The other three analyses in Table V are of materials that may have originally been glass; they now consist of zeolites or of mixtures of zeolites, opal, and kaolin. The low summations may be accounted for by the fact that water has not been estimated in these very hydrous materials.

TABLE VI. *Glasses**

	1	2	3	4	5
SiO_2	58·12	64·18	65·8	74·87	75·31
Al_2O_3	19·23	16·94	16·2	13·88	13·51
FeO	0·43	3·21	1·9	2·05	1·54
MgO	1·14	0·78	0·23	nd	1·64
CaO	4·10	4·77	1·3	0·77	1·07
Na_2O	1·34	2·94	4·5	2·14	1·49
K_2O	2·20	5·08	6·3	6·18	4·79
TiO_2	0·89	0·29	1·2	nd	0·16
MnO	0·14	0·09	0·04	0·05	0·03
Cl	—	0·51	—	0·33	—
Sum	97·59	98·79	97·5	100·22	99·51

1. From absarokite, between Orangie Bay and Milne Bay, East Papua, T.P.N.G. Anal. N. G. Ware.
2. From shoshonite, Lewololo, Lomben, Lesser Sunda Islands, Indonesia (see Table I, Anal. 4). Anal. J. R. Widdowson.
3. From shoshonite, Yellowstone National Park, U.S.A. (Nicholls and Carmichael, 1969). Anals. I. S. E. Carmichael and J. Hempel.
4. From latite, between Tokodjain and Lamawolo, Lesser Sunda Islands, Indonesia (see Table I, 6). Anal. J. R. Widdowson.
5. From latite (vulsinite), Viterbo Region, Italy. Anal. N. G. Ware.

* Electron-probe analyses; total iron as FeO, H_2O not determined.

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