

FIRST FIND OF ALKALIC MELANOCRATIC MINERALS IN LATE
CENOZOIC LAVAS OF KAMCHATKA ¹

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Among Late Cenozoic lavas of the Central Range, Kamchatka, are extrusive domes, subvolcanic intrusions and dikes, composed of trachyte and comendite and emplaced in closing stages of evolution of large Pliocene-Quaternary basalt and andesite-basalt stratovolcanoes in the rear zone of the Central Kamchatka volcanic belt [1-3]. Basalts and andesite-basalts of these old stratovolcanoes also are relatively alkalic and, together with silicic rocks, constitute one alkalic olivine basalt-trachyte-comendite series. All its rocks are high in alumina, so their agpaite coefficient (a. c.) generally is less than one even in rhyolite and exceeds unity only in subaphyric varieties. In trachyte, though, this coefficient in the rock matrix may exceed unity—a trend that indicates the agpaite mode of magma differentiation and, perhaps, the presence of alkalic melanocratic minerals in the lava matrix [4]. Indeed, detailed microscopic examination of crystalline phases of alkalic rhyolite and their analysis with the Camebax electron microprobe in the Far Eastern Institute of Volcanology revealed these very minerals in both porphyritic and aphyric rock varieties.

Porphyritic alkalic rhyolite from the Belogolovaya paleovolcano has an a. c. of less than one, despite its alkali-metal oxide content of more than 10 percent. Phenocrysts in it are composed of sodic sanidine and manganoferroaugite; the matrix consists of sanidine, quartz and small quantities of manganoferroaugite, ilmenite and titanomagnetite. Near edges of some clinopyroxene phenocrysts and among microlites are deep-green segregations of sodic manganoferrohedenbergite and manganese aegirine-augite (Table 1). The compositional change from central phenocryst zones to the marginal is gradual. Thus, the sodium-iron pyroxenes studied are end members of one evolutionary series of clinopyroxenes of variable composition and present in all rock types from mafic to silicic (Fig. 1). The crystallization temperature of minerals of the rhyolite matrix, as determined from the Buddington-Lindsley geothermometer, is 680° C for $P_{O_2} = 10^{-18.7}$ atm. On the whole, clinopyroxenes from Late Cenozoic alkalic lavas of the Central Range, Kamchatka, are similar in evolutionary trend (Fig. 1) to those from alkalic lavas of Dogo Island, western Japan [5], which are of comparable age and occupy a geologically analogous position. In the Dogo Island lavas, though, sodic clinopyroxenes occur in the matrix of trachyte and quartz trachyte, whereas alkalic amphiboles are characteristic of the matrix of alkalic rhyolite.

In the studied rock association, alkalic amphiboles also were found in the matrix of alkalic rhyolite lavas, but only in subaphyric varieties with a. c. ≥ 1 in the Nyul-kandya paleovolcano. The only phenocrysts in these lavas consist of sodic sanidine and titanium biotite; the matrix is composed chiefly of laths of potassiodic feldspar and quartz. Sporadic alkalic amphibole segregations no larger than 0.05 to 0.08 mm are commonly associated with ilmenite and titanomagnetite and generally are anhedral relative to feldspar. Amphibole exhibits intense pleochroism from deep blue-green to orange-yellow and anomalous extinction. The crystallization temperature of matrix minerals, as determined from the Buddington-Lindsley geothermometer, is 800° C for $P_{O_2} = 10^{-15}$ atm. They crystallized, just like minerals in the matrix of porphyritic rhyolite at an oxygen partial pressure close to that of the quartz-fayalite-magnetite buffer.

All the studied minerals, as far as their chemical composition is concerned, are high in alkalis and manganese, but low in aluminum, and contain variable quantities of calcium, magnesium and iron (Fig. 2). On the classification diagram for alkalic amphiboles [6], our samples fall mainly into two fields: 1) arfvedsonite-riebeckites

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Fig. 1. Compositional variations of clinopyroxenes from alkalic lavas of the Central Range, Kamchatka, in the system Mg-Fe-Na: 1 to 4) points for clinopyroxenes from 1) alkalic olivine basalt, 2) trachyte and 3, 4) trachyrhyolite and comendite [3] crystal cores, 4) outer zones]; 5, 6) crystallization trends of clinopyroxenes from 5) alkalic lavas, Central Range, Kamchatka, and 6) trachyte and quartz trachyte, Dogo Island, western Japan [5]; 7) field of clinopyroxenes from trachybasalt, Dogo Island [5].

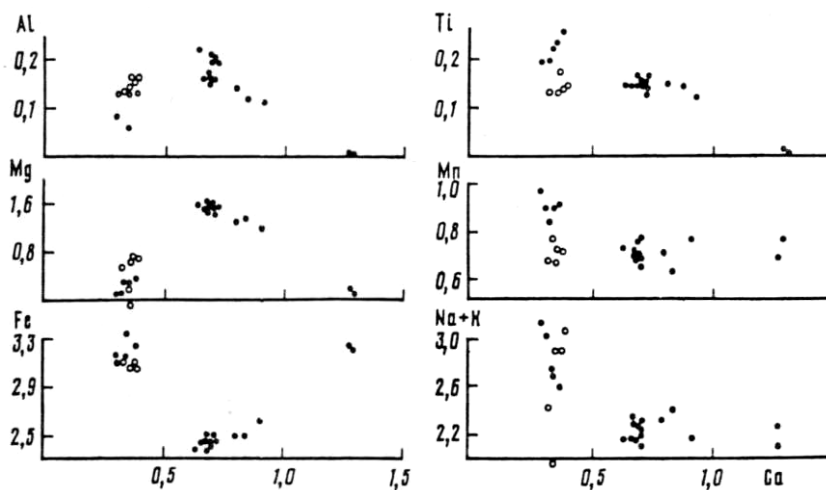


Fig. 2. Compositions of amphiboles from the matrix of comendite lavas of the Central Range, Kamchatka. Empty and filled circles denote amphiboles from different lava samples.

($Ca < 0.5$ per formula unit, $Al < 0.5$); II) richterites, calcium riebeckites, sodium tremolites ($0.5 < Ca < 1$, $Al < 0.25$). However, there also are amphiboles that are still higher in calcium (1.28 to 1.29 per formula unit with $Al = 0$) and, despite their high alkali content, fall into the field of subcalcic varieties. In cation content of group X + A [6], our arfvedsonite-riebeckites may be divided (Table 1) into arfvedsonite, arfvedsonite-riebeckite and riebeckite, although arfvedsonite is clearly predominant. Amphiboles of field II, judging by their alkali and calcium content [7], should be classified as richterites (Table 1). Nevertheless, the calcium content of richterite may increase to 1.5 per formula unit [7], so the subcalcic amphiboles studies could be classified as calcic richterites. Such an assumption is confirmed by data of Fig. 2, where their points complete the cluster for amphiboles of the richterite series. On the other hand, analysis of the same diagram shows that among our samples there are no amphiboles intermediate in composition between arfvedsonite-riebeckite and richterite.

Thus, Late Cenozoic comendite lavas of Kamchatka contain alkalic amphibole of two isomorphous series: arfvedsonite-riebeckite and richterite-calcic richterite. In specific samples, though, we observed arfvedsonite associated either with arfvedsonite-riebeckite and riebeckite, or with richterite and calcic richterite.

Table 1

Compositions of alkalic melanocratic minerals in Late Cenozoic comendite lavas of the Central Range, Kamchatka

Ser. No.	Sp. No.	SiO ₂	TiO ₂	Al ₂ O ₃	FeO	MnO	MgO	CaO
1	6295/1	48,4	0,18	0,11	25,8	3,37	2,31	15,7
2		49,5	0,30	0,05	26,8	2,61	1,80	13,9
3	6407	52,0	1,43	0,74	26,5	5,72	0,95	2,07
4		51,8	1,02	0,68	23,1	4,98	2,32	1,90
5		51,1	1,13	0,86	23,1	5,19	2,99	2,21
6	6442	50,5	1,79	0,56	23,6	6,59	0,93	1,95
7		51,3	1,17	0,92	18,9	5,39	6,48	4,38
8		51,1	0,54	0,00	24,1	5,39	0,64	7,50

Table 1 (end)

Ser. No.	Sp. No.	Na ₂ O	K ₂ O	H ₂ O	<i>e</i>	<i>n</i>	MI	X + A
1	6295/1	1,81	0,00	–	97,68	3	87,7	–
2		3,50	0,00	–	98,46	6	90,2	–
3	6407	5,53	1,30	1,88	98,12	1	95,0	2,32
4		7,08	1,19	1,86	95,93	1	87,2	2,78
5		8,77	1,33	1,89	98,57	3	84,2	3,34
6	6442	8,24	1,28	1,86	97,30	5	94,9	3,18
7		6,72	1,16	1,93	98,35	13	67,8	2,98
8		7,14	0,02	1,88	98,31	2	96,2	3,50

Note. 1) sodic manganoferrohedenbergite; 2) manganoeigirine-augite; 3) manganoriebeckite; 4) manganoarfvedsonite-riebeckite; 5, 6) manganoarfvedsonite; 7) manganorichterite; 8) calcic manganorichterite; *n*) number of analyses for calculation of mean; MI) mafic index, at. percent; X + A) cation concentration (in f.u.) in that position; FeO) total iron content; H₂O) calculation based on computer program. Deficit of sums in amphibole analyses could be due to the sizable fluorine content of samples.

A combination of low- and high-calcium amphiboles in the same rock type is characteristic of many alkalic granites of Mongolia (i.e., riebeckite and kataphorite [6]), as well as of pantellerites of British Columbia (arfvedsonite and kataphorite [8]) and elsewhere. Arfvedsonite-riebeckite amphiboles have been found in young granites of Nigeria, in some alkalic granites of Mongolia [6], in alkalic rhyolites of western Japan [5], and in alkalic trachytes and comendites of southeastern Australia [9]. Richterite, in turn, has been described in phenocrysts and microlites from pantellerites of Kenya [6].

The distinguishing feature of our amphiboles is their very high manganese content (4.7 to 7 percent MnO in separate grains), so the prefix "mangano" should be added to their names. Such high-manganese amphiboles have so far been described only in certain metamorphosed limestones and pegmatites [7] and are still unknown in alkalic granite and rhyolite [6, 8]. We should note, too, that manganese enrichment of amphiboles is systematically accompanied by relatively high manganese concentrations in other melanocratic minerals of the alkalic rhyolite lavas studied.

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