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HALOGENS IN MICAS OF VOLCANIC ROCKS OF THE KURILE-KAMCHATKA ISLAND-ARC SYSTEM[1]

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The role of volatiles in island-arc magma generation is widely discussed in the geologic literature. Two of the most important volatile mineralizers are fluorine and chlorine, whose principal accumulator minerals in igneous rocks include mica. We used the X-ray spectroscopic method to study the distribution of these elements in micas from 83 samples of volcanic rocks of the Kurile-Kamchatka island-arc system.

Among the Late Cenozoic volcanics here, we can distinguish the following geochemical rock series [1]: slightly potassic, moderately potassic, highly potassic, calcalkalic and subalkalic, shoshonite-latite, lamproite-type potassic basalt and alkalic olivine basalt-trachyte-comendite. No mica phenocrysts were found in lavas of the slightly potassic series or in moderately potassic lavas of the frontal zone of the island-arc system. However, they are fairly abundant in silicic and intermediate lavas of the moderately and highly potassic series of the rear zones of the Kuriles and southern and eastern Kamchatka, the moderately and highly potassic series of the Central Kamchatka Range, the alkalic olivine basalt-trachyte-comendite series of this region, and the shoshonite-latite series of the same Central Range, the Kamchatka Isthmus and western Kamchatka. They also sometimes occur in highly potassic subalkalic basalts of the Kuriles and Kamchatka and are widespread in trachybasalts, subvolcanic shonkinites and syenites of the lamproite series of western Kamchatka. We should emphasize that lavas in slightly, moderately and highly potassic series of all regions, as well as in the shoshonite-latite series of the Central Range and the Kamchatka Isthmus, have geochemical properties typical of island-arc extrusives, whereas lavas of the alkalic olivine basalt-trachyte-comendite series of the Central Range and the shoshonite-latite and the lamproite series of Western Kamchatka should be regarded as postsubduction and rift varieties [1, 2].

Fluorine and chlorine concentrations in the micas were determined in the Ural Institute of Geology and Geochemistry with the JXA-5 electron microprobe. The procedure has already been stated [3]. Two to four mica grains were analyzed in each sample, and three to 10 determinations made on each grain. Average fluorine and chlorine concentrations were successively calculated first for individual grains, then for all grains in each sample and finally, by the "average of averages" method, for rocks of each geochemical series in each specific region.

That fluorine and chlorine concentrations both in individual grains of each sample and in individual samples of each series vary significantly is due chiefly to the disequilibrium conditions of magma crystallization. Fluorine and chlorine concentrations in different grains of the same sample usually differ by a factor of 1.5 to 2, although sometimes the difference is still higher (three - to fivefold). There are zoned grains whose fluorine content decreases markedly from the center outward (over threefold in high-potassium rhyolite from the Bol'shaya Ketepana volcano), or increases (1.5–fold in quartz latite from the Kamchatka Isthmus). Their chlorine content also varies in the same direction, but less contrastingly. Nevertheless, as calculated from data of independent control determinations run at different times, the average concentrations of fluorine in micas from the same sample do not differ by a factor of more than 1.2 to 1.5, and those of chlorine are virtually identical.

Despite such variations, the differences in fluorine and chlorine content on the whole are stable, as are the Cl/F ratios in micas from rocks of the different geochemical series (Table 1). As the K/(K + Na) of rocks increases from lavas of the calcalkalic series to those of the shoshonite-latite and to potassic basalts of the lamproite series, the fluorine content of micas successively increases while their chlorine content and Cl/F ratio decrease. The range of variation in the fluorine and chlorine content of micas from rocks of the different series is as wide as 1.5 orders

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Table 1

Halogen concentrations in micas from Late Cenozoic volcanics of the Kurile-Kamchatka island-arc system

Region	Petro-chemical series	SiO_2 rock type	*n*	Fluorine, wt.%	Chlorine, wt. %	Chlorine/ fluorine
Kurile Islands	MP and HP CA	I, S	9	0,07 / 0,01–0,16	0,15 / 0,08–0,25	2,14 / 0,80–8,00
	HP SA	M	2	1,35 / 1,23–1,47	0,06 / 0,06–0,06	0,04 / 0,04–0,05
Southern and eastern Kamchatka	MP and HP CA	S	11	0,31 / 0,02–0,098	0,11 / 0,05–0,16	0,35 / 0,16–2,50
	HP SA	M	1	0,93 / –	0,04 / –	0,04 / –
Central Kamchatka Range	MP and HP CA	S	15	0,56 / 0,22–1,03	0,07 / 0,04–0,09	0,13 / 0,04–0,36
	ABTC	I, S	13	0,74 / 0,33–1,62	0,04 / 0,02–0,07	0,05 / 0,02–0,09
	SL	S	4	2,25 / 1,41–2,88	0,05 / 0,03–0,06	0,02 / 0,02–0,02
Kamchatka Isthmus	SL	I, S	3	1,72 / 0,55–3,87	0,07 / 0,04–0,10	0,04 / 0,03–0,11
Western Kamchatka	SL	I, S	6	0,37 / 0,19–0,56	0,03 / 0,02–0,03	0,08 / 0,04–0,16
	PB	M, I	19	1,40 / 0,65–2,48	0,01 / 0,00–0,03	0,01 / 0,00–0,03

Note. Abbreviations: rock series – MP) moderately potassic, HP) highly potassic, CA) calcalkalic, SA) subalkalic, ABTC) alkalic olivine basalt-trachyte-comendite, SL) shoshonite-latite, PB) potassic basalt (lamproitic); SiO_2 rock type – M) mafic, I) intermediate, S) silicic. Numbers in numerator) average value, in denominator) range; *n*) number of samples.

even for average values. Moreover, micas from lavas of the same geochemical series in different regions of the Kurile-Kamchatka island-arc system may differ markedly in the concentration level of fluorine and chlorine, as illustrated by micas from intermediate to silicic lavas of the moderately and highly potassic calcalkalic series of the Kuriles, southern and eastern Kamchatka, and the Central Range.

There also are differences in fluorine and chlorine content of micas from mafic to silicic rocks of the same series or series of similar alkalinity in the same region. Thus, micas from basalts of the highly potassic subalkalic series of the Kuriles and eastern Kamchatka are much higher in fluorine and lower in chlorine than micas from intermediate to silicic lavas of the moderately and highly potassic calcalkalic series in these regions. In structurally more complex potassic basalt bodies of western Kamchatka, though, the chlorine concentration remains virtually constant while their fluorine content regularly increases from the more mafic to the more silicic (and more potassic) differentiates, i.e., from about 1.1 or 1.2 percent in trachybasalt and shonkinite to about 1.4 percent in syenite with a basalt level of silica content and to about 1.6 or 1.7 percent in syenite with the andesite-basalt and the andesite silica levels.

On our paired correlation diagram for fluorine and chlorine concentrations in micas (Fig. 1), several fields can be distinguished on the basis of rock composition and the regional criterion. Fields I to III correspond to micas from intermediate and silicic rocks of the calcalkalic series, exposed in the Kurile-Kamchatka island-arc system in the Kuriles (I), in southern and eastern Kamchatka (II), and in the Central Range (III); field IV unites micas from intermediate and silicic lavas of the subalkalic and alkalic series. Finally, field V corresponds to micas from potassic basalts of the lamproite series. From fields I to V, the fluorine content of micas on the whole increases while their chlorine content decreases, although within each field their fluorine concentration generally varies in direct proportion to the chlorine.

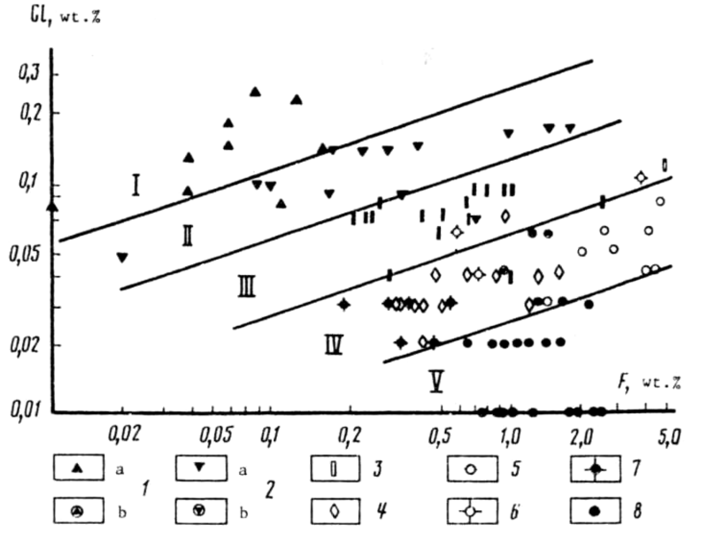

Fig. 1. Relationship between chlorine and fluorine in micas: *1)* Kurile Islands — a, b) intermediate and silicic rocks of moderately and highly potassic calcalkalic series, respectively; *2)* southern and eastern Kamchatka — a) silicic rocks of moderately and highly potassic calcalkalic series, b) mafic rocks of highly potassic subalkalic series; *3* to 5) Central Kamchatka Range — *3)* silicic rocks of moderately and highly potassic calcalkalic series, *4)* intermediate and silicic rocks of alkalic olivine basalt-trachyte-comendite series, 5) silicic rocks of shoshonite-latite series; *6)* Kamchatka Isthmus — intermediate and silicic rocks of shoshonite-latite series; *7, 8)* western Kamchatka — *7)* intermediate and silicic rocks of shoshonite-latite series, *8)* mafic and intermediate rocks of potassic basalt (lamproite) series. *I* to *V)* fields of composition of micas from lavas of different regions and geochemical series.

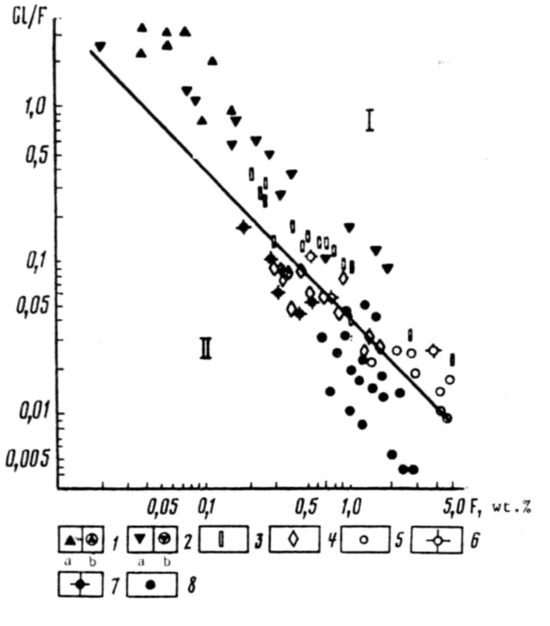

Fig. 2. Relationship between Cl/F ratio and fluorine content of micas. *1* to *8*) same as in Fig. 1. *I, II*) fields of composition of micas from rocks of island-arc (I) and nonisland-arc (*II*) volcanic series.

Differences in the fluorine and chlorine content of micas both from rock series differing in alkalinity and from the same calcalkalic series in different parts of the Kurile-Kamchatka island-arc system are due primarily to the level of fluorine and chlorine concentration in the magma chamber. Knowing their partition coefficient for the pairs melt-fluid and mica-melt [4-6], we can very roughly estimate the halogen concentration in the melt and, hence, the ore potential of volcanic rocks for fluorophile and chlorophile groups of ore elements.

A noteworthy feature in this sense is that micas from lavas of island-arc volcanic series proper are higher in chlorine and have higher Cl/F ratios than those of nonisland-arc series, but contain the same amount of fluorine (Fig. 2). The boundary between these two mica groups coincides with a chlorine content of about 0.4 percent

It was presumed earlier [1, 2] that the fluid involved in island-arc magma generation contains volatiles released during dehydration of the subducted plate and is enriched somewhat in seawater components, including chlorine. Data on variations in the chlorine content and Cl/F ratio of micas are not inconsistent with this assumption. On the other hand, the gradual increase in fluorine and decrease in chlorine concentrations and Cl/F ratios in micas from intermediate to silicic lavas of the calcalkalic series of the same age, from the Kuriles across eastern and southern Kamchatka to the Central Range (Table 1, Fig. 1), could be due to the fact that such lavas are confined to regions whose substrates differ in composition at the magma-generating level. At the same time, this trend could reflect a change in fluid composition, particularly a decrease in the fraction of seawater components, as the Kurile-Kamchatka island-arc system became successively more stable.

Thus, the composition and concentrations of volatiles in minerals can be used to reconstruct the geodynamics of volcanic rock formation.

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