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Spectrographic Distribution of Minor Elements in the Quartzs and Feldspars Contained in Granites and Pegmatites of the Oku-Tango District, Kyoto Prefecture

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Abstract

The distribution of minor elements in quartzs and feldspars of granite and pegmatite in the Oku-Tango district, Kyoto Prefecture is studied by spectrographic method.

Ti, Al, Mg, Na and Sn are detected in all quartzs, while Ca and Ag in a small number of quartzs. Ba, Sr, Pb, Mn, Mg, Ti, Sn, V and Ag are detected in feldspars.

The following interesting facts about the distribution of minor elements in quartzs and feldspars are found:

(1) Both quartz and feldspar of pegmatite are, in general, chemically purer than those of its parent rock (granite).

(2) Lead only is most abundant in the potash feldspars of pegmatite.

The results are discussed from the petrological, mineralogical and geochemical standpoints.

Introduction

The distribution of minor elements in minerals and rocks has been studied, particularly in Europe, almost exclusively from the view-point of geochemical distribution, but the writer has studied, mainly from the purely petrological standpoint, the distribution of minor elements in the quartzs and feldspars contained in pegmatites and their parent rock (granite) of the Oku-Tango district, Kyoto Prefecture in order to make clear how minor elements in magma behaved in the process of evolution from granite to pegmatite.

In this province granites are mainly coarse or medium-grained biotite granites, but, in the south of Yuwaya and Nishitani, they are partly hornblend-bearing biotite granites, and all pegmatites are distributed in biotite granites as shown in Fig. 1.

Samplings

Black spots on Fig. 1 locate the samples. Pegmatite samples were collected at Ōro, Nagaoka, Kōbe, Taniuchi, Mié and Morimoto.

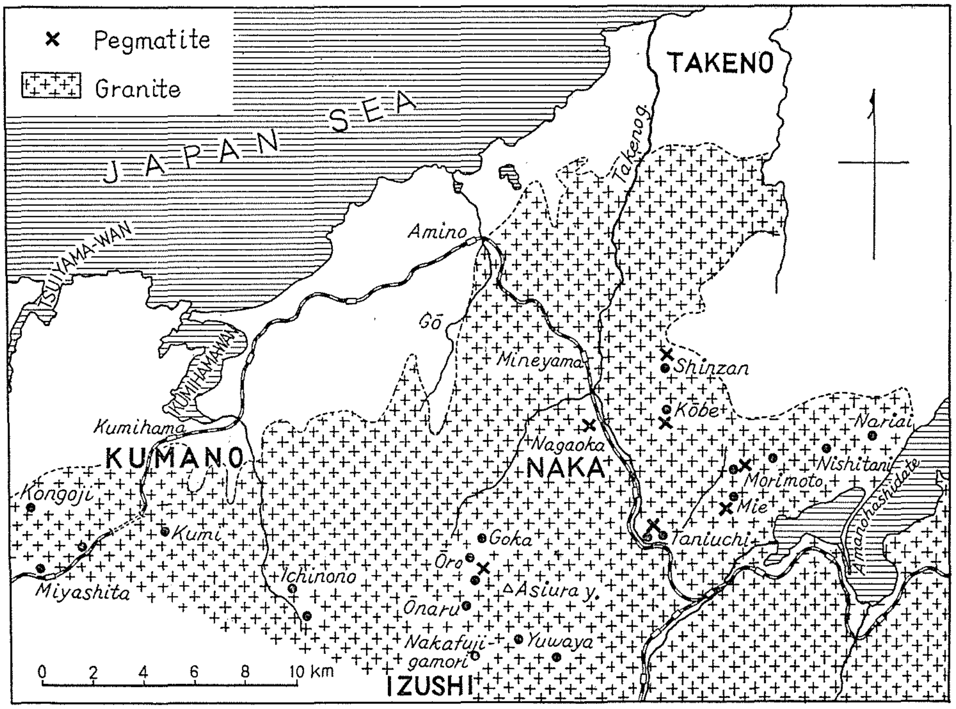

Fig. 1 Locations for samples

The samples of feldspar and quartz, after being passed through a 70 mesh sieve, were caught on a 120 mesh sieve, and only the pure particles, thus got, were picked out with a pointed, moist needle under the microscope.

Spectrographic examination

Using a Hilger E_2 type spectrograph with a focal setting 2380–4500Å and a Hilger D type spectrograph with a focal setting 4030–6680Å, the material was arced between carbon electrodes for 45 seconds at 10 Amp., 220V.

Table 1 and 2 list the results of the analyses. As the spectrographic sensitivities of the elements have many varieties, the intensities can be used for comparison in each separate element only. A notation nd means that the elements were present in a quantity below the detection limit when this particular method was used.

The detected minor elements are: Ba, Sr, Pb, Mn, Mg, Ti, Sn and V in feldspars; Ti, Al, Mg, Na, Sn, Ca and Ag in quartzs. And the following elements are not detected in both samples: Ni, Co, Cr, Zn, Cd, Sb, Mo, Cb, Ta, Li, Rb, Ge, Ga, Tl, Sc, Cs and the rare earths.

TABLE 1 Spectrograhpic analysis of quartzs
(relative intensities using an arbitrary scale 1-10)

Sample no.	Ti	Al	Mg	Na	Sn	Ca	Ag
G. 1	6	9	10	5	nd	8	nd
G. 2	7	7	9	3	nd	10	nd
G. 3	5	9	7	5	1	nd	nd
G. 4	4	9	7	8	1	9	nd
G. 5	5	9	7	8	1	nd	nd
G. 6	7	7	6	5	1	6	ud
G. 7	6	8	6	3	1	nd	nd
G. 8	5	8	6	3	1	nd	nd
G. 9	5	9	5	3	2	nd	nd
G. 10	5	8	5	5	7	nd	nd
G. 11	5	9	4	5	nd	nd	nd
G. 12	4	9	4	5	nd	nd	nd
G. 13	5	9	4	3	1	nd	nd
G. 14	3	9	2	3	1	nd	nd
P. 1	5	8	3	3	1	nd	nd
P. 2	3	7	3	3	1	nd	nd
P. 3	6	7	2	3	1	nd	nd
P. 4	3	6	2	3	1	1	nd
P. 5	3	7	2	3	1	nd	nd
P. 6	1	7	2	3	nd	4	nd
P. 7	3	6	2	3	1	nd	nd
P. 8	5	7	2	3	1	nd	nd
P. 9	5	6	2	3	1	nd	4
P. 10	6	9	2	3	1	nd	nd
P. 11	4	8	2	3	nd	nd	nd
P. 12	4	7	2	3	1	nd	nd

G. 1	the quartz of the granite at Yuwaya village
G. 2	the quartz of the granite at Kōbe village
G. 3	the quartz of the granite at Ichinono, Kawakami village
G. 4	the quartz of the granite at Morimoto, Mié village
G. 5	the quartz of the granite at Ōro, Goka village
G. 6	the quartz of the granite at Kōbe village
G. 7	the quartz of the granite at Masutome, Goka village
G. 8	the quartz of the granite at Ōro, Goka village
G. 9	the quartz of the granite at Ōro, Goka village
G. 10	the quartz of the granite at Nakafujigamori, Shibo village
G. 11	the quartz of the granite at Taniuchi, Mié village
G. 12	the quartz of the granite at Taniuchi, Mié village
G. 13	the quartz of the granite at Nariai Fuchû village
G. 14	the quartz of the granite at Shinzan village
P. 1	the quartz of the pegmatite at Taniuchi, Mié village
P. 2	the quartz of the pegmatite at Shinzan village
P. 3	the quartz of the pegmatite at Mié, Mié village
P. 4	the quartz of the pegmatite at Morimoto, Mié village
P. 5	the quartz of the pegmatite at Ōro, Goka village
P. 6	the colorless and the transparent quartz of the pegmatite at Nagaoka, Chōzen village
P. 7	the white quartz of the pegmatite at Nagaoka, Chōzen village
P. 8	the smoky quartz of the pegmatite at Nagaoka, Chōzen village
P. 9	the white quartz of the pegmatite at Kōbe village
P. 10	the gray quartz of the pegmatite at Kōbe village
P. 11	the milky quartz of the pegmatite at Kōbe village
P. 12	the smoky quartz of the pegmatite at Kōbe village

TABLE 2 Spectrographpic analysis of feldspars
(relative intensities using an arbitrary 1–10)

Sample no.	Pb	Ba	Sr	Mn	Mg	Sn	V	Ag
G. 1	2	10	nd	3	8	2	nd	nd
G. 2	1	nd	nd	4	4	nd	nd	nd
G. 3	2	nd	nd	6	2	1	nd	nd
G. 4	2	8	nd	1	6	nd	nd	nd
G. 5	3	nd	nd	1	2	1	2	nd
G. 6	3	8	nd	2	4	1	nd	nd
G. 7	3	10	5	10	8	4	nd	nd
G. 8	2	3	nd	2	6	1	nd	nd
G. 9	1	nd	nd	2	4	1	nd	nd
G. 10	2	1	nd	1	4	1	nd	nd

G. 11	1	nd	nd	1	6	2	2	nd
G. 12	1	3	nd	4	4	1	nd	nd
P. 1	9	nd	nd	1	4	7	8	nd
P. 2	8	nd	nd	nd	3	nd	10	nd
P. 3	2	nd	nd	nd	2	nd	nd	nd
P. 4	8	nd	nd	nd	4	7	6	nd
P. 5	8	nd	nd	nd	2	2	2	nd
P. 6	8	nd	nd	nd	nd	nd	10	nd
P. 7	8	nd	nd	nd	2	1	nd	nd
P. 8	10	nd	nd	nd	4	10	nd	nd
P. 9	8	nd	nd	nd	3	1	nd	nd
P. 10	8	nd	nd	nd	8	1	nd	nd
G. P. 1	2	nd	5	6	9	6	6	nd
G. P. 2	3	nd	5	6	9	4	2	nd
G. P. 3	2	nd	5	3	7	4	nd	nd
G. P. 4	2	nd	5	2	8	4	6	nd
G. P. 5	2	nd	5	7	10	1	2	nd
G. P. 6	2	nd	3	4	8	4	nd	nd

G. 1 the potash feldspar of the granite at Yuwaya village
G. 2 〃 〃 Nishitani, Fuchû village
G. 3 〃 〃 Nariai, Fuchû village
G. 4 〃 〃 Yuwaya village
G. 5 〃 〃 Morimoto, Mié village
G. 6 〃 〃 Kōbe village
G. 7 〃 〃 Kongōji, Tazuruno village
G. 8 〃 〃 Ōro, Goka village
G. 9 〃 〃 Ōro, Goka village
G. 10 〃 〃 Taniuchi, Mié village
G. 11 〃 〃 Taniuchi, Mié village
G. 12 〃 〃 Ichinono, Kawakami village
P. 1 the potash feldspar of the pegmatite at Mié, Mié village
P. 2 〃 〃 Morimoto, Mié village
P. 3 〃 〃 Morimoto, Mié village
P. 4 〃 〃 Taniuchi, Mié village
P. 5 〃 〃 Taniuchi, Mié village
P. 6 〃 〃 Ōro, Goka village

P. 7	〃	〃	Ōro, Goka village
P. 8	〃	〃	Shinzan village
P. 9	〃	〃	Kōbe village
P. 10	〃	〃	Kōbe village
G. P. 1	the plagioclase	of the granite at	Yuwaya village
G. P. 2	〃	〃	Nariai, Fuchû village
G. P. 3	〃	〃	Ikaga village
G. P. 4	〃	〃	Morimoto, Mié village
G. P. 5	〃	〃	Kōbe village
G. P. 6	〃	〃	Taniuchi, Mié village

Discussion

1. On the distribution of minor elements in quartzs.

Table 3 summarizes general relations of the contents of minor elements in quartzs found by the spectrographic analysis.

Titanium, alminium, magnesium and sodium are detected in all samples and these elements are richer in quartzs of granite than those of pegmatite. Tin is detected also in all the samples and the content of it is almost the same in each sample. Calcium and silver are not detected in most of the samples, and therefore the tendency of the distribution of these two elements is not clear.

V. M. GOLDSCHMIDT[1)] pointed out that the ionic radius of silicium surrounded by four oxygens in the crystal structure of the quartz is 0.39Å and that of aluminium in tetrahedral coordination is about 0.45Å; therefore these two elements can probably replace each other in crystal lattices of the quartz. The same can be said of the result of the present investigation on the quartz of granite and pegmatite.

As to the following four combinations: Al-Mg, Al-Na, Mg-Na and Ti-Al, the correlation between the orders in the contents of these two elements in each combination was statistically examined. The result was that there are the correlations in all but the last combination. These correlations seem to indicate that the electrostatic unbalance of the crystals in the substitution of trivalent aluminium for tetravalent silicium is compensated by the entrance of sodium or magnesium into vacancy or interstitial position in the crystal lattices.

According to V. M. GOLDSCHMIDT[2)] the presence of quadrivalent titanium seems to indicate that a small amount of it can enter 4-coordination position in quartz crystal for silicium. In this work also, it was proved to be true.

The presence of calcium and silver is probably caused by the presence of such minor minerals as apatite and argentite included in the quartz.

All elements except tin, calcium and silver are richer in quartzs of granite than in those of pegmatite. In other words, quartzs of pegmatite are chemically purer than those of its parent rock. BUERGER[3)] has pointed out that crystals are in more dynamic disorder at higher temperature than at lower temperature, and crystals are more tolerant to substitutional solid solution than at lower temperature when the structures have become more orderly. Since the quartzs of granite may have formed at higher temperature than those of pegmatite; therefore in the former the crystal structures may have been more disorderly and more tolerant of both aluminium and titanium as substitutes for silicium, and of both sodium and magnesium which entered into vacancy or into interstitial position in the crystal lattices.

TABLE 3

Element		relative intensities	7	6	5	4	3	1		
Ti	quartz of granite		14.3*	14.3	14.3	50.0	7.1	—		
	quartz of pegmatite		—	16.7**	25.0	16.7	33.3	8.3		
Al		relative intensities	9	8	7	6				
	quartz of granite		64.3	21.4	14.3	—				
	quartz of pegmatite		8.3	16.7	50.0	25.0				
Mg		relative intensities	10	9	7	6	5	4	3	2
	quartz of granite		7.2	7.2	21.4	21.4	14.3	21.4	—	7.2
	quartz of pegmatite		—	—	—	—	—	—	16.7	83.3
Na		relative intensities	8	5	3					
	quartz of granite		14.5	42.75	42.75					
	quartz of pegmatite		—	—	100.0					

* The percentage of the granite quartz whose relative intensity is 7.

** The percentage of the pegmatite quartz whose relative intensity is 6.

2. On the distribution of minor elements in feldspars.

Table 4 summarizes general relations of the contents of the minor elements in the feldspars found by the spectrographic analysis.

Lead is most abundant in the potash feldspars of pegmatite. Barium is only detected in the potash feldspars of granite. Strontium is also detected only in the plagioclases of granite. Magnesium is most abundant in the plagioclases of granite and is scanty in the potash feldspars of pegmatite except sample P. 10. Manganese is detected in the feldspars of granite and not detected in the feldspars of pegmatite except sample P. 1.

The substituting ion should have chemical, physical, and geochemical properties similar to those of the displaced ion in host minerals, and according to V. M. GOLDSCHMIDT[4] ionic size is, above all, the most important factor among them, though ionic type is important, too.

TABLE 4

Element		relative intensities	10	9	8	3	2	1		
Pb	potash feldspar of granite		—	—	—	25.0*	41.7	33.3		
	potash feldspar of pegmatite		10.0**	10.0	70.0	—	10.0	—		
	plagioclase of granite		—	—	—	16.6***	83.4	—		
Ba		relative intensities	10	8	3	1	nd			
	potash feldspar of granite		16.7	16.7	16.7	8.3	41.6			
	potash feldspar of pegmatite		—	—	—	—	100.0			
	plagioclase of granite		—	—	—	—	100.0			
Sr		relative intensities	5	3	nd					
	potash feldspar of granite		8.3	—	91.7					
	potash feldspar of pegmatite		—	—	100.0					
	plagioclase of granite		83.4	16.6						
Mn		relative intensities	10	7	6	4	3	2	1	nd
	potash feldspar of granite		8.4	—	8.4	16.5	8.4	25.0	33.3	—
	potash feldspar of pegmatite		—	—	—	—	—	—	10.0	90.0
	plagioclase of granite		—	16.6	33.3	16.6	16.6	16.6	—	—
Mg		relative intensities	10	9	8	7	6	4	3	2
	potash feldspar of granite		—	—	16.7	—	25.0	41.7	—	16.7
	potash feldspar of pegmatite		—	—	10.0	—	—	30.0	20.0	30.0
	plagioclase of granite		16.7	33.3	33.3	16.7	—	—	—	—

* The percentage of the granite potash feldspar whose relative intensity is 3.

** The percentage of the pegmatite potash feldspar whose relative intensity is 10.

*** The percentage of the granite plagioclase whose relative intensity is 3.

The divalent ion of lead (1.32Å), barium (1.43Å) and strontium (1.27Å) has a radius similar to that of potassium; therefore potash feldspars may be the most important hosts in granite and pegmatite for these ions. Divalent ions of strontium (1.27Å) and manganese (0.91Å) have a radius similar to that of calcium (1.06Å); therefore plagioclases may be the important hosts in granite and pegmatite for these ions. Barium and potassium could replace each other in potash feldspars at the temperature that granite in this region formed, but hardly at lower temperature that pegmatite formed. Strontium and potassium could hardly replace each other in potash feldspars, but strontium and calcium could, to some extent, replace each other in plagioclases at the temperature that granite and pegmatite formed.

Divalent ionic radius of lead is nearly equal to univalent ionic radius of potassium; therefore lead and potassium could always freely replace each other in all feldspars of both stages, and moreover, lead was concentrated into residual magma (pegmatitic magma) on account of larger ionic size as pointed out by V. M. GOLDSCHMIDT[5]. Hence lead is most abundant in the potash feldspars of pegmatite. It seems that divalent manganese and calcium could also replace each other at the temperature that feldspars of granite formed.

It is not clear for what element divalent magnesium substitutes in feldspar in spite of its abundance in plagioclase of granite.

Summary

The above may be summarized as follows:

(1) Each mineral contains characteristic minor elements, which in most cases substitute for the major elements of host minerals (quartz and feldspar). And the substituting ions have chemical, physical and geochemical properties similar to those of the displaced ions; particularly similarity in the ionic radii is the most important factor.

(2) Generally the quartzs and the feldspars of pegmatite are purer than those of its parent rock (granite). In other words each mineral of pegmatite, on the average, containts almost every minor element less than that of granite.

The writer presumes this as follows: The potash feldspars and quartzs of pegmatite were formed at lower temperatures than the same minerals of granite; therefore in the former the crystal structures were more orderly and less tolerant of substitution for ions.

(3) Lead alone is most abundant in the potash feldspars of pegmatite. The reason seems to be that the ionic radius of lead (1.32Å) is nearly equal to that of potassium (1.33Å); therefore at the lower temperature that pegmatie formed, the tolerance for the lead ion is nearly equal to that at the higher temperature that granite formed. Moreover, on account of its larger ionic size lead is concentrated in residual magma (pegmatitic magma).

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