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Distribution of Radioactive Minerals in the Granite of Gyojayama, Kyoto Prefecture, Japan

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Abstract

In this paper the writer treats of the paragenetic relationship between radioactive minerals and major constituents in Gyojayama granite, Kyoto Prefecture. The radioactive minerals occur not only enclosed in biotite, quartz and feldspar, but also rather frequently on the boundaries of biotite and feldspar, and on those of biotite and quartz. Based on the observed distribution of these minerals, some problem concerning crystallization stage of accessory minerals is discussed.

Introduction

There is a contention about the sequence of crystallization of essential constituents and accessories in igneous rocks. MOORHOUSE (1956) says that accessories such as apatite and zircon were found to be crystallized later than essential constituents by microscopically studying various igneous rocks. SCHERMERHORN (1958) is, on the contrary, of the opinion that the former were crystallized earlier than the latter, by examining the data from which MOORHOUSE deduced his conclusion. Recently the writer has studied distribution of zircon and monazite with thin sections of specimens from Gyojayama granite, using nuclear emulsion method as well as optical. Nuclear emulsion method is highly advantageous in such investigation, for how tiny the radioactive grains may be they can easily be detected.

Petrography

Gyojayama granite, intruded by quartz veins bearing scheelite and cassiterite, intrudes into Palaeozoic formation and extends over 3 km east and west and 4 km south and north. The granite is more or less weathered in its outcrops, and is as a whole medium grained and homogeneous in texture. But there are some porphyritic parts especially at the northern margin of the area, where quartz is slightly dominant in volume, and aggregates of biotite, several centimeters in diameter, are often met with. On some occasions a banded arrangement of biotite is seen at the contact with the Palaeozoic formation.

The results of microscopic observations on this granite are as follows:

(1) Biotite is rather abundant, pleochroic haloes are well developed and many radioactive minerals are recognized in it. Frequently it is chloritized especially near the quartz vein. In this case the rock looks like to be leucocratic. Small crystals of muscovite, which may be a secondary production, are often present near biotite.

(2) Plagioclase belongs to oligoclase or andesin, in which weak zonal structure is usually developed and its An-content increases slightly with shifting from margin to core. The mineral is frequently changed to clustered tiny secondary minerals due to the effect of decomposition.

(3) Quartz and alkalifeldspar are both variable in volume and the latter mineral often shows perthite structure.

(4) Hornblende was not detected in thin sections, but was found in small amount in the heavy minerals separated by Thoulet's solution.

(5) Magnetite is very little in amount.

(6) Apatite is comparatively abundant and is found mainly in biotite.

(7) Sphene is rarely met with at the contact between biotite and magnetite.

(8) As radioactive accessory minerals, zircon and monazite are usual, but xenotime is rare and allanite has not yet been found. This aspect of the occurrence of these minerals was reported previously by HAYASE and the writer (1956).

Modal composition of the granite determined with about twenty thin sections is shown in Table 1.

Table 1. Volume percentage of constituent minerals.

Constituent mineral	Range of volume per cent	Average mode of volume per cent
Quartz	20.8 –28.0	22.7
Alkalifeldspar	14.9 –19.5	16.4
Plagioclase	43.2 –51.8	45.8
Biotite	9.0 –16.8	12.0
Chlorite	0.13– 2.7	1.48
Muscovite	0.00– 0.77	0.20
Magnetite	0.03– 1.75	0.34
Apatite	0.11– 0.52	0.21
Sphene	0.07– 0.25	0.16
Zircon, Monazite	0.01– 0.03	0.018
Hornblende	—	—
Allanite	—	—
		99.31

Distribution of radioactive minerals

More than thirty thin sections made of the samples which were collected at random from all over the outcrop of the Gyojayama granite, were tested with photographic plates ET-2E, all sampling points are shown in Fig. 1. The plates were developed after about a month's exposure. A number of alpha tracks arranged radially from one point was counted by the aid of high power lens microscope. On the other hand, the positions of the radioactive minerals corresponding to the assemblages whose number of alpha tracks had been counted, were searched for, and the areas of these minerals on the thin section were measured as precisely as possible by using micrometer ocular. Then the number of alphas emitted per 1 sec. per 1 cm^2 was estimated with each of the assemblages.

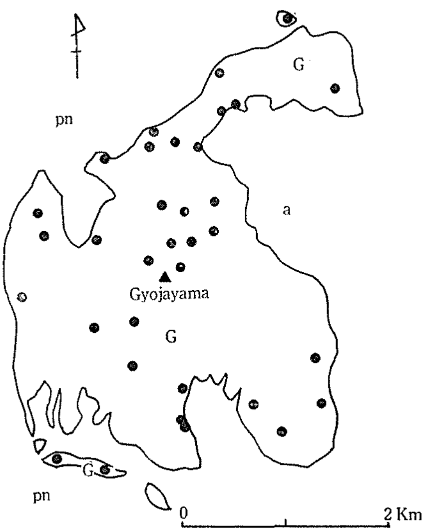

Fig. 1. Distribution of sampling points
G: Granite, pn: Palaeozoic, a: Alluvium

Numbers of the grains of the radioactive minerals classified by the positions of the grains to be found, are as follows: *

a) Included in biotite 75
b) On the boundaries of biotite and feldspar 75
c) On the boundaries of biotite and quartz 71
d) Included in feldspar 29
e) Included in quartz 19
f) On the boundaries of feldspar and quartz 11
g) On the boundaries of biotite and chlorite, among biotite and feldspar and quartz, and included in magnetite, chlorite, etc. 11

The results obtained are illustrated histogramatically in Figure 2, where abscissa denotes alphas per sec. per cm^2, and ordinate the number of grains.

The areas of the radioactive minerals measured with about thirty thin sections, on the unit of 100 square micron, were summed up by every class described above, and are shown at the second column in Table 2. In the third column of the table are shown the percentages of the areas of each of the classes. The numbers in the fourth column in the table are the quotients obtained by dividing the numbers

* The radioactive minerals on the boundaries have no tendency as to in which main constituent they are more deeply imbedded.

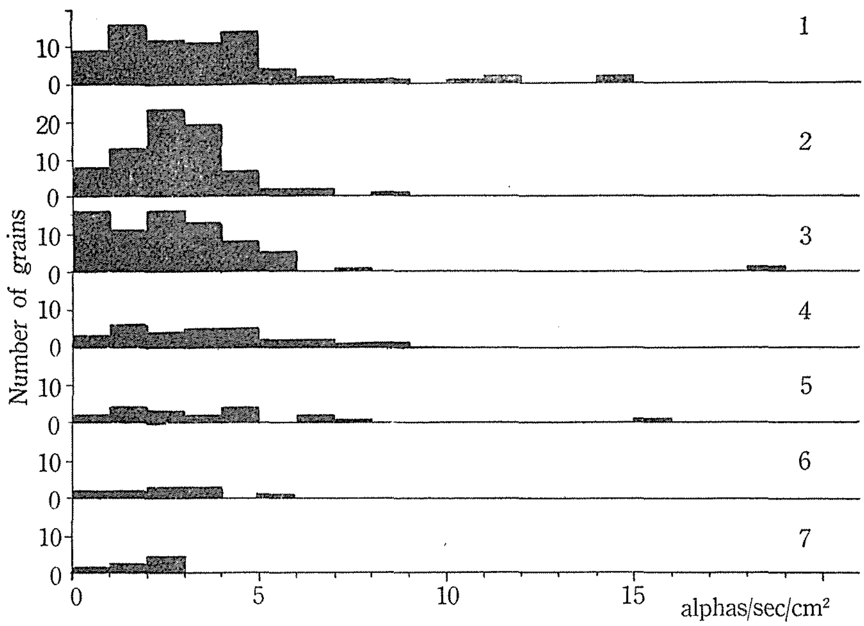

Fig. 2 Relationship between the number of radioactive minerals and their radioactivity.

1. Biotite, 2. Biotite-Feldspar, 3. Biotite-Quartz, 4. Feldspar, 5. Quartz, 6. Feldspar-Quartz, 7. Magnetite, Chlorite etc.

Table 2. The areas of the radioactive minerals and their association ratioes.

Class	Total area of radioactive accessories	Per cent	Association ratio
Included in biotite	$971.2 \times 100\mu^2$	18.3	1.52
On the boundary of biotite and feldspar	1392.1	26.3	
On the boundary of biotite and quartz	1708.0	32.2	
Included in feldspar	570.0	10.7	0.17
Included in quartz	253.2	4.8	0.22
On the boundary of feldspar and quartz	182.3	3.4	
On the boundary of biotite and chlorite	19.5	0.4	
On the boundary among biotite and feldspar and quartz	65.0	1.2	
On the boundary of chlorite and quartz	36.0	0.7	
On the boundary of chlorite and feldspar	28.3	0.5	
Included in magnetite	68.0	1.3	3.82
Included in chlorite	19.6	0.4	0.27
Total	5313.2		

in the third column by those in the last column in Table 1. These numbers represent the ratioes of the density of radioactive accessories in host mineral and were called association ratio* by MOORHOUSE (1956).

Comparing the association ratioes, it may be concluded:

(1) The radioactive minerals are densely distributed in biotite.

(2) The radioactive minerals are sparsely distributed in quartz and feldspar, and there is no remarkable difference in amount between them.

The numbers of the radioactive minerals classified by their positions, which were described before, prove:

(3) The sum of the number of the radioactive minerals that situate on the boundaries of biotite and feldspar and of biotite and quartz, is about twice of that included in biotite, and the areas of the formers amount to about 59 per cent of the total area of all the radioactive minerals (Table 2).

(4) The number of the radioactive minerals on the boundary of biotite and feldspar or of biotite and quartz, is about seven times of that on the boundary of feldspar and quartz.

Total area of the radioactive minerals included in biotite is only 971.2×10^2 square micron though their number is as large as 75. This means that they are smaller in size. In the present investigation the radioactive minerls included in biotite have been found to be more or less high in radioactivity (Figure 2). The writer previously reported that smaller radioactive accessories in granite under consideration had an inclination for higher radioactivity.

It is remarkable that the radioactive minerals are distributed most densely in magnetite when it is present.

Consideration

The sequence of the crystallization of rock forming minerals has been described by many authors and whether a crystal is formed earlier or later than others has been decided by virtue of the fact whether the former is enclosed or not in the latter and the crystal enclosed is idiomorphic or xenomorphic. The order of crystallization written in many text books is:

(a) Minor accessories (apatite, zircon, sphene, garnet, etc.)

(b) Ferro-magnesian minerals (olivine, augite, hornblende, biotite, etc.)

(c) Felspathic minerals (plagioclase, orthoclase, etc.)

(d) Quartz and microcline.

SHAND (1949) described concerning the crystallization order as follows:

"If little crystals of mineral A are seen to be enclosed in larger crystals of mineral B, does that really demonstrate that the period of crystallization of A was earlier than that of B? It depends, as Bowen showed, on the position of the enclosures within the host. If an enclosed grain lies at the center of its host, then it is probably safe to say that the former

* This term was used first by P. A. PEACH in his unpublished paper, Tront Univ., 1949. Here the writer adopted the area of minerals instead of the number of grains, even in a case of accessories too.

crystallized first; but that conclusion applies only to the grain actually studied. It does not prove that all of A crystallized before all of B, for the same accidental enclosure of one mineral within the other might happen during simultaneous crystallization of both minerals at a cotectic surface. Again, if an enclosed grain of A lies just within the margin of B, then it is possible that crystallization of A may only have begun as that of B was finishing."

In the present investigation the writer has observed as described above that accessories were included in biotite and also in feldspar and quartz, and that most of them were idiomorphic. The writer also observed that accessories were located not only near the center, but also on the periphery of host minerals. Furthermore, accessories are situated more frequently on the boundary of the main constituents as described above. Then it is apparent that the crystallization of the accessories is earlier than that of the main constituents and the former continue to crystallize even after the finishing of the latter crystallization.

Now, we must pay attention to the facts of (1), (2), (3), and (4) described before.

SCHERMERHORN (1958) says that zircon and the other primary accessories crystallize early and move about in the magma (they may serve as convenient crystallization centers for the older main constituents) and become successively incorporated in the early main constituents, such as biotite and hornblende in granites, by coming into contact with, and adhering to, growth surfaces of the latter. The present writer considers that SCHERMERHORN's view is not always reasonable because the heavy minerals that crystallize first do not seem to meet in biotite. MOORHOUSE (1956) has inferred from his statistical study of accessories that they crystallize late in igneous rocks. SCHALLER (1927) implied that the accessory minerals and other hydrous minerals such as hornblendes and micas in granite, were not original pyrogenic minerals formed directly from magma but were later reaction products in an already formed rock. The present writer considers that a greater part of the accessories were crystallized later than biotite, for they are more densely distributed on the boundaries of biotite and other main constituents. This interpretation will not be inconsistent with the geochemical aspect that zircon and monazite are associated with pegmatite.

But, if a greater part of the accessories are crystallized later than biotite, the accessories must be included more abundantly in feldspar and in quartz so far as we consider that feldspar and quartz are crystallized later than biotite. The fact obtained above is quite contrary to this. TSUBOI (1920) reported by studying Usugiri granite in Japan that biotite, hornblende, and plagioclase were growing in the magma at the same time. The writer is inclined to believe that feldspar and quartz begin to crystallize earlier than biotite, from the fact that a preferential association of radioactive accessory minerals to biotite is found, at least, in Gyojayama granite.

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