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The Relations between the Petrology and the Radioactivity of Some Granitic Bodies (2)

By

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Abstract

This is the second report treating the distribution of radioactive elements in granitic intrusives. Up to the present, seven intrusions have been examined for radioactivity. The results of determination of radioactivity using a radioscope, an alpha-scintillation counter and a low-background gas-flow counter showed such tendencies of the radioactive elements as to concentrate towards the periphery of the intrusive mass, to increase with SiO_2 and KO_2 content, and to be modified in content by weathering.

Introduction

Investigations on the alpha- and beta-radioactivities of some granitic bodies have been reported in the first paper[1]. Most of the inferences in it were those concerning *the problem of granite and granites* from geological field evidence and laboratory examination of the sample specimens. A new attempt is reported in this study, in which the radioactive distribution relevant to the problem is presented. The data presented in this paper consist of alpha- and beta-radioactivities of *287* samples from seven plutons.

Procedure

Sampling: Samples were collected from seven granitic intrusives; Tanakami, Mikumo, Kitashirakawa, Rokkô, Hira, Yoshino and Nabari. In order to obtain a reliable average value of radioactivity, more than *3–4* kgs of samples were collected at each site of Tanakami-Mikumo, Rokkô, Yoshino and Nabari intrusives, and more than four or five fist-sized samples at each station of Kitashirakawa and Hira intrusives. These samples were pulverized to a *270* mesh sieve fineness and provided for measurements.

Measurement of alpha-radioactivity: The procedure of measurements by means of a radioscope and an alpha-scintillation counter was fully described by Z. HATUDA and S. NISHIMURA (1964).[2] The difference observed between the alpha-radioactivity obtained by the radioscope and that by the alpha-scintillation counter seems to depend on the different sensitivities to uranium and thorium, i. e., the radioscope is more sensitive to thorium than the alpha-scintillation counter.

Measurement of beta-radioactivity by means of low-background gas-flow counter: The effect of absorption of beta-rays by aluminium foil and by the sample itself was discussed in the first report.[1] As the result, it was found that the potassium content was largely reflected in the beta-radioactivity, whilst the uranium and thorium contents were mainly reflected in the alpha-radioactivity.

The radioactivity measured by the radioscope, and the beta-radioactivity of the samples collected from Kitashirakawa, Tanakami, Mikumo and the east part of Rokkô have been reported in the first paper.[1]

Some descriptions of the geology of the localities from where samples were taken

The description on Kitashirakawa, Tanakami, Mikumo and the east part of Rokkô was made in the first report, so in this paper it may be excluded.

Hira: Hira mountain is situated in the east part of the Tamba mountain district. The west side of this district is bounded by the Hanaore fault which runs along the river Ado and its east side by Lake Biwa with a great fault. Igneous rock in this sampling area is mostly biotite granite. This granitic body intruded into the Chichibu Paleozoic formations, altering them into hornfels at the contact zone. The geological map is shown in Fig. 1. Samples near the west margin and in the north part of the area are medium-grained biotite granite. Potash feldspar of the samples collected from the east of the main ridge is pinkish in colour. Generally speaking, rocks found in this granitic body have been weathered to a moderate degree, but the samples were preferably collected from the fresh part of the exposures.

Yoshino and Nabari: The granitic rocks in this region are metamorphic rocks, plutonic rocks and mylonitic rocks as shown in Fig. 2. Lithologically,

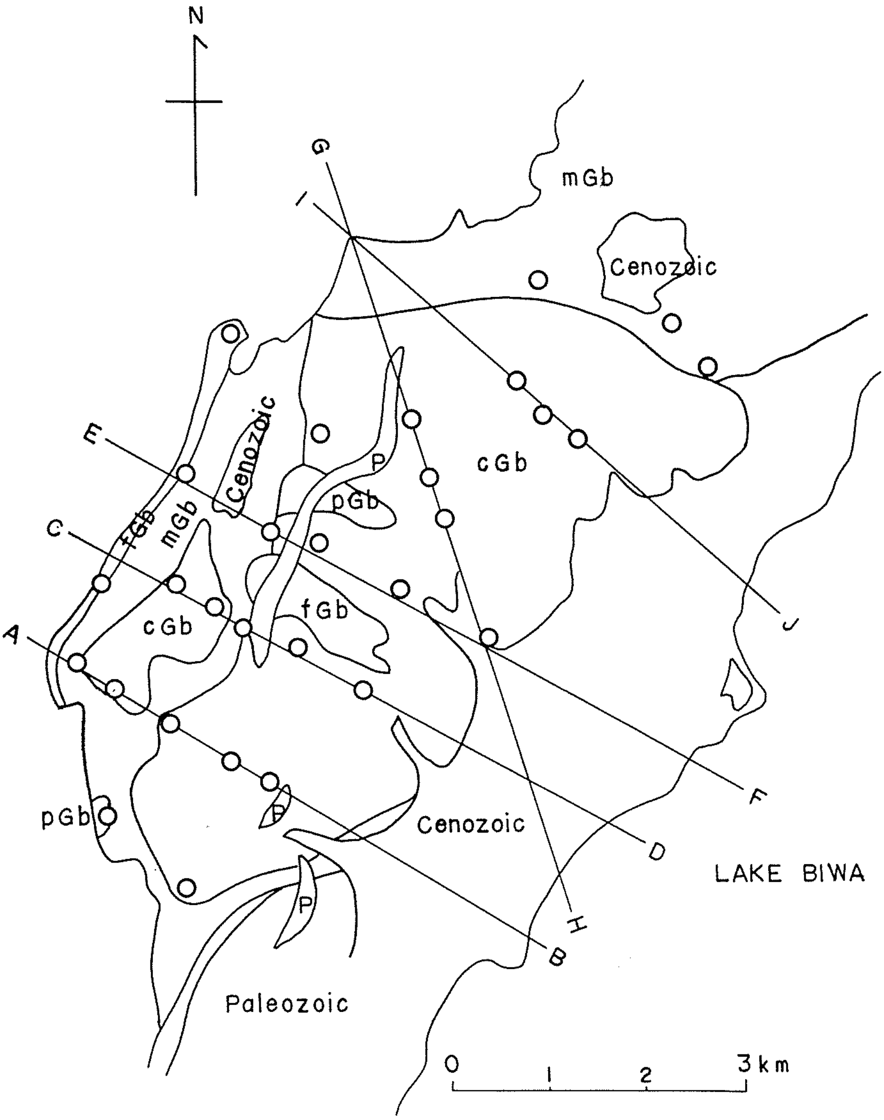

Fig. 1 Geological and sample station map (Hira).
cGb : coarse-grained biotite granite
mGb : medium-grained biotite granite
fGb : fine-grained biotite granite
pGb : porphyritic biotite granite
P : porphyrite

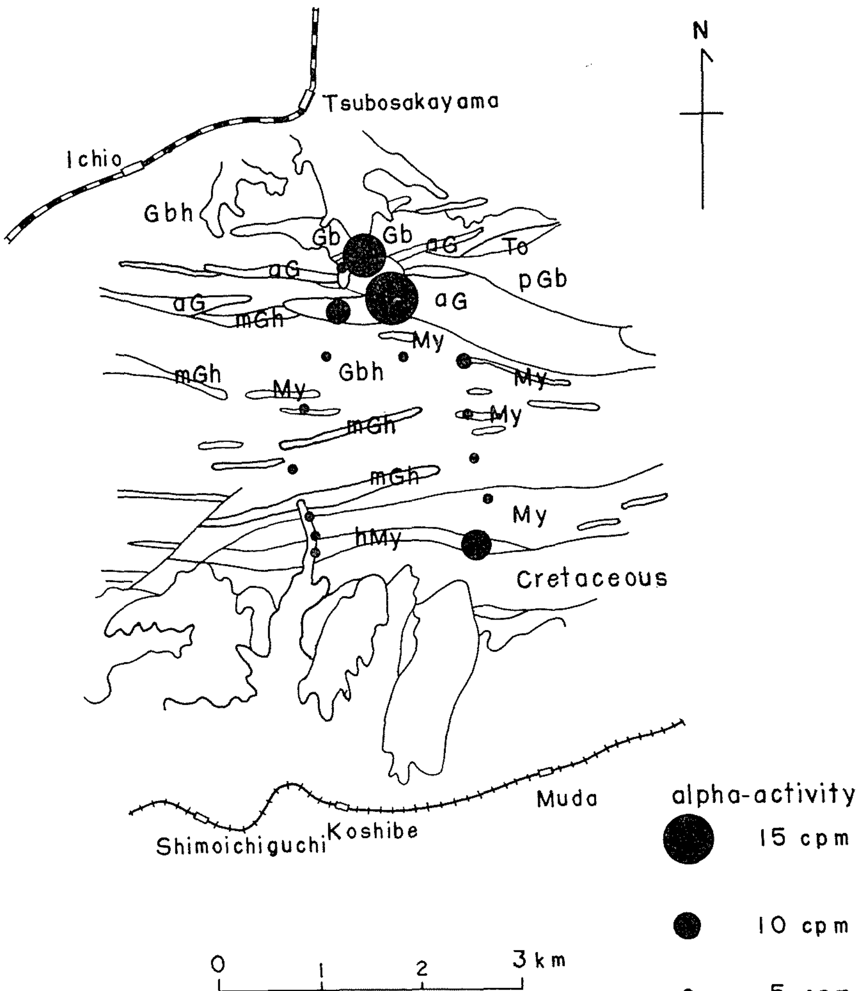

Fig. 2 Geological map and distribution of alpha-radioactivity (Yoshino).

aG	:	aplitic biotite granite
hMy	:	Hällenflinta-like mylonite
My	:	mylonite
mGh	:	mylonitic biotite hornblende granite
Gb	:	medium-grained biotite granite
pGh	:	porphyritic biotite granite
Gbh	:	biotite hornblende granite
To	:	hornblende bearing biotite granite

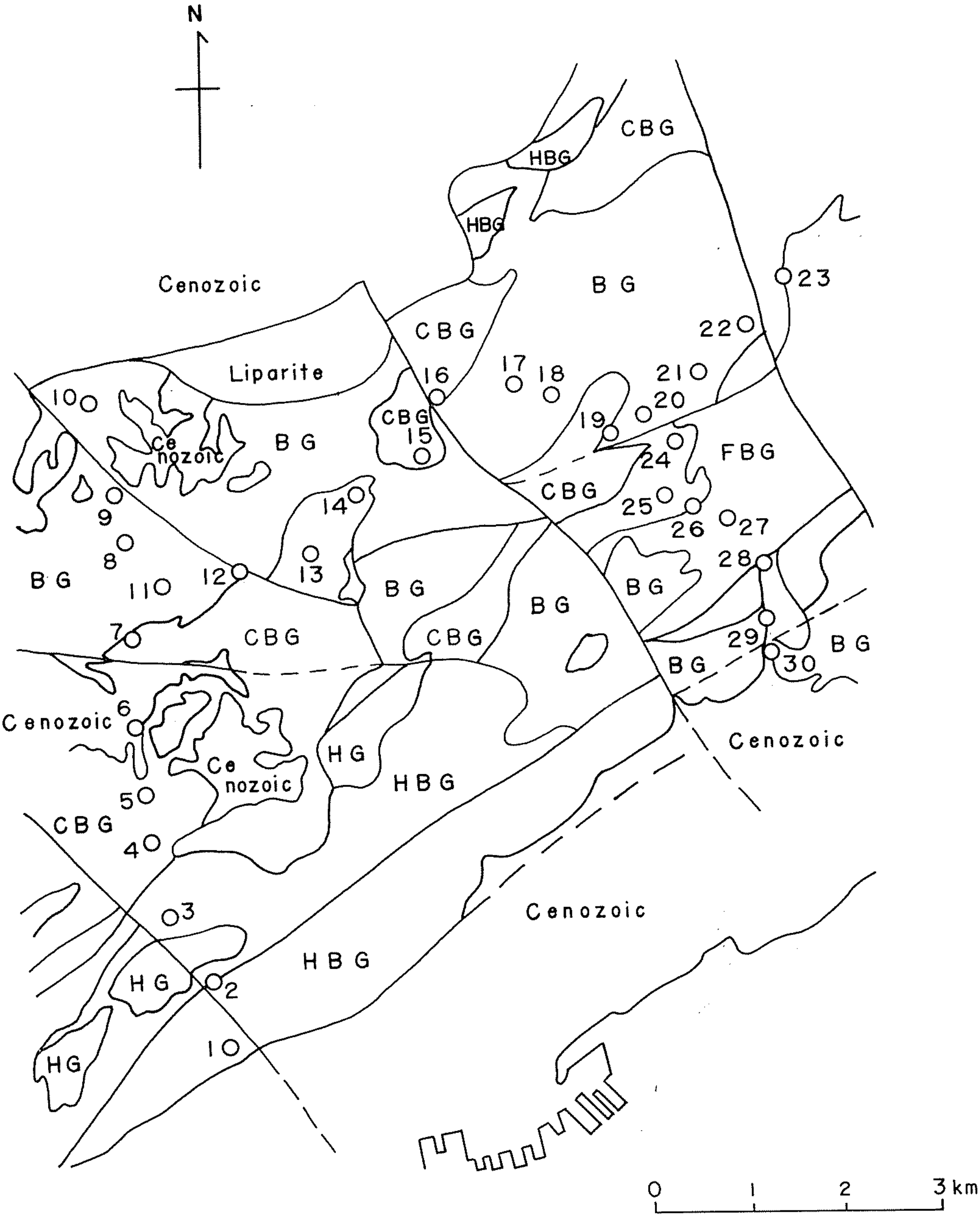

Fig. 3 Geological and sample station map (the west part of Rokkô).
CBG : coarse-grained biotite granite BG : medium-grained biotite granite
FBG : fine-grained biotite granite HBG : hornblende-bearing biotite granite

they are gneissose granite, tonalite, biotite hornblende granite, felsic porphyritic biotite granite, medium-grained biotite granite and mylonite. Granitic rocks in Yoshino and Nabari are called *Ryôke type* in general. The mylonitic rocks showing zonal distribution are developed in the limited area of the southern part of the granite region and are supposed to be the derivatives of granitic rocks by the tectonic movement of a later stage.

The west part of Rokkô: The west part of Rokkô mass consist of granites.

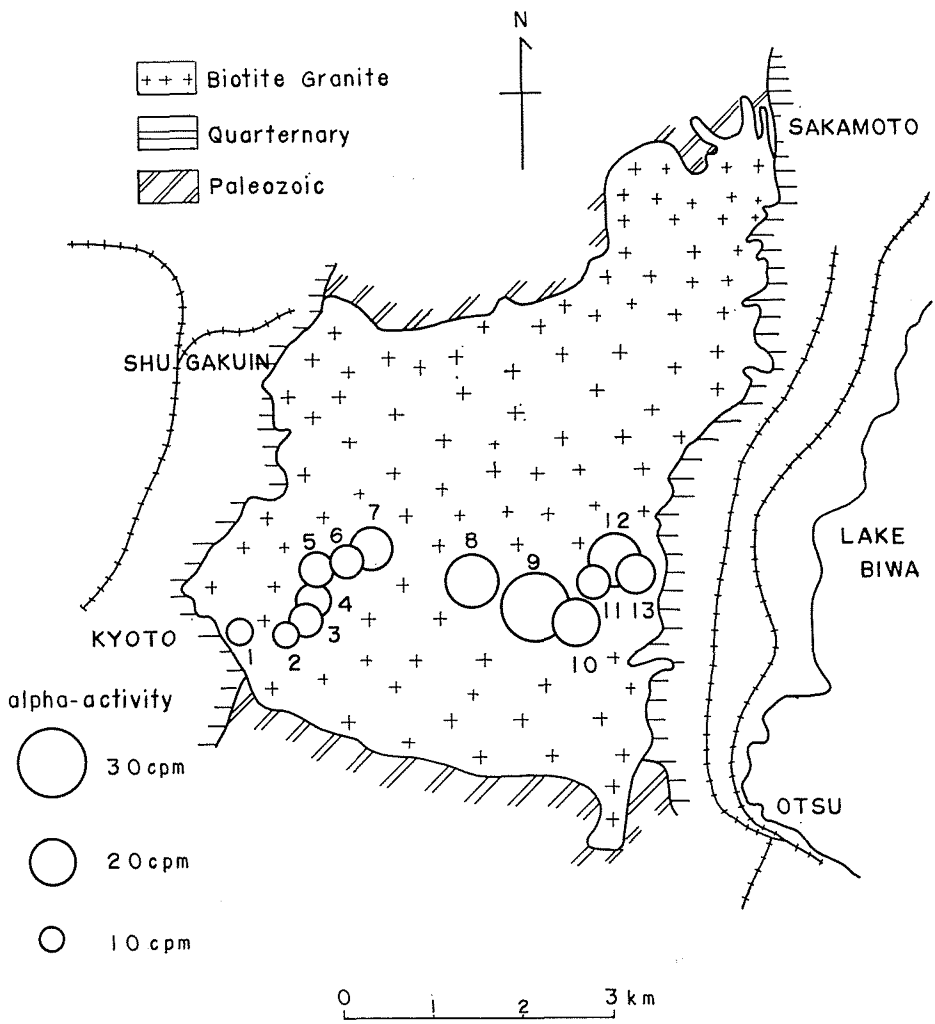

Fig. 4 Distribution of alpha-radioactivity (Kitashirakawa).

These are biotite granite, hornblende granodiorite and hornblende-bearing biotite granite (Fig. 3).

Results

The results of radioactivity determination are shown in Table 1, and Figs. 2, 4, 5, 6, 7, 8 and 9.

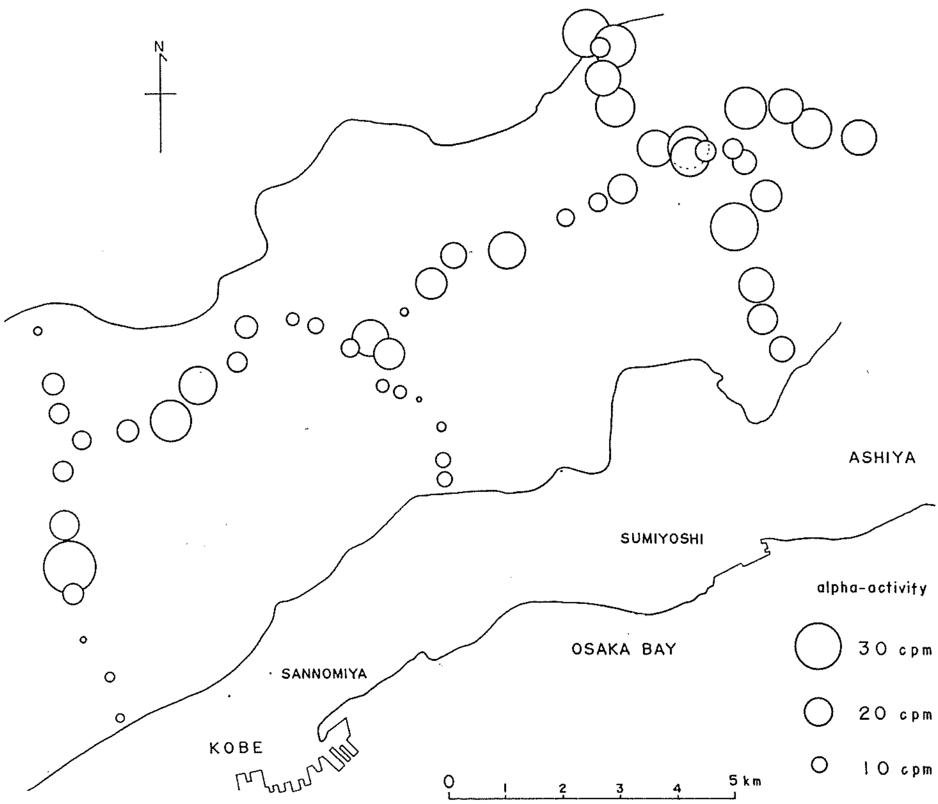

Fig. 5 Distribution of alpha-radioactivity (Rokkô).

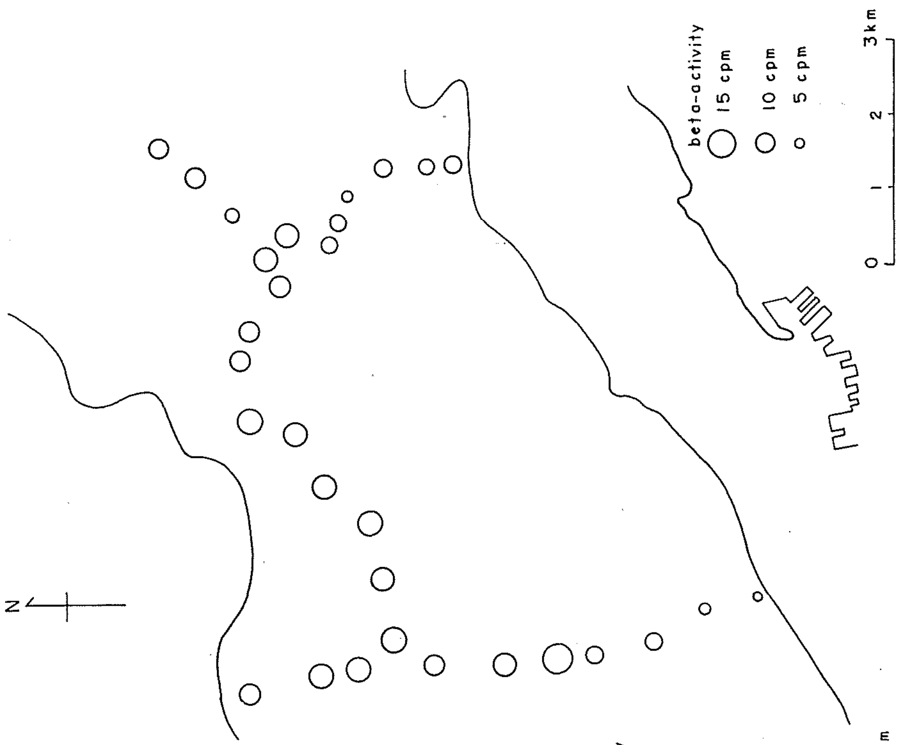

Fig. 6 Distribution of beta-radioactivity (the west part of Rokkô).

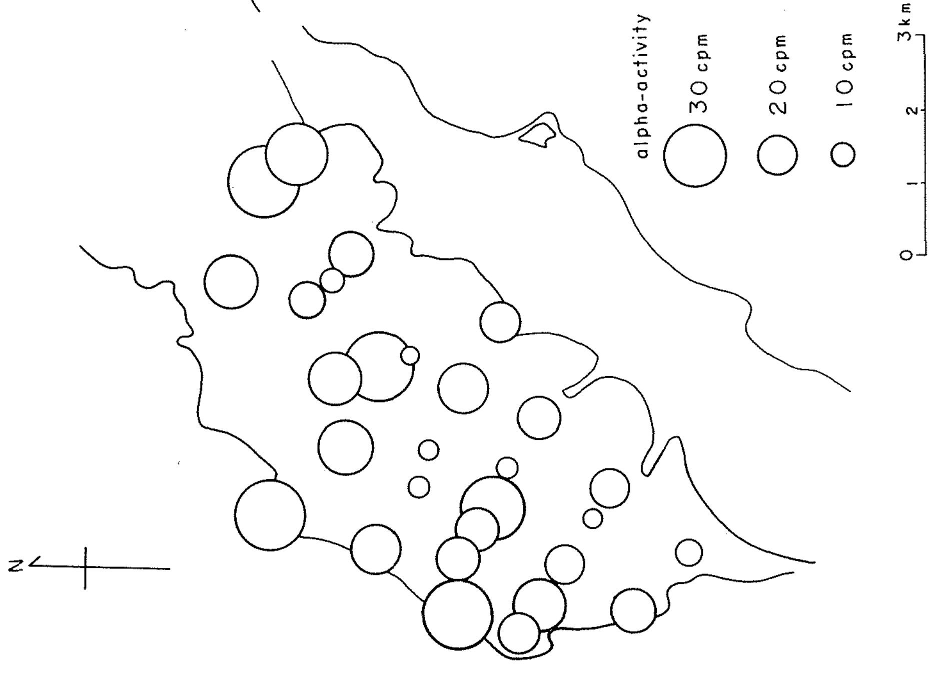

Fig. 7 Distribution of alpha-radioactivity (Hira).

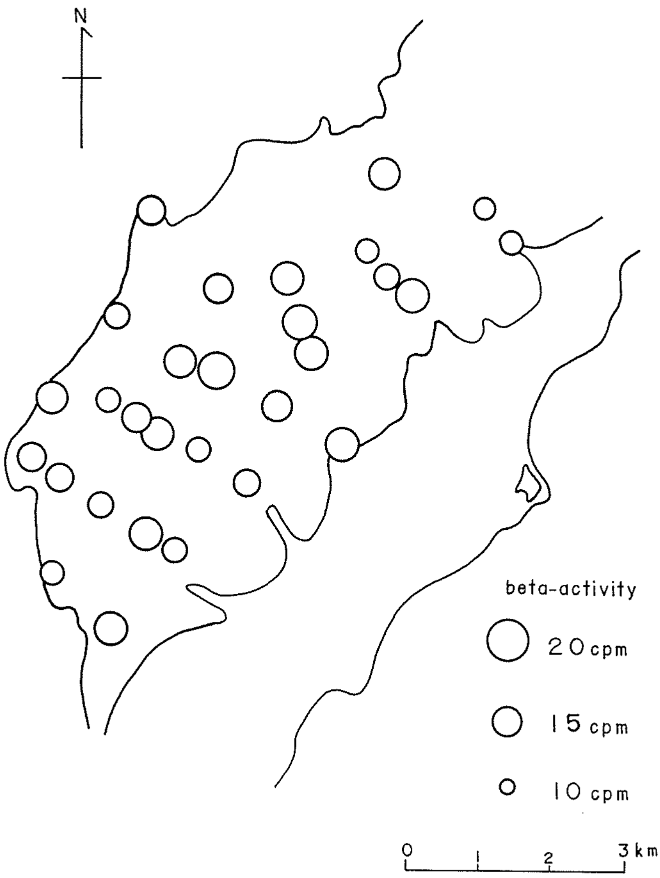

Fig. 8 Distribution of beta-radioactivity (Hira).

Table 1 Radioactivity of granitic rocks

Granitic mass	no. of sample	α-activity (cpm)	β-activity (cpm)
Kitashirakawa	13	17.4±1.1	10.4±0.5
biotite granite	7	13.8±0.7	10.1±0.6
porphyritic biotite granite	6	21.5±1.4	10.7±0.4
Tanakami	6	17.7±0.7	10.4±0.4
Mikumo	9	9.0±0.7	13.3±1.2
Rokkô			
granite	51	17.5±0.9	11.9±0.3

coarse-grained	21	20.8±3.3	13.1±0.3
medium-grained	19	15.3±2.0	12.4±0.5
fine-grained	4	7.4±0.1	9.6±0.6
hornblende-bearing biotite granite	4	6.4±0.6	8.2±0.5
Hira			
granite	28	23.2±1.3	15.6±0.3
coarse-grained	17	20.8±1.3	15.9±0.3
coarse-medium grained	4	20.5±1.6	14.7±0.5
medium-grained	6	30.1±1.6	15.5±0.7
medium-fine grained	1	32.5	13.3
porphyrite	1	24.1	14.3
Yoshino			
medium-grained biotite granite	1	16.9	…………
aplitic biotite granite	2	13.4±3.7	…………
biotite hornblende granite	8	4.4±0.2	…………
Hällenflinta-like mylonite	2	7.5±1.9	…………
mylonite	3	1.6±0.1	
Nabari			
biotite hornblende granite	13	3.1±0.3	…………
dacite	2	3.2±0.5	…………
gabbro	2	2.2±0.3	…………

Discussion of the results

If we arrange the granitic masses in the decreasing order of alpha-activity, the arrangement goes parallel with the contact-types from I to IV, while beta-radioactivity does not show such a definite order (Table 2).

Table 2 The relation between the types of radioactivity distribution across contacts and radioactivity of granitic mass

Granitic mass	no. of sample	type of contact	α-activity (cpm)	β-activity (cpm)
Hira	28	I	23.2±1.3	15.6±0.3
Tanakami	6	I	17.7±0.7	10.4±0.3
Rokkô	51	II	17.5±0.9	11.9±0.3
Kitashirakawa	13	II	17.4±1.1	10.1±0.6
Mikumo	9	III	9.0±0.7	13.3±1.2
Yoshino	16	III - IV	6.1±0.9	…………
Nabari	13	IV	3.1±0.3	…………

This order of arrangement of the granitic intrusives, in turn, seems to have some relation with the average ***silica*** and K_2O content as well as feldspar components as shown in Table 3 and Fig. 9. Presumably, owing to the

Table 3 The average silica and K_2O content of granitic mass

Granitic mass	no. of sample	SiO_2 (in weight per cent)	K_2O (in weight per cent)
Hira	3	73.47±0.57	4.49±0.38
Tanakami	12	74.27±0.49	4.08±0.13
Rokkô	2	75.24±0.49	2.90±0.96
Kitashirakawa	17	72.19±0.89	2.93±0.09
Mikumo	10	73.63±0.84	3.63±0.22
Yoshino	2	65.65±0.16	2.52±0.12
Nabari	2	66.26±0.44	1.83±0.12

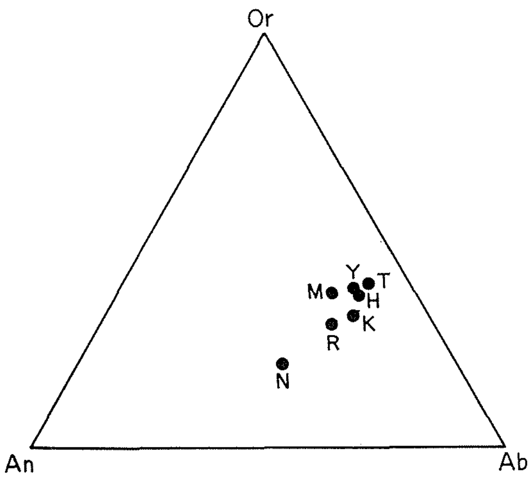

Fig. 9 Ternary diagram of the system, orthoclase - albite - anorthite relations obtained from norm calculation showing significant bearings on alpha-radioactivity.
H: Hira
T: Tanakami
M: Mikumo
K: Kitashirakawa
R: Rokkô
Y: Yoshino
N: Nabari

insufficient number of the available chemical data of rocks as a representative of each of the igneous masses, some disturbances are found in the order arrangements of SiO_2 and K_2O content, and also in the feldspar relation obtained by the norm calculation.

The variation of the alpha-radioactivity of different parts of Hira granitic mass has been studied. The results for the granitic rocks reveal a contrast in alpha-radioactivity between the core (mainly coarse-grained granite) and border (mainly fine-grained granite) zones of the intrusive (Fig. 10). The average alpha-radioactivity for the core is *20.7±0.9* cpm and that for the border zone is *30.4±1.5* cpm.

The variation of the alpha-radioactivity of different grain size of each granitic mass has been also found. It was shown that the alpha-radioactivity of the samples from the core of intrusives increases with increasing grain size

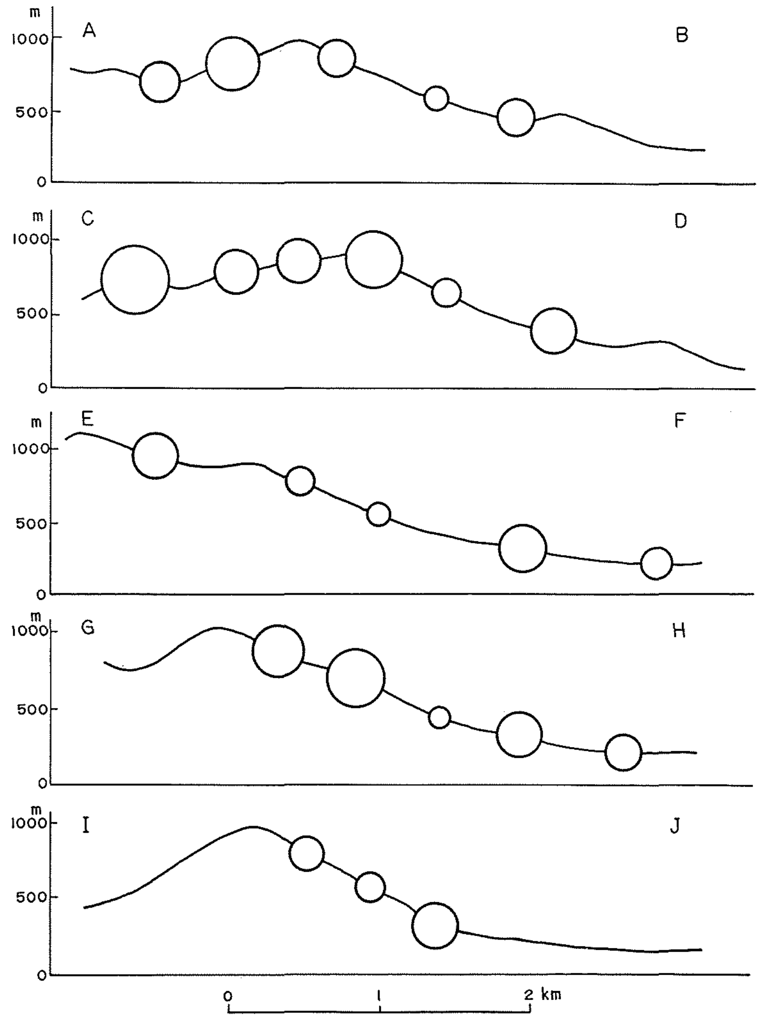

Fig. 10 Distribution of alpha-radioactivity across Hira intrusive mass.

(Table 4), while beta-radioactivity does not show such a relation. (Table 5).

The original granitic rocks would have suffered oxidation and leaching through weathering and erosion. Under such conditions the uranium may be oxidized into a very soluble uranyle form and carried away by ground- and surface-water. Thorium, on the other hand, cannot be oxidized under usual geologic conditions to a hexa-valent state to form an analogue of the uranyle

Table 4 The frequency of alpha-activity in granitic rocks of each mass.

Granitic mass \ α-activity (cpm)	~10.0	10.1~15.0	15.1~20.0	20.1~25.0	25.1~30.0	30.1~
Kitashirakawa		7	3	2	1	
biotite granite		6	1			
porphyritic biotite granite		1	2	2	1	
Rokkô						
biotite granite	4	17	6	9	8	2
coarse-grained	1	4	1	6	7	2
medium-grained	2	10	5	3	1	
fine-grained	1	3				
hornblende bearing biotite granite	5					
Yoshino						
biotite granite			1			
aplitic biotite granite	1		1			
hornblende bearing biotite granite	8					
Hällenflinta-like mylonite	1	1				
mylonite	3					
Nabari						
hornblende bearing biotite granite	13					
Hira						
biotite granite		7	3	8	5	6
coarse-grained		6	3	3	4	2
coarse-medium-grained		1		3		
medium-grained				2	1	3
fine-grained						1
porphyrite				1		

Table 5. The frequency of beta-activity in granitic rocks of each mass.

Granitic mass \ β-activity (cpm)	5.1~7.5	7.6~10.0	10.1~12.5	12.6~15.0	15.1~17.5	17.6~
Kitashirakawa	1	6	4	2		
biotite granite	1	3	2	1		
prophyritic biotite granite		3	2	1		

Rokkô						
biotite granite	2	4	24	14	6	
coarse-grained		1	10	5	6	
medium-grained	1	3	10	9		
fine-grained	1		4			
hornblende bearing biotite granite	2	1	1			
Hira						
biotite granite			1	12	11	4
coarse-grained				7	8	2
coarse-medium-grained				3	1	1
medium-grained			1	1	2	1
fine-grained				1		
porphyrite				1		

ion. This fundamental effect in weathering is partly responsible for the wide-dispersal of uranium, and it also gives rise to a very low Th/U ratio observed in natural water. On the other hand, the degree of weathering of rocks was not defined clearly. So that the relation between the degree of weathering and radioactivity is not defined, but it too must be considered. Using the coarse-grained biotite-granite of Hira, the semi-quantitative analysis of this problem was done as follows:

The rock samples were classified into five according to the degree of apparent weathering. The relation between this degree of weathering and radioactivity was shown in Figs. 11~13. From these results, it was found

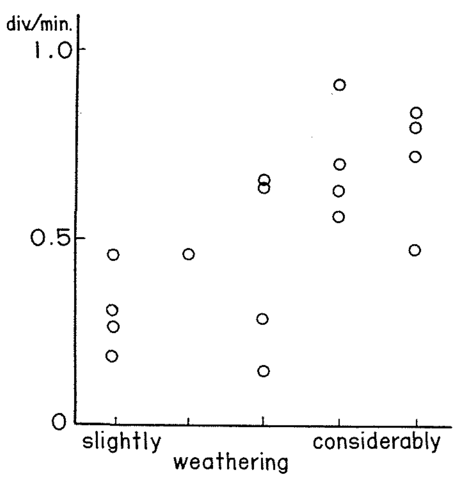

Fig. 11 Relation between alpha-radioactivity and the degree of weathering for the Hira intrusive mass by a radioscope.

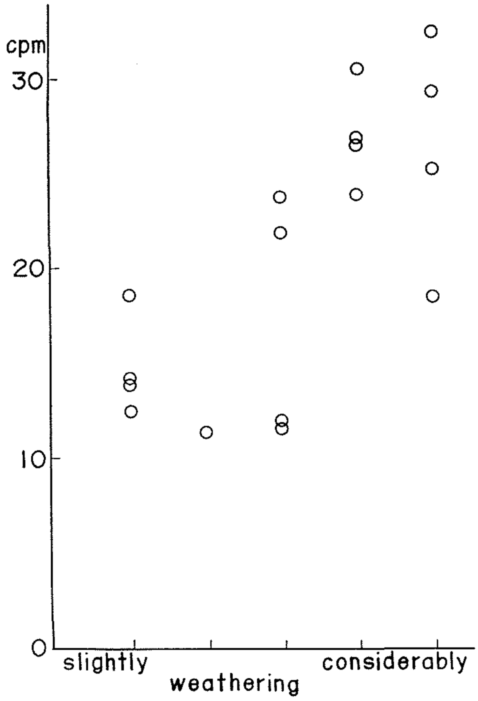

Fig. 12 Relation between beta-radioactivity and the degree of weathering for the Hira intrusive mass by an alpha-scintillation counter.

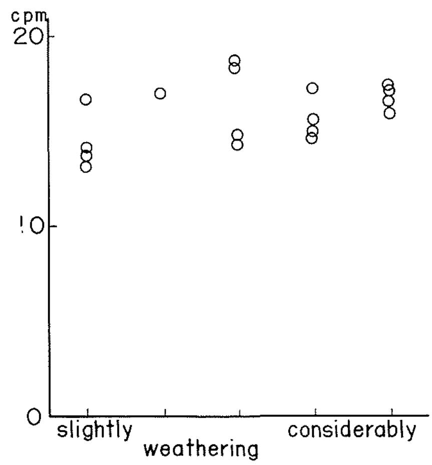

Fig. 13 Relation between beta-radioactivity and the degree of weathering for the Hira intrusive mass by a low-background gas-flow counter.

that alpha-radioactivity increases with advancing weathering, but beta-radioactivity does not.

Conclusions

From the above discussion, the following conclusions may be deduced; (1) alpha-radioactivity of granitic masses increases with *silica* and K_2O contents, (2) alpha-radioactivity increases with increasing normative albite and orthoclase and with decreasing normative anorthite, (3) radioactive elements concentrate towards the margin of the intrusive mass and this is remarkable in the granitic mass intruded in shallower depth, (4) alpha-radioactivity increases with grain size, and (5) alpha-radioactivity increases with advanced apparent weathering.

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