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Variation in Radioactivity across Igneous Contacts (The Third Reports)

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Abstract

Newly obtained data in the distribution of radioactivity along traverses across igneous contacts have been shown in this third paper. A trial study to find out that a peak or hump observed in the curves of radioactive distribution may be caused by any of the predominating kind of the radioactive elements, has been made by the comparison of the two different curves with the same samples taken along a traverse, of which the one representing mainly alpha-activity and the other, beta-activity. The results, however, were rather dim presumably owing to the lack of sensitivity of the measuring apparatus.

Introduction

In the previous papers[1,2], it has been shown that radioactivity distribution displays a peculiar variation across igneous contact, especially conspicuous within the igneous body, and that the figures of the variation seem to be classifiable into several types which are significant of the mode of igneous contact.

Since the last report, fifty three profiles of radioactivity distribution were traced. The localities from which the present samples were collected are various parts of Japan covering Shiga, Kyoto, Ehime, Okayama, Hiroshima, Yamaguchi and Ôita Prefectures.

An inquiry has been made on the method of sampling, and the usual way of sampling hitherto adopted has been proved to be not inadequate for the present purpose.

On the other hand, with a view of finding some information on the kinds of elements whose distribution probably give rise to, or at least modifies the characteristic profiles of radioactivity distribution in a traverse, normal to the plane of contact, measurement of beta plus gamma activity was undertaken with the same samples as used in the usual measurement in which total activities mostly due to alpha-rays are treated. No definite results were observed, however, owing perhaps to insufficiency of the sensitivity of the measuring apparatus, except a tendency suggestive of concentration of potassium, uranium and thorium, presumably rubidium as well, at or very close to the boundary of igneous contact.

Measurement of ionization by beta-rays

The routine method of measuring radioactivity of pulverized rocks by means of the sensitive radioscope with Lauritsen element, designed by Z. HATUDA was described in detail in the first report[1]. It may, however, be necessary to recall that the measured ionization is mostly due to alpha-ray, and the rest to beta- and gamma-rays; the last two kinds of rays playing only a fractional rôle in the ionization. With a suitable absorber, for example, Al-foil thicker than 0.043 mm, the most penerating alpha-ray from ThC′ can be checked.

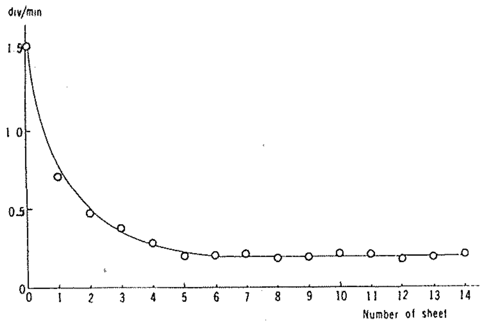

Fig. 1. The change of shifting rate of indicator with increasing number of sheets of aluminium alpha-ray absorber.

In this connection, some experiments on the stopping power of aluminium for alpha-rays were carried out. As shown in Fig. 1, it was found that practically all of the alpha-rays from the rock powder were stopped with six sheets of aluminium foil corresponding to a thickness 9.6 mg/cm^2 and that the ionization is reduced to ca. 15% of that without any absorber.

As the radioactive distribution energy in rock is almost completely converted into heat, the contributions of radioactive elements to heat generation in rock may be considered as nearly proportional to those of the ionization effects in air of respective radio-elements. The amount of heat generated by the radioactive elements in granites is given as follows[3].

Radioactive families or nuclides		Calculated annual rate of heat generation in granites 10^{-6} cal g^{-1}
Uranium and actinum families		3.00
Thorium family		2.74
Potassium	^{40}K	0.92
Rubidium	^{87}Rb	0.04
Samarium	^{147}Sm	0.006
Total		6.706

Thus the heat generation by ^{40}K is considerable, i.e., the contribution of potassium is about 14% of the total, and so will be its ionizing effect. On the other hand, the energy of the gamma rays from ^{40}K is so high that they would not be filtered off by a thin layer of absorber, and as SENFTLE[4)] has pointed out, on occasion, will cause mistakes for indication of uranium or thorium deposits by producing a few times increase in the normal background in the count with a Geiger counter during the radioactive prospecting.

In the ionization measured with electroscope, though only a certain portion

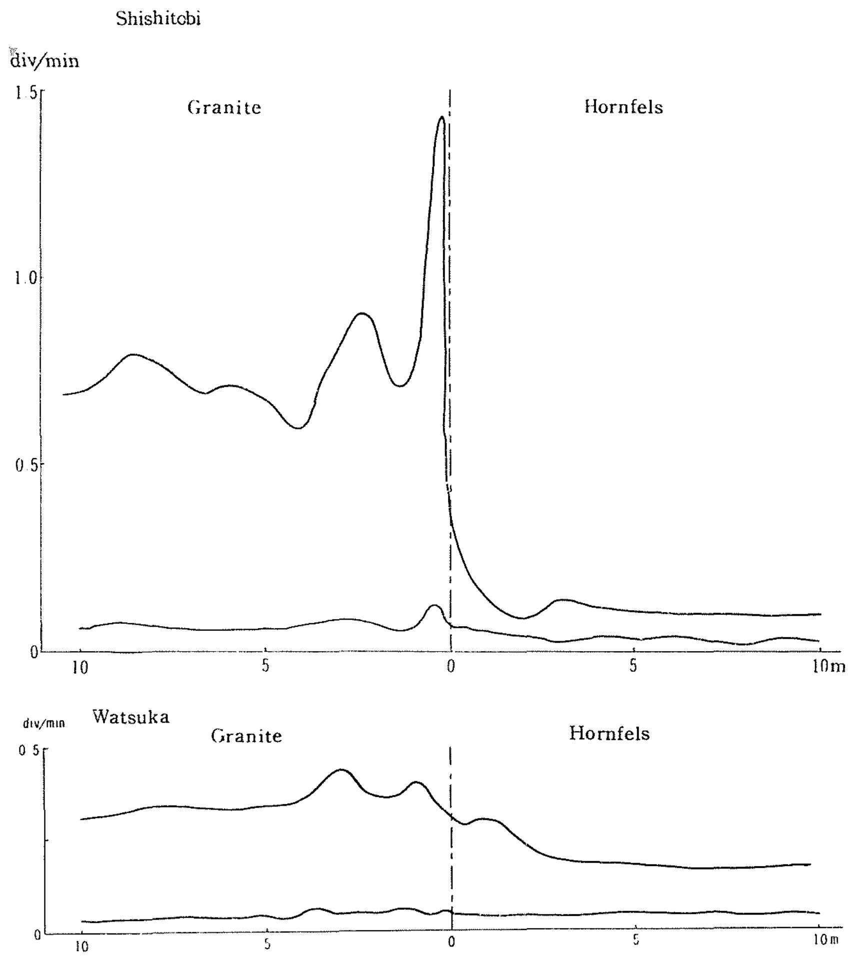

Fig. 2. Radioactive profiles with practically continuous samples from Shishitobi, Shiga Pref. (the upper figure) and Watsuka, Kyoto Pref. (the lower figure). The upper curves represent the total activity, while the lower ones the beta- and gamma-activity in either figure.

of the whole range of gamma-ray as well as that of beta-ray is effective, the like tendency will still be observed as we compared the ionization with and without Al–foil absorber on the pulverized sample of rock.

Trial observations were made with absorber of aluminium foil of 9.6 mg/cm^2, but the ionization by beta- and gamma-rays was so weak that with the present apparatus the results of the variation of radioactivity obtained with each of the samples are not definite. In Fig. 2, the upper figure shows the results along a traverse across contact at Shishitobi in Shiga Pref., the lower one those at Watsuka in Kyoto Pref. The lower curves in either of the figure in Fig. 2 represent the beta- and gamma-ray activities, while the upper curves the total activities.

Referring to the upper figure in Fig. 2, a hump observed in the lower curves corresponds to the conspicuous peak and the second peak appearing close to the boundary nearly two meters or so from it in the upper one. One of the probable explanations for this is that, uranium, thorium and potassium reveal considerable concentration at distances corresponding to the first and second peaks. The fact that uranium and potassium concentrate together in the liquid phase as crystal fractionation proceeds is a known phenomenon, and HENSON, F. A.[5] found that rubidium and elements usually associated with potassium in nature, concentrate at or near the boundary of contact. One of the isotopes of rubidium ^{87}Rb itself is a radioactive nuclide, but its contribution to the ionization may be negligible owing to its lower relative abundance.

Tracing of radioactivity with closer intervals

The way of sampling of rock specimens, with which radioactive distribution across igneous contact has been determined until the present, is such that the nearer the contact boundary is, the closer is the interval between two adjacent sites of sampling. The distance of sampling sites from the boundary are, for example, 0.1; 0.2; 0.3; 0.4; 1; 2; 3; 5; 7; 10 meters.

With a view to checking the above-mentioned way of sampling, along two of the traverses in which the types of curve of radioactivity distribution greatly differ, measurements were made on the samples taken at as regular intervals of 10 cm as exposure allowed through the whole range of sampling, 10 m each on both sides of the contact boundary.

Practically, this sampling may be considered as continuous, if we take into account the bulk of each sample, as compared with the usual way of sampling in which intervals are closer towards and separated progressively against the contact boundary. The results are seen in Fig. 2, showing nearly the same tendency of variation which may be expected in case of usual way of sampling. In conclusion, the usual way of sampling is proved to be not inadequate.

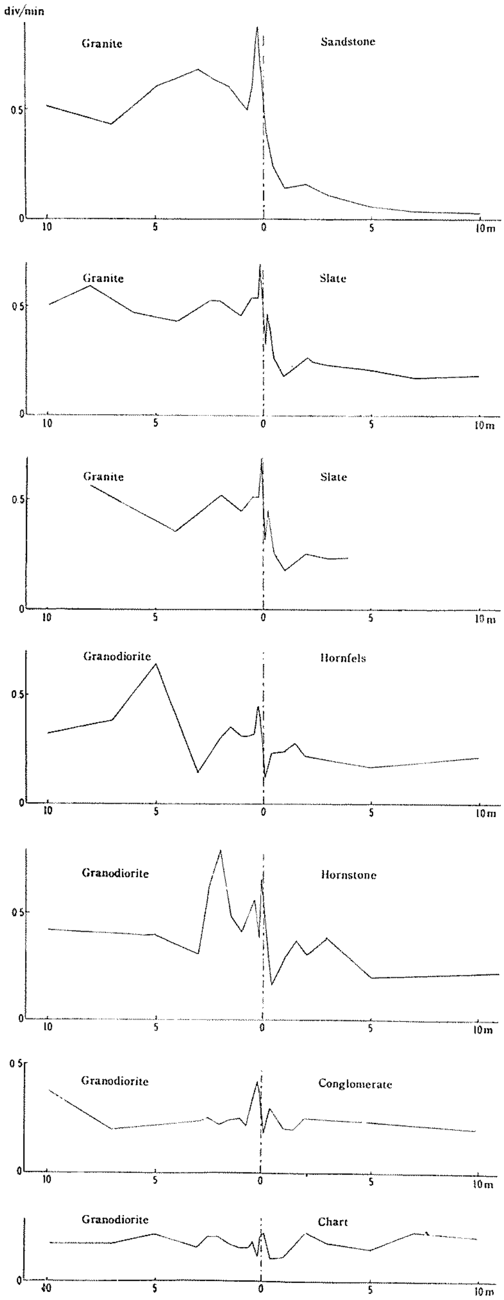

Fig. 3. Radioactive profiles (Matsuyama-Saijô).

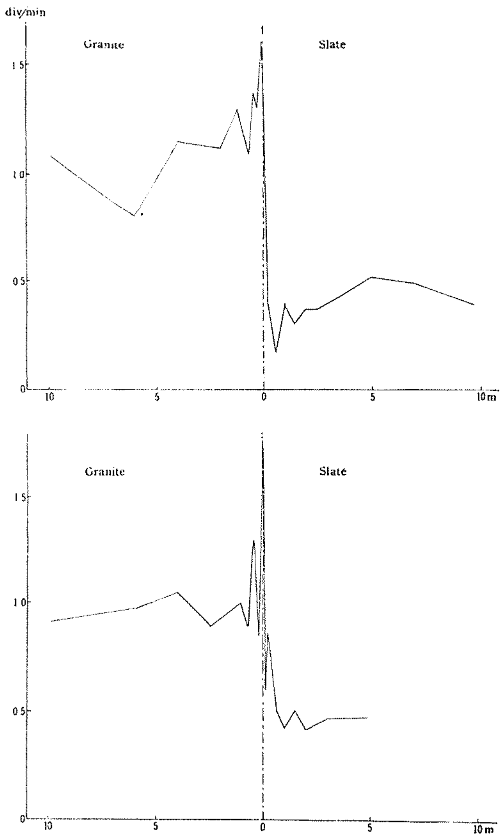

Fig. 4. Radioactive profiles (Tamano).

New data on the distribution of radioactivity across igneous contact

Since 1958, 53 sites of igneous contacts were examined for the distribution of radioactivity. The total number of sites studied since the beginning of this study amounts to 167. Usually several traverses were traced on the radioactivity across contact boundary in each locality. Some remarkable features found were as follows:

Matsuyama-Saijô area:—Along the route from Matsuyama to Saijô, the types of the variations was normally of the III-type. The variations of the IV-type (refer to the second paper) were found, except at a part, in Saijô area. There, the country rocks were intensely silicified rock such as chart or hornstone. The representative examples are shown in Fig. 3.

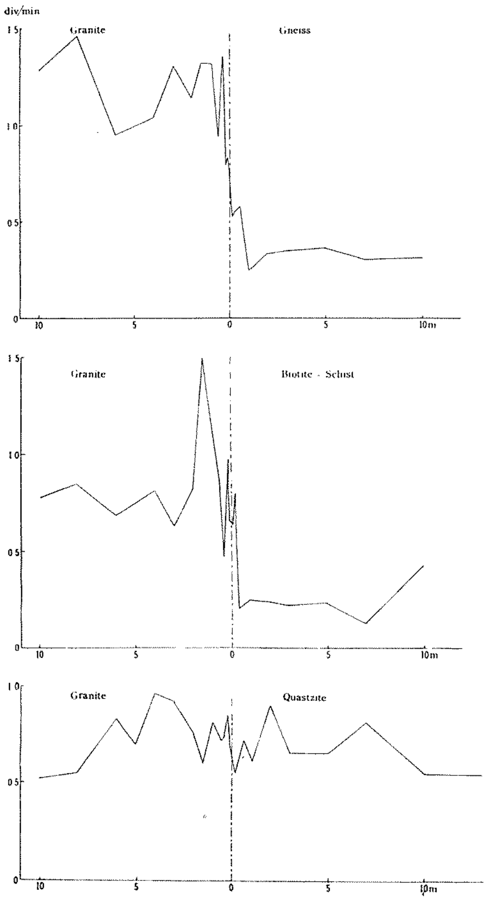

Fig. 5. Radioactive profiles (Mitajiri).

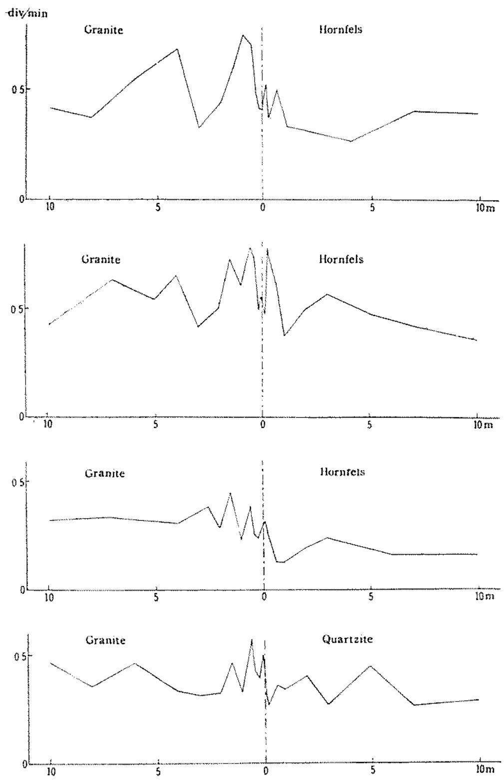

Fig. 6. Radioactive profiles (Takamizu).

Tamano city:—In this area, the variation of Type I was observed at each traverse tested. The country rock is usually slate. The representative examples are shown in Fig. 4.

Mitajiri area:—In the northern part of this area, radioactivity variations of Type I–II were found, while in the sourthern part, the type changes into Type II or III corresponding to the silicious wall rocks such as quartzite etc. In Fig. 5 are shown the representative examples.

Takamizu area:—The intrusive rock in this area is the so-called "Ryoke granite". Radioactivity profiles found across contact belong to Type III–IV. (Fig. 6).

Area between Itozaki and Fukuyame: —The radioactivity profiles of Type III are commonly observed. The rock near contact surface is highly weathered (Fig. 7).

Hita city:—The radioactivity distribution curves across contact here showed rather a peculiar feature resembling those at Sugi Pass of the Type II in the first paper, this type having being omitted in the second report[2]. The radioactivity rapidly decreases as the distance from the boundary of contact (Fig. 8).

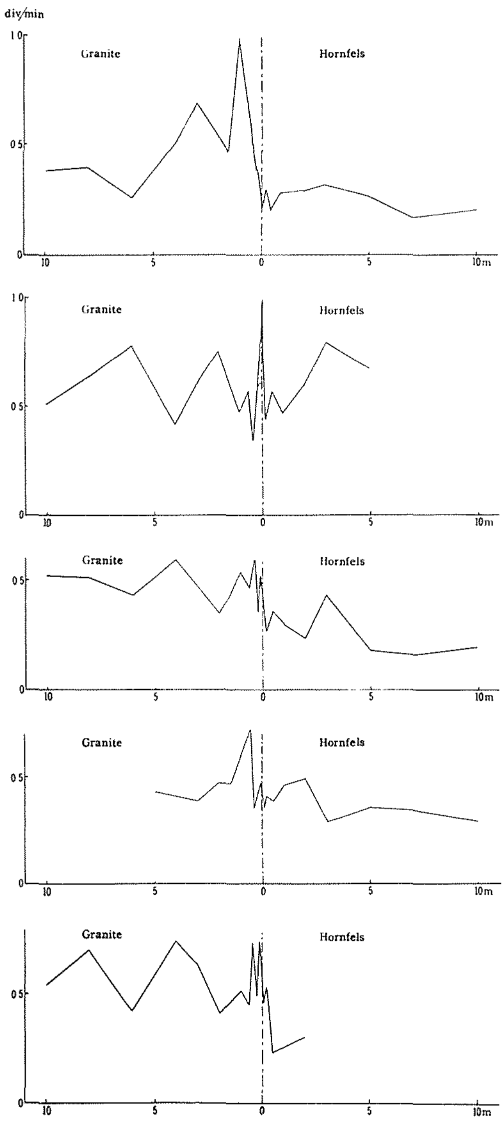

Fig. 7. Radioactive profiles (Itozaki-Fukuyama).

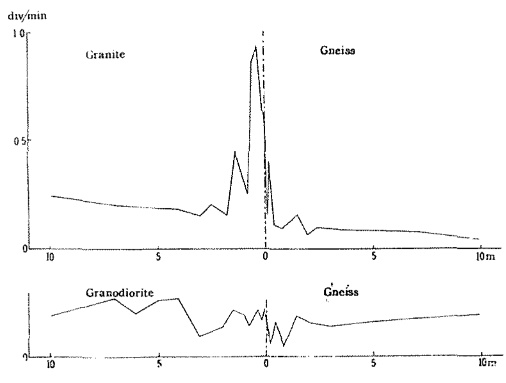

Fig. 8. Radioactive profiles (Hita).

Some descriptions of geology of the localities where samples were taken

Matsuyama and Saijô, in the northern part of Ehime Pref.

In the northern part of and along the Saijô-Matsuyama route, the samples are collected from the contact of Paleozoic sediments with hornblende-biotite granite. Paleozoic sediments: These sediments are metamorphosed by hornblende-biotite granite to mica-schist, quartz-schist or hornfels, the colour of which is blackish to grayish. They crop out in several detouched small areas surrounded by granite. Hornblende-biotite granite: This rock is grayish white in colour and is generally coarse- and sometimes medium-grained. The principal constituents are quartz, orthoclase, plagioclase, biotite and hornblende. This granite intruded into Paleozoic sediments and metamorphosed them. The rock shows gradual transition to biotite-granite in the northern part of this region.

Tamano, in the southern part of Okayama Pref.

In this district, biotite-granite intruded into Paleozoic formations of slate and sandy-slate, and metamorphosed them into hornfels and mica-shist. The biotite-granite here presumably represents the shallower part of the same intrusion as Matsuyama-Saijô granite. The principal constituents are orthoclase, plagioclase, quartz and biotite.

Mitajiri, in the south-eastern part of Yamaguchi Pref.

Biotite-granite, porphyritic granite and granite-porphyry occur in the great bosses in this district. The samples are collected from the contacts of Paleozoic sediments with biotite-granite. This granite is medium-grained and white in colour especially near the contact. The principal constituents are orthoclase, quartz and biotite associated with few plagioclase and occasionally with zircon. The sedimentary rock of Upper Paleozoic were altered to hornfels and hornstone by contact metamorphism. The latter is white in colour and the greater part of it consists of fine-grained quartz.

Hita, in the northern part of Ôita Pref.

In this district, the samples were collected from the contacts of Paleozoic sediments with granodiorite and with biotite-granite. Paleozoic sediments are metamorphosed by biotite-granite to hornfels. Granodiorite is gray in colour, and its principal constituents are plagioclase, hornblende and biotite. Biotite-granite is grayish white in colour, and its components are quartz, orthoclase, plagioclase and biotite.

Takamizu, in the eastern part of Yamaguchi Pref.

In this locality, the samples are collected from the contacts of hornstone with biotite-granite or with hornblende-biotite granite. These igneous would be of the same origin with biotite-granite in Mitajiri. They are grayish white in colour and medium-grained. The principal constituents are orthoclase, plagioclase, quartz and biotite with small amounts of hornblende.

Itozaki-Fukuyama, in the earstern part of Hiroshima Pref.

The contacts are hornfels with biotite-granite. Biotite-granite is pink in colour and belongs to the so-called "Hiroshima type granite". The constituents minerals are orthoclase, quartz and biotite. Sandy-shale was altered into hornfels by the contact-metamorphism, and its colour is grayish black to brown. In the earstern part, for example, at Saizaki, it is suspected that along the contact surface, faulting might have occurred.

Shishitobi, in the sourthern part of Lake Biwa, Siga Pref.

As the general geology and petrology of this district have been mentioned by T. Asayama and I. Hayase, *et al.*[5], only the additional description will be given below: Paleozoic sediments are altered to hornfels by contact-metamorphism. Biotite-granite is in most cases coarse- sometimes medium- and rarely fine-grained, and occasionally they contains small quantity of muscovite. This granite body is often found intruded by felsic pegmatite in this locality.

Watsuka, in the sourthern part of Kyoto Pref.

The rocks consist of Ryôke metamorphic rocks such as biotite-schist, biotite-hornfels and granites. The granite is generally a fine-grained hornblende-biotite granite. As mentioned already in the first report, granitization of low grade seemed to have prevailed in this locality.

Summary remarks

(1) The results of the measurements of radioactivity with samples practically continuously collected along a line perpendicular to the line of igneous contact, has revealed nearly the same tendency of variation found as in the case of usual way of sampling, in which the nearer the contact boundary was, the closer was the span between the two adjacent sites of sampling.

(2) Beta (+gamma)-ray ionization was measured, but it was so weak that any definite conclusion could not be reached, except that a hump observed in the beta ray curve close to the contact boundary, presumably corresponding to the conspicuous peak appeared in the profile of the alpha-ray ionization, is suggestive of concentration of Th, U and ^{40}K as well as ^{87}Rb.

(3) Fifty three profiles of radioactivity distribution traversing igneous contacts have been newly established, of which typical ones have been shown as representatives. The general discussion of these results will be given in the next report.

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