The Contamination-trends in the Kyûshû Outer Zone Granites and Some Typical Granitic Rocks in Other Regions

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I. Introduction

The heterogeneity found in the Kyûshû Outer Zone granites, which show some conspicuous petrochemical features common to the whole of them, is recognized to have related with the contamination-effect which would have been brought secondarily during the intrusion of these granites which would have accompanied with the Shimanto Orogeny. From various petrographical evidences, it is hardly questionable that the contamination-effect found in these granites have had an intimate relation with xenoliths, among which pelitic xenoliths and basic ones are the most common and distinguishable from each other, and also that these granites were generally contaminated with both kinds of pelitic rocks and basic ones. In order to consider what substances have had mainly something to give the contamination-effect on certain granitic rocks, the comparison between the contaminated granitic rocks and the normal or less contaminated ones on the AKF diagram is available. Thus, the AKF diagrams of the Kyûshû Outer Zone granites were shown and examined in the previous paper (ÔBA, 1962 b). According to these diagrams, each of these granites shows that it was much more dominantly contaminated with either pelitic rocks or basic ones.

In the present paper, the contamination-trends of the Kyûshû Outer Zone granites will be compared with those of some typical granitic rocks which have been proved hitherto as having had a conspicuous contamination with either pelitic rocks or basic ones in other regions or petrographic provinces. The general contamination-trends in granitic rocks will also be discussed.

2. The Contamination-trends of the Kyûshû Outer Zone Granites and Some Typical Granitic Rocks in Other Regions

The AKF diagram regarding the contamination-effect of the Kyûshû Outer Zone granites is as shown in Fig. 1. As seen from the trend-lines on the diagram regarding the contamination-effect on granites, two systems of granites are recognized in the Kyûshû Outer Zone granites; furthermore, probably in the Southwestern Outer Zone ones, too. That is, the granites which were much more dominantly contaminated with pelitic rocks are in the direction towards the apex A or the A-K line, while, those which were much more dominantly contaminated with basic ones are in the direction towards the apex F or the diabasic field. For convenience, the granitic rocks contaminated remarkably with pelitic rocks and those with basic ones are named the pelitic contaminated granitic rocks and the basic contaminated ones. Also, the contamination with the pelitic rocks and that with the basic ones are named the pelitic contamination and the basic one, respectively, by the present author.

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The contamination-trends of the Kyûshû Outer Zone granites will be compared with those of granitic rocks which have been proved as having been affected by a conspicuous contamination with either pelitic rocks or basic ones in other regions or petrographic provinces in Japan as follows: Older Dando-type (Ryôke region), Younger Abukuma-type (Abukuma mountainland), Tanohata (Kitakami mountainland), Kisokoma-type (Kiso mountainland), Tanzawa-type in the green tuff region, and some granitic rocks in the Hidaka zone. They will be also compared with the contamination-trend of the Dartmoor granites as an example of the foreign granites.

Fig. 1. The AKF diagram of the Kyûshû Outer Zone granites in regard to the contamination-effect.

1. Normal or less contaminated granitic rock. 2. Contaminated granitic rock. 3. Pelitic xenolith. 4. Diabasic xenolith. 5. Pelitic rock. 6. Hornfels. 7. Diabasic rock. 8. Aver. of 63 analyses of the Southwestern Outer Zone granites (ÔBA, 1962 a). 9. Ôsumi. 10. Takakumayama. 11. Shibisan-Shimokoshikijima. 12. Ichifusayama. 13. Ôkueyama. 14. Owase.

P : Pelitic field. D : Diabasic field.

Older Dando-type granitic rocks:

The Older Dando-type granitic rock (SHIBATA et al., 1954) is one of the granitic rocks which have been petrographically studied hitherto in the most detail in Japan. Among the granitic rocks, KOIDE (1949, 1958) recognized three types of granitic rock as follows: Sumikawa-, Kiyosaki- and Busetsu-type. SHIBATA et al. (1954, 1956) considered that the Sumikawa-type is the main magma-type, the Kiyosaki-type is the magma-type which was contaminated with basic forerunners, and the Busetsu-type is the magma-type which was contaminated with argillaceous sediments. The contamination-trends in these three types are

Fig. 2. Distribution of the Older Dando-type granitic rocks on the AKF diagram (data from KOIDE, 1958, SHIBATA et al., 1954, 1956).

1. Sumikawa-type. 2. Kiyosaki-type. 3. Busetsu-type. 4. Basic xenolith. 5. Meta-basic rock and least-granitized basic rock. 6. Hornfels. 7. Shale.

Fig. 3. Distribution of the Younger Abukuma-type granitic rocks on the AKF diagram (data from SHIBATA et al., 1954).

1. Granodiorite, pink granite, acidic granite and two-mica granite. 2. Contaminated granodiorite. 3. Metadiabase (data from WATANABE, 1957).

very well represented on the AKF diagram respectively (Fig. 2). That is, the plotted points of granitic rocks of the Busetsu-type fall certainly in the area close to the apex A against those of the Sumikawa-type, but, on the contrary, those of the Kiyosaki-type is clearly in the direction towards the diabasic field.

Younger Abukuma-type granitic rocks:

Among the Younger Abukuma-type granitic rocks, the Tamanoyu A- and C-facies granites (SHIBATA et al., 1954), which correspond to the Tokiwa-type of the first younger granitic series (SENDÔ, 1958), are remarkably poor in alumina and alkalis, and, on the other hand, remarkably rich in ferrous iron oxide and lime. The age of their intrusions was presumed by SHIBATA et al. (1954) to be the Middle Cretaceous. It was also described by them that they were affected by the contamination-effect on basic rocks. Their contamination-trend is in the direction towards the apex F* on the AKF diagram (Fig. 3).

Tanohata composite granitic rocks:

The Lower Cretaceous Tanohata composite granite mass intrudes discordantly into the surrounding sedimentaries, the age of which is the Palaeozoic, consisting of mainly shale and sandstone. The granite mass is a solidification product at the shallower depth and also highly heterogeneous. As the granitic rocks were under the conditions analogous to the Kyûshû Outer Zone granites in many points except the age of their intrusions, they are convenient for comparison with the Kyûshû Outer Zone granites in regard to the contamination-effect.

The Kawaguchi-type of the composite mass is rich in basic xenolith and

* The basic xenolith plotted on the diagram was used by supposing that a metadiabase described by WATANABE (1957) has a composition very alike to that of the diabasic xenolith included in the granitic rocks.

contains xenocrysts of basic plagioclase, and is also rich in minor elements such as Ni, Cr etc. Its partial facies-changes are also conspicuous. From these facts, Ishii et al. (1955) concluded that the Kawaguchi-type granitic rocks were contaminated with basic rocks. On the other hand, it was also deduced by KANÔ (1959) that the marked diversity in composition of the Tanohata composite granitic rocks, especially of the Kawaguchi-type, has an important relation with the mechanism of formation of an aplitic magma contaminated by lime and silica. The contamination-trend of the granitic rocks is very well shown on the AKF diagram (Fig. 4).

Fig. 4. Distribution of the Tanohata composite granitic rocks on the AKF diagram (data from ISHII et al., 1955).

1. Moichi-, Ogiu-, Otomo- and Ôtanabe-type. 2. Kawaguchi-type. 3. Shimoakka-type (hypabyssal).

Fig. 5. Distribution of the Kisokoma-type granitic rocks on the AKF diagram (data from SHIBATA et al., 1954, 1958, ÔKI, 1958).

1. Kurokawa-type. 2. Kisokoma-type. 3. Contaminated Kisokoma-type granitic rock contacting with the surrounding sedimentaries.

Kisokoma-type granitic rocks:

As a result of the contamination which was taken place between the Kisokoma-type granitic rocks of the Fore-Ryôke intrusives and the surrounding Palaeozoic pelitic sedimentaries, the marginal facies of the granitic rocks has come so as to be rich remarkably in alumina, and, on the other hand, to be poor in alkalies, ferrous iron oxide, magnesia and lime, and also to grade into the Kurokawa-type in both cases of the chemical composition and the mineral assemblage (SHIBATA et al., 1954, 1958, ÔKI 1958). The contamination-trend of the granitic rocks is well shown on the AKF diagram (Fig. 5).

Comparison between two Neogene Tertiary granitic rocks of the green tuff region and the non-green tuff region:

The Neogene Tertiary Plutonic Province was divided by SHIBATA et al. (1960) into the Southwestern Outer Zone (Miocene) Province and the Tôhoku Japan Miocene one (the Tanzawa-type Trondhjemite Series). The Tanzawa-type granitic rocks are remarkably rich in soda, and, in many cases, rich in alumina, and also trondhjemitic. From these facts, SHIBATA et al. (1955, 1960) considered that

this trondhjemitic magma might have been produced through the palingenesis of the thick spilitized pyroclastic strata intercalating pelitic sediments. The Kansai Tertiary-type granitic rocks were also presumed by them as having the same origin.

On the AKF diagram (Fig. 6), the plotted points of the Tanzawa-type (and the Ashikawa-type) granitic rocks fall in the side of the apex A; while, those of the Tôhoku Neogene Tertiary-type in the side of the apex F, and also those of the Kansai Tertiary-type, accidentally, just between the former two. The fact that the plotted points of the Tôhoku Neogene Tertiary-type granitic rocks among these three types fall in the side closest to the apex F suggests that the granitic rocks of this type have an intimate relation with the green tuff, which is intruded by the granitic rocks and the same granitic rocks are overlaid by the green tuff (ISHII et al., 1955). From the mode of distribution of these types on the diagram, it is found that their plotted areas on the diagram differ from each other according to their localities, though these three types belong to the same green tuff province. Such difference concerning their positions on the diagram seems to indicate the differences in time and space as has been mentioned by MATSUMOTO et al. (1960). Nevertheless, all plotted points of the granitic rocks found in the green tuff region are biased to the side very close to the A-F line in comparison with those of the Kyûshû Outer Zone granites.

According to KATÔ (1955), the activity of dioritic intrusives in the green tuff region took place subsequently from a volcanic activity predominating in andesitic volcanics in an early phase of transgression in the Middle Miocene. On the other hand, the geological age of a part of the Kyûshû Outer Zone granites was presumed as the Palaeogene, and that of the others as the Neogene by means of the zircon method (MIYAHISA et al., 1953). From the likeness of the mass color of the zircon, however, it was reconsidered lately by MIYAHISA (1960) that the age of their intrusions will be almost the same as that of the Osuzuyama acidic rocks, that is, the Middle Miocene. It will be possibly regarded, therefore, from the macroscopic viewpoint, that the activity of the granitic rocks in the green tuff region would have probably taken place almost contemporaneously with that of the Kyûshû Outer Zone granites. The plotted areas of the granitic rocks of the green tuff region, however, differ apparently from those of the Kyûshû Outer Zone granites on the diagram. Such difference in their positions on the diagram shows obviously the essential difference concerning petrochemical natures between the granitic rocks of the green tuff region and the Kyûshû Outer Zone granites; in other words, between the granitic rocks of the green

Fig. 6. Distribution of the Tanzawa-type granitic rocks on the AKF diagram (data from SHIBATA et al., 1955, 1956, 1960, ISHII et al., 1955).
1. Ashikawa-type. 2. Tanzawa-type.
3. Tôhoku Neogene Tertiary-type.
4. Kansai Tertiary-type.

tuff region and those of the non-green tuff region. Considering the genesis of these granitic rocks, it is thought that the above fact not only depends on the difference of petrochemical natures between their granitic magmas, but also on the difference of the geological conditions of the environment of their intrusions, that is, probably, of the nature of the basement complexes which would have affected the contamination on the granitic magmas.

Hidaka granitic rocks:

Some granitization gaitic rocks derived from sediments are available for comparison with the pelitic contaminated granitic rocks. Then, all of granites, gneisses, migmatites and hornfelses derived from sedimentaries consisting of mainly clayslate and sandstone in the Hidaka zone were plotted on the AKF diagram (Fig. 7). On the diagram, the plotted points of the above granitic rocks,

Fig. 7. Distribution of granitic rocks and associated rocks from the Hidaka metamorphic zone.

Southern extreme of the zone (data from FUNAHASHI et al., 1956): 1. Gneiss. 2. Migmatite. Northwestern end of the zone (data from KIZAKI, 1953): 3. Gneiss. 4. Migmatite. Southern end of the zone (data from SHIBATA and SOTOZAKI, unpublished M. S.): 5. Granitic rock. 6. Migmatite. 7. Hornfels.

on the whole, are biased to the apex A and the A-F line as compared with those of the Kyûshû Outer Zone granites. Such scattering of the plotted points as shown on the diagram may have resulted from the special mechanism of their formation as has been described by FUNAHASHI et al. (1956). The Kyûshû Outer Zone granites, therefore, should be compared with the Tertiary granitic intrusives in the Hidaka zone for the future.

Dartmoor granites:

BRAMMALL et al. (1932) recognized that some petrographical features found in the Dartmoor granites have an important relation with both kinds of shale and basic rock. In this sense, the granites are available for comparison with the Kyûshû Outer Zone granites in regard to the contamination-effect. The Dartmoor granites consist of the Older main granite and the Newer granite (aplogranite). All of these granites, and aureole shales and also xenoliths were plotted on one and the same AKF diagram (Fig. 8).

On the whole, the plotted points of these granites are biased to the side of the apex K or the A-K line against those of the Japanese granitic rocks. The distribution of plotted points of the marginal facies of the main granite are biased to the side closest to the A-K line. BRAMMALL et al. concluded that the main granite, which was initially sodipotassic acidic magma, was affected with both kinds of basic rock and shale while differentiation was proceeding. On the diagram, the plotted area representing the main granite falls apparently between two areas for pelitic rocks and basic ones, though it is slightly biased to the A-K line.

Fig. 8. Distribution of the Dartmoor granites and related rocks on the AKF diagram (data from BRAMMALL et al., 1932).

1. Older main granite. 2. Older granite (aplitic) of marginal facies.
3. Older granite of contact-facies. 4. Newer granite. 5. Newer granite of contact-facies.
6. Aureole shale. 7. Hornfelsed shale-xenolith. 8. Basic xenolith. 9. Granitized basic xenolith.

3. The Contamination-trends

For consideration of the contamination-trend, all trend-lines of the Kyûshû Outer Zone granites and some typical granitic rocks in other regions or petrographic provinces were collectively drawn on one and the same AKF diagram (Fig. 9). The arrows show the contamination-trends.

On the diagram, plotted points for all contaminated granitic rocks from Shibisan, Shimokoshikijima and Ichifusayama among the Kyûshû Outer Zone granites and also Owase belonging to the Southwestern Outer Zone granites are in the direction towards the apex F or the diabasic field against those for their normal or less contaminated ones, and also these granites show a tendency similar to each other. That is, the positions of the arrows of their trend-lines are considerably biased to the side of the apex F against the plotted point representing the average of 63 analyses of the Southwestern Outer Zone granites, and also show such a tendency so as to become much more basic than the normal or less contaminated granitic rocks. The contamination-trends of these contaminated granitic rocks are also in good accord with those of the Kiyosaki-type among the Older Dando-type granitic rocks, the Tanohata composite granitic rocks and the Younger Abukuma-type ones. On the other hand, the plotted points for the

Fig. 9. Comparison of the contamination-trends of the Kyûshû Outer Zone granites with those of some typical granitic rocks from other regions.

O: Ôsumi. TK: Takakumayama. SK: Shibisan-Shimokoshi-kijima. I: Ichifusayama. OK: Ôkueyama. W: Owase. A: Younger Abukuma-type. TN: Tanohata. S: Sumikawa-type. B: Busetsu-type. K: Kiyosaki-type. T: Tanzawa-type.

1. Aver. of 63 analyses of the Southwestern Outer Zone granites.
2. Aver. of 440 analyses of Japanese granitic rocks (HATTORI et al., 1960).
3. Aver. of 546 analyses of granites (DALY).

contaminated granitic rocks from Ôsumi and Ôkueyama among the Kyûshû Outer Zone granites are generally in the direction towards the apex A or the A-K line against those for their normal or less contaminated ones. Their contamination-trends are roughly in accord with those in the Busetsu-type among the Older Dando-type granitic rocks, the Tanzawa-type among the granitic rocks found in the green tuff region and the Kisokoma-type granitic rocks. As compared with the fact that the contamination-trends of the basic contaminated granitic rocks, such as Shibisan, Shimokoshikijima, Ichifusayama, Owase, Kiyosaki-type, Tanohata, and the Younger Abukuma-type, are generally simple and sharp, the contamination-trends of the pelitic contaminated ones, such as Ôsumi, Ôkueyama, Busetsu-type, Tanzawa-type and Kisokoma-type, show somewhat sporadic extent and a slightly complex manner.

If the fact mentioned above is true, and, when suppose that the asterisk O

on the diagram of Fig. 10 represents an original and homogeneous granitic magma of a petrographic province or a single mass of a granite body, the contamination-trend of granitic magma which was remarkably contaminated with pelitic rocks should generally indicate the direction towards the apex A or the A-K line, as shown by the arrows of OP and OP'; while, that which was remarkably contaminated with basic rocks should generally indicate the direction towards the apex F or the diabasic field, as shown by the arrow OD. The character of the contamination-trend in granitic magma, however, is thought that it differs generally in different petrographic provinces or granite bodies, as seen from the cases of the Kyûshû Outer Zone granites and the granitic rocks found in the green tuff region. Such difference concerning the contamination-trend among granitic magmas, as shown by the deviation between the asterisks of O and d on the diagram, is considered as a reflection of the combined natures of these granitic magmas and the geological conditions of the environment of their intrusions. For instance, two examples of the Tanzawa-type granitic rocks and the Kyûshû Outer Zone granites, as already mentioned, show that even if the age of the activity of some granitic rocks is almost contemporaneous, when the geological conditions of the environment of their intrusions had been different from each other, their plotted areas representing these granitic rocks on the diagram would be generally different, and furthermore, that even if some granitic rocks belong to one and the same genetical system, the mode of their contamination-trends will be not always the same. That is, the positions of the lines representing the contamination-trends in certain granitic rocks on the diagram will be generally proper to each other.

Fig. 10. Schematic diagram representing the contamination-trends in granitic magma.

However, if quite the same chemical composition alone had been obtained from two series of secondarily contaminated magmatic granitic rocks and dry diffused granitization ones which were derived in situ from a certain rock, it would be hardly possible in general to distinguish the above two series of granitic rocks from each other on the AKF diagram, for instance, as seen from two cases of the following examples; the Tanohata composite granitic rocks in the Kitakami Mountainland (Fig. 4) and granitic rocks presuming to have been derived through the process of granitization from amphibolites in the Abukuma Mountainland (Fig. 11), and the Ichifusayama granitic rocks (Fig. 1) and granitic rocks grading into metadiabases due to local granitization in the vicinities of the Koshibu River, Nagano Prefecture (Fig. 12). For distinguishing them from each other, therefore, field evidences and other means should be required.

From the mode of distribution of the above granitic rocks on the diagram, it is also found that the plotted points of all of the Kyûshû Outer Zone granites, and

Fig. 11

Fig. 12

Fig. 11. Distribution of so-called granitized basic rocks from the Abukuma Mountainland on the AKF diagram (data from OGURA, 1956).

1. Amphibolite. 2. Quartz diorite (fine-grained type). 3. Ditto (medium-grained type). 4. Ditto (coarse-grained type).

Fig. 12. Distribution of the granitized rocks from the vicinities of the Koshiu River, Nagano Prefecture, on the AKF diagram (data from ISHII et al., 1962).

1. Amphibolite. 2. Metadiabase. 3. Fine-grained quartz-diorite. 4. Gneissose quartz-diorite. 5. Gneissose granodiorite.

furthermore, also of the Southwestern Outer Zone ones, and probably most of the Japanese ones, fall restrictively within a triangle AMF ($M \cdots A=50$, $K=50$, $F=0$) (Fig. 10). Granitic rocks plotted in the side of the apex K against the M-F line are rare or scarce. However, the plotted extent of the foreign granites, which are generally rich in potash, for instance, such as the Dartmoor granites, may be much more enlarged to the R-Q line ($R \cdots A=40$, $K=60$, $F=0$, and $Q \cdots A=0$, $K=10$, $F=90$). The R-Q line which was drawn based on analysis data, therefore, may represent the limit of the plotted extent for granitic rocks on the diagram.

4. Conclusion

For consideration of the contamination-effect on granitic rocks, the contamination-trends in the Kyûshû Outer Zone granites were compared with those in some typical granitic rocks in other regions or petrographic provinces to each other on the AKF diagram. As a result, it was found that two systems of contamination-trends recognized in the Kyûshû Outer Zone granites are in quite accord to each other with those in some typical granitic rocks which have been proved hitherto as havign been affected by a conspicuous contamination. These contamination-trendd can be reflected comparatively well on the diagram. That is, on the diagram, the granitic rocks which were remarkably contaminated with pelitic rocks are indicated by the trend-lines which are generally in the direction towards the apex A or the A-K line, while, those which were remarkably contaminated with basic rocks by the trend-lines which are generally in the direction towards the apex F or the diabasic field, against their normal or less contaminated granitic rocks.

The mode of the contamination-trend in granitic rocks, however, differs generally in different regions or petrographic provinces of their occurrences from each other, even if the geological age of their activities is almost contempo-

aneous. Such difference concerning the mode of the contamination-trend in the granitic rocks is considered as a reflection of the combined natures of the mechanism of their production and the geological conditions of the environment of their intrusions, and also, probably, of the nature of the basement complexes which would have had an intimate relation with the contamination, in a broader sense, in the granitic magmas.

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九州外帯花崗岩類および各地の代表的な花崗岩質岩類における汚染傾向

大 庭 昇

(要 旨)

花崗岩質岩類における汚染傾向は A K F 図で比較的良好に示される。この論文では、九州外帯花崗岩類と各地の代表的な花崗岩質岩類について、それらの汚染傾向を比較し、かつ、一般的汚染傾向について考察した。その結果、九州外帯花崗岩類において認められた 2 系統の汚染傾向は、汚染作用を蒙つたことの明らかにされている各地の代表的な花崗岩質岩類の示すそれらの傾向と全く一致することが明らかにされた。すなわち、汚染されていないか、または汚染の程度が少いと認められる花崗岩質岩類に比べ、泥質岩類によつて著しく汚染されたものは、一般に、A K F 図上、頂点 A または A—K 線側に指向的であり、一方、塩基性岩類によつて著しく汚染されたものは、一般に、頂点 F または輝緑岩フィールド側に指向的である。しかし、他方、花崗岩質岩類における汚染傾向の様子は、ほとんど同時期に活動したものであつても、地域あるいは岩石区が異れば一般に異なる。このような違いは、それらの形成のメカニズムおよび、遡入環境の地質条件の性質、また、おそらく、花崗岩質マグマにおける広義の汚染作用と密接な関係をもつていた基盤岩類の性質の反映であると考えられる。