FINDING OF A-TYPE GRANITOIDS FROM OUTER ZONE OF SOUTHWEST JAPAN

Nobuhide Murakami

Laboratory of Geography, Beppu University, Beppu, Japan

and

Teruyoshi Imaoka

Institute of Earth Sciences, Yamaguchi University, Yamaguchi, Japan

Abstract

A-type granitoids were found from the Cape of Ashizuri, Outer Zone of Southwest Japan. The igneous rocks of this area constitute a small (about 8 km in diameter) ring complex occurring in Mesozoic to Tertiary accretionary terrain, Shimanto Belt. They are of Miocene age and composed of five stages of rocks.

Detailed investigations on petrography and petrochemistry indicate the similarity of the granitic rocks of this complex with A-type granites after Loiselle and Wones (1979). Almost all of the granitic rocks from Outer Zone belong to S- or I-type granites after Chapell and White (1974), therefore A-type granitic rocks are of quite uncommon occurrence in this zone. This may mean the formation of small rift zone and relatively high rate of descending of slab beneath the southern part of Shikoku Island during Miocene time.

Introduction

The Japanese Islands are separated by "Fossa Magna" traversing the middle of Honshu into Northeast Japan and Southwest Japan. The latter is divided by the "Median Tectonic Line" into two zones, Inner Zone and Outer Zone. In the Inner Zone, acid to basic igneous rocks ranging from Cretaceous to Recent in age, are broadly distributed. Among them, Cretaceous to Paleogene acid to intermediate igneous rocks (largely I-type after Chappell and White, 1974) are most extensive.

On the other hand, the Outer Zone is characterized by the belty distribution of Paleozoic to Tertiary sedimentary and metamorphic rocks separated by some conspicuous strike faults. Acid to intermediate shallow-facies granites are intruded into these formations as stocks and dikes, often accompanied by volcanic rocks similar to the intrusives in chemistry. They are almost of Miocene age and scattered sporadically from Kinki to Kyushu, along Pacific coast.

The chemistry of the igneous rocks of the Outer Zone are investigated recently in detail by some workers (Murata, 1984 ; Nakada and Takahashi, 1979 ; Nakada and Okamoto, 1984 ;

Okamoto *et al.*, 1987). Nakada and Takahashi (1979) and Nakada and Okamato (1984) divided them into I- and S-types according to the criterion by Chappell and White (1974) mainly on the basis of major element chemistry and storontium isotopic data. According to them, I-type granites are relatively low in strontium initial ratio and found in the northern side, whereas the most of the granites of the southern side is occupied by S-type granites which are characterized by the higher strontium initial ratio as well as higher Al_2O_3 content. Besides these, tholeiitic gabbroic intrusives are found at the southernmost capes of Southeast Shikoku and Kinki. They are older in age than the above-cited granites. Lately, we found another type of intrusives different from both of I- and S-type granites, at the Ashizuri, southwesternmost part of Shikoku. They are similar to A-type granites after Loiselle and Wones (1977) in chemistry, as will be described in the following.

Geology and petrography of the Ashizuri igneous complex

The Cape of Ashizuri is located to about 40 kilometers southeast of the outcrops of S-type granites, Kashiwa-jima area.

The igneous rocks at the Cape of Ashizuri constitute a ring-like mass of about 8 kilometers in diameter, intruding the Paleogene Shimizu Formation, although its southern half cannot be observed (Fig.1).

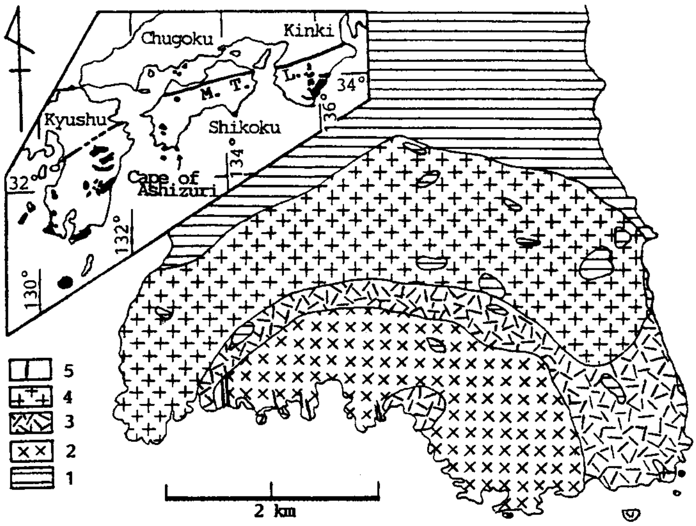


Fig. 1. Distribution of granitic rocks in Outer Zone of Southwest Japan and geological map of Cape of Ashizuri.
1: Shimizu Formation. 2: Stage II. 3: Stage III. 4: Stage IV. 5: Stage V. M.T.L.: Median Tectonic Line.

The component rocks of this complex range from gabbro to granite. They form concentric three zones (inner, central and outer) in which the age becomes younger from inner to outer. Five stages are discerned in them.

The component rocks of stage I are gabbro and dolerite contained as enclaves attaining to some ten meters in diameter, in the inner and central zones. In most of the outcrops they occur as aggregate mass composing of abundant angular to rounded blocks penetrated by the network of the syenites of stage Ⅱ or Ⅲ. According to the chemical features on the whole rocks and constituent minerals such as clinopyroxene, they are considered to belong to the alkaline rock series (Murakami and Imaoka,1985).

The rocks of stage Ⅱ are composed of medium-grained melanocratic syenite, qurartz syenite, alkali granite and alkali granite porphyry, in the inner zone. They are fairly poor in plagioclase and dominated by alkali feldspar, quartz (in alkali granite and alkali granite porphyry), clinopyroxene (hedenbergite and aegirine-augite), hornblende (ferro-edenite) and biotite (annite). Fayalite is an accessory mineral in the melanocratic syenite and accompanied pegmatite. Hornblende and biotite usually show interstitial occurrence.

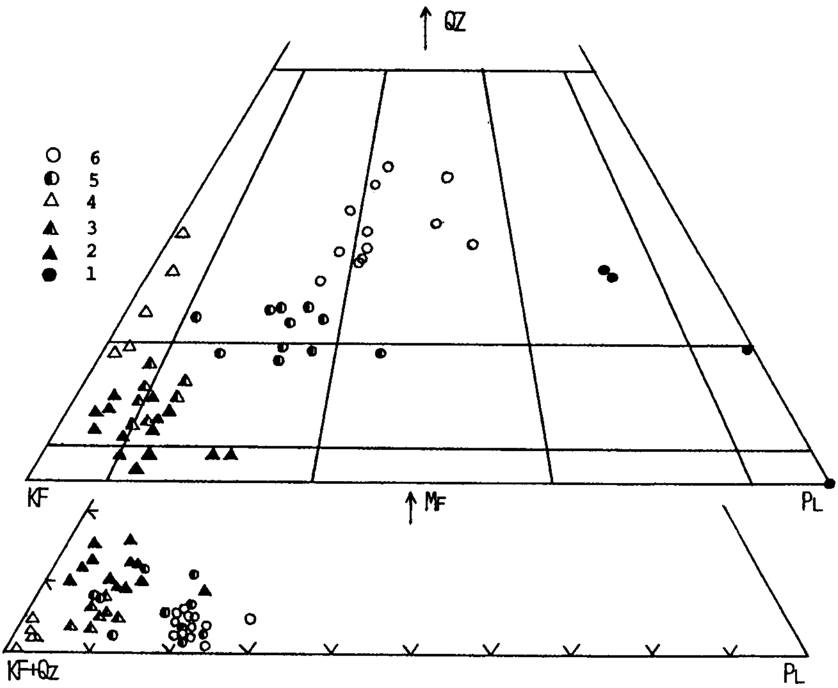
The central zone is occupied by the coarse-grained syenitic rock and succesively intruded rapakivi granite (Stage Ⅲ). The rapakivi granite is presumed to have been formed as a result of comingling of crystallizing coarse-grained syenitic rock with successively invading granodiorite magma (Murakami and Imaoka, 1985). The main constituents of the component rocks of stage Ⅲ are plagioclase, alkali feldspar, quartz, hornblende (ferro-edenitic hornblende ~ferro-edenite) and biotite. The ferromagnesian minerals are more magnesian than those in stage Ⅱ.

The outer zone consists of coarse-grained biotite grannite (Stage Ⅳ). It often contains hornblende of ferro-edenitic hornblende to ferro-edenite composition. Many aplite and pegmatite dikes are accompanied. In the marginal part, small granite porphyry dikes are intruded. Many sedimentary (shale and sandy shale) xenoliths possibly derived from the Shimizu Formation, are included sporadically.

The igneous rocks of stage V are represented by the alkali dolerite and quartz syenite porphyry penetrating the older rocks as dikelets of NNE-SSW direction at the southwestern part of the complex. The alkali dolerite is composed of plagioclase, alkali feldspar, titan-augite, kaersutite and titan-biotite, whereas the essential minerals in the quartz syenite porphyry are alkali feldspar, quartz and arfvedsonite.

Fig.2 shows the modal composition of the component plutonic rocks. As is clear in this figure, the rocks are highly rich in alkali feldspar. In Q-KF-PL triangular diagram, they are almost plotted on the granite, alkali granite, quartz syenite, quartz alkali syenite, syenite and quartz monzonite areas.

The component rocks of the Ashizuri igneous complex have several characteristic features which have not been recognized in the other granites of Japan. For example, in stage Ⅱ, almost all of the ferromagnesian hydrosilicates such as hornblende and biotite, occur interstitially filling the interspaces of quartz and feldspar crystals, as stated before. This indicates the crystallization under relatively dry condition as already stressed by Maaløe and Wyllie (1975).



1:Gabbro(Stage I). 2:Melanocratic syenite(Stage II). 3:Quartz syenite(Stage II). 4:Alkali granite(Stage II). 5:Coarse-grained syenitic rock and rapakivi granite(Stage III). 6:Coarse-grained biotite granite(Stage IV).

Fig. 2. QZ-KF-PL and MF-(KF+QZ)-PL triangular diagrams of component plutonic rocks.

QZ: Quartz. KF: Alkali felspar. PL: Plagioclase. MF: Mafic minerals.

Petrochemistry of the Ashizuri igneous complex

In chemistry too, the component rocks of the Ashizuri igneous complex have various characterisitic features.

1) They are alkali-rich, mostly belonging to the alkaline rock series as suggested in the $SiO_2-(Na_2O+K_2O)$ diagram in Fig. 3.

2) Comparing to the average Japanese granites after Aramaki *et al.* (1972), they are somewhat poor in Al_2O_3, high in Na_2O+K_2O and low in CaO. This is suggestive of relatively high agpaitic index, but there is no great difference in $FeO+Fe_2O_3$ among them (Fig.3).

3) Besides these, they are comparatively high in total FeO/(total FeO+MgO) ratio, indicating the low MgO content. Fairly broad range of ferric/ferrous ratio and low to moderate value of magnetic susceptibility are also characteristic of this complex.

4) High fluorine content is also a characteristic feature as already stressed by Murakami *et al.* (1983). Comparing with some ordinary Japanese granites, the rocks of the Ashizuri igneous complex have higher content of fluorine. It is especially high in the rocks of stage V, attaining to four to seven times higher than these ordinary Japanese granites.

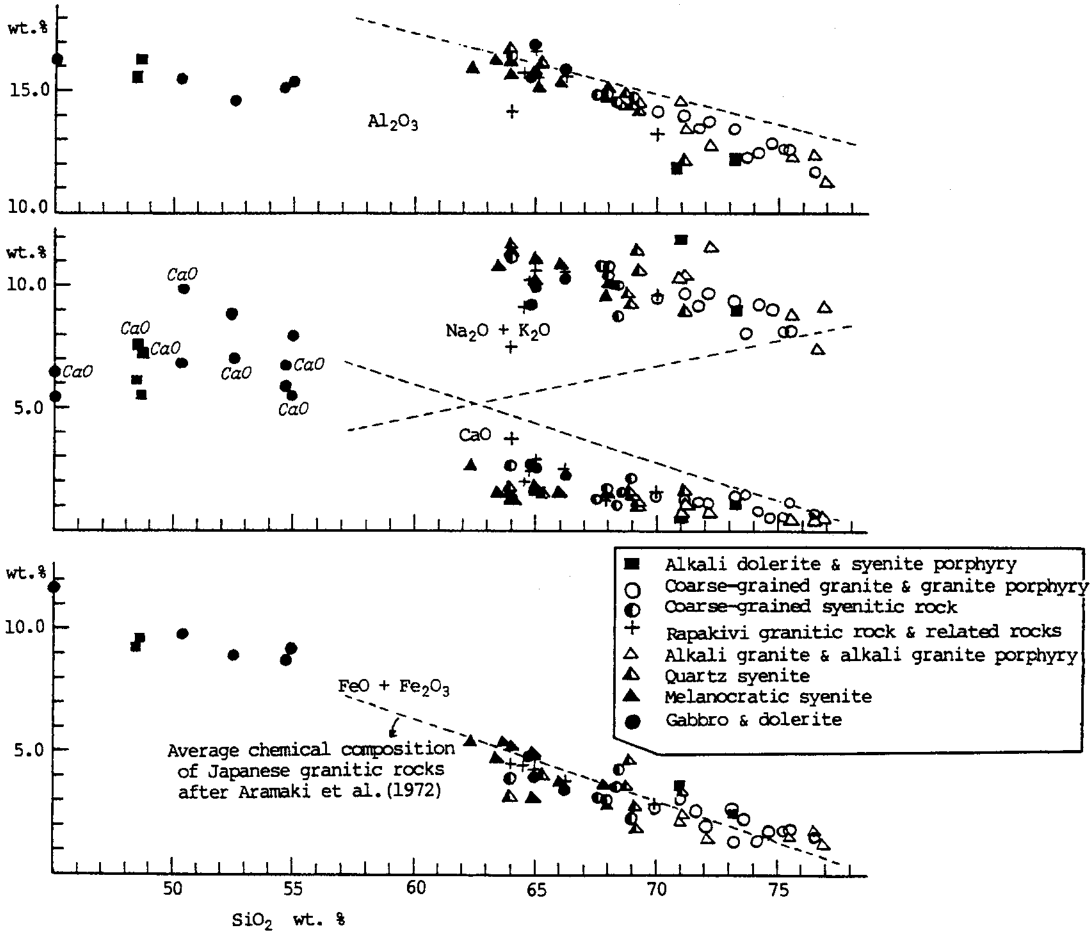


Fig. 3. Relations between SiO_2 and Al_2O_3, CaO, Na_2O+K_2O, and $FeO+Fe_2O_3$ in whole rocks.

5) Minor elements such as U, Th, Zr, Y, Ce, Ga, Rb, and Zn are generally high in value in comparison with the ordinary Japanese granites, and the ordinary I- and S-type granites after Whalen *et al.* (1987), although no great difference can be detected in the other elements as Sr, Cu, V, Co, Sc, Ba and Cs. For example, in Fig. 4 showing the relation between Zr and 10,000 Ga/Al of whole rocks, the Ashizuri igneous rocks are, on the whole, plotted on the area of A-type granites after Whalen et al. (1987), excepting some of the basic rocks.

Lately, Ishihara *et al.* (1990) pointed out the high contents of Hf, Ta and U in these rocks.

6) Rare earth elements are also conspicuously high, comparing with those of the Cretaceous to Paleogene granites (largely I-type) from Chugoku area after Masuda *et al.* (1983) as seen in the chondrite-normalized REE abundances in Fig. 5.

7) In chemical composition of the constituent minerals, too, the component rocks of the Ashizuri igneous complex are fairly unique.

(a) Olivines and clinopyroxenes (Stages II and V) are generally high in Fe content, excepting the magnesian clinopyroxenes in the alkali dolerite of stage V. The iron-rich

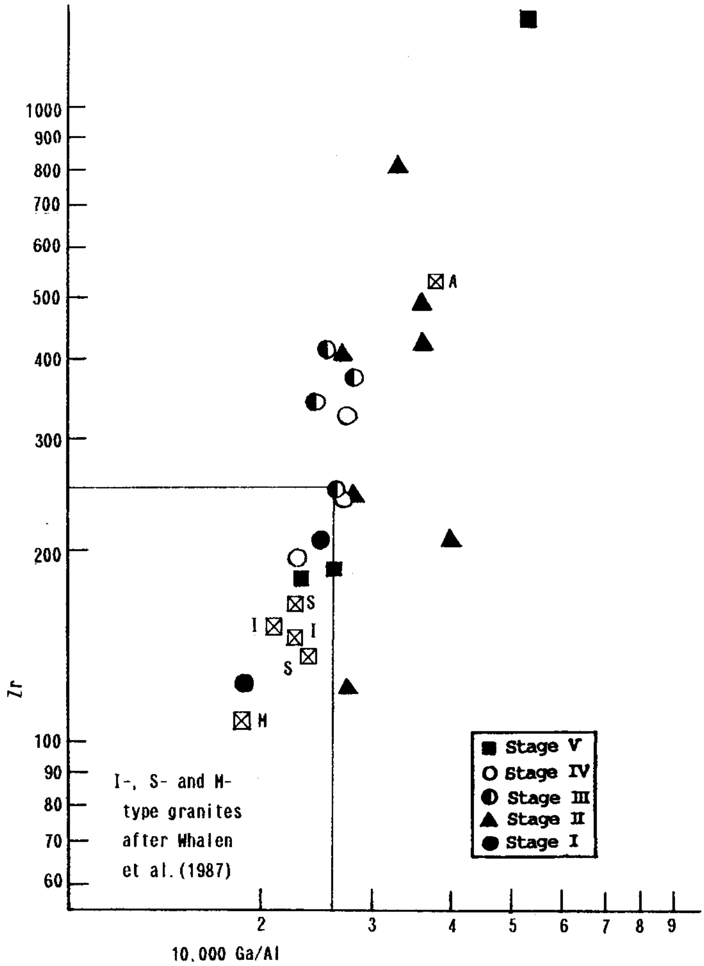


Fig. 4. Relation between Zr and 10,000 Ga/Al in whole rocks.
I, S, H and A are I-type, S-type, H-type and A-type granite average after Whalen *et al.* (1987).

clinopyroxenes in the rocks of stage II belong to the hedenbergite to aegirine-augite, while the olivines are all of fayalitic composition (Fig. 6).

(b) Amphiboles (Stages II, III and IV) are ferro-edenite to ferro-edenitic hornblende after Leake's classification (Leake, 1978), whereas the amphiboles in the dolerite of stage V are kaersutite characterized by brownish pleochroism.

(c) The constituent biotites are generally high in annite molecule with the exception of titaniferous biotite in the dolerite of stage V. It is highest in the biotites of stage II. In addition, H_2O content in these biotites is fairly low as revealed by chemical analysis (2.0-2.5 wt. percent), comparing to those in the ordinary Japanese granites. This possibly means the high content of fluorine in them.

8) Sr initial radio is 0.704 in stage II, 0.706 in stage IV, and 0.710 in stage V (Iizumi and Murakami, 1985).

Summarizing the above description, the component rocks of the Ashizuri igneous complex are low in CaO, MgO, Al_2O_3, H_2O and high in alkali (especially K_2O), F, incompatible elements such as REE, Zr, Ce, Y and Ga. In addition to this, they are low to moderate in magnetic susceptibility and low to a little high in Sr initial ratio.

These data seem to show the similarity of the Ashizuri igneous complex with A-type granites after Loiselle and Wones (1979).

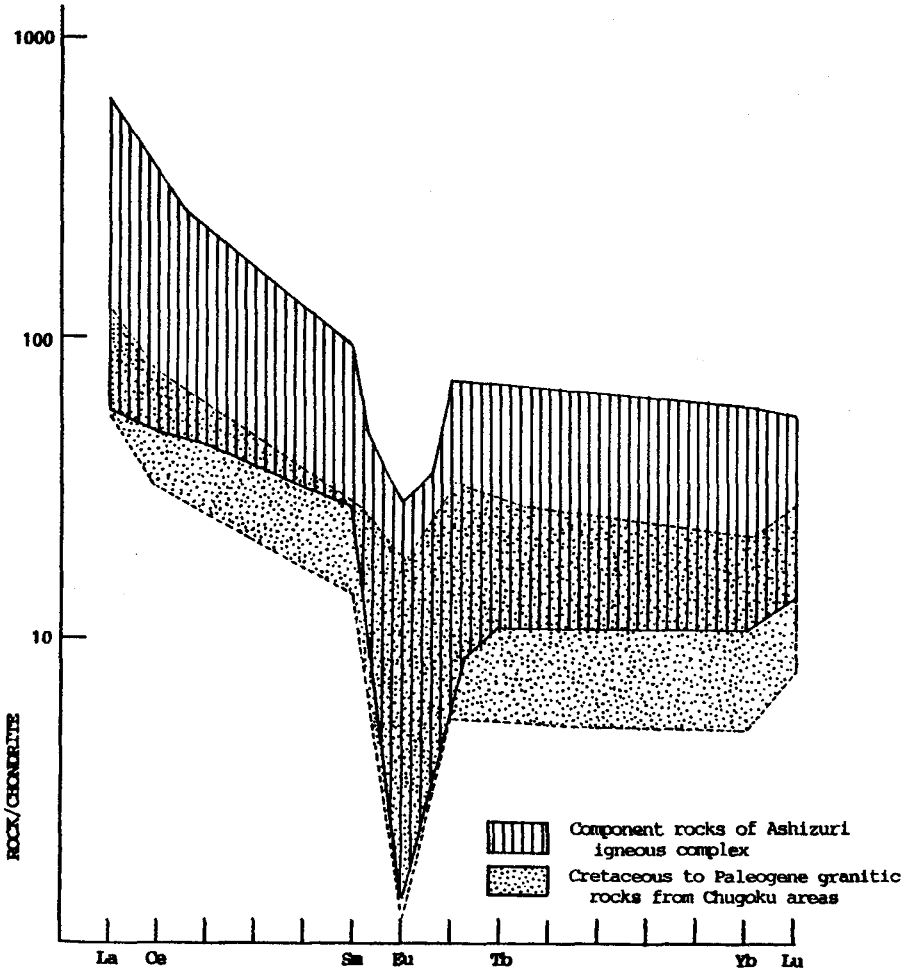


Fig. 5. REE distribution pattern in comparison with that of Cretaceous to Paleogene granitic rocks from Chugoku area (Masuda *et al.*, 1983).

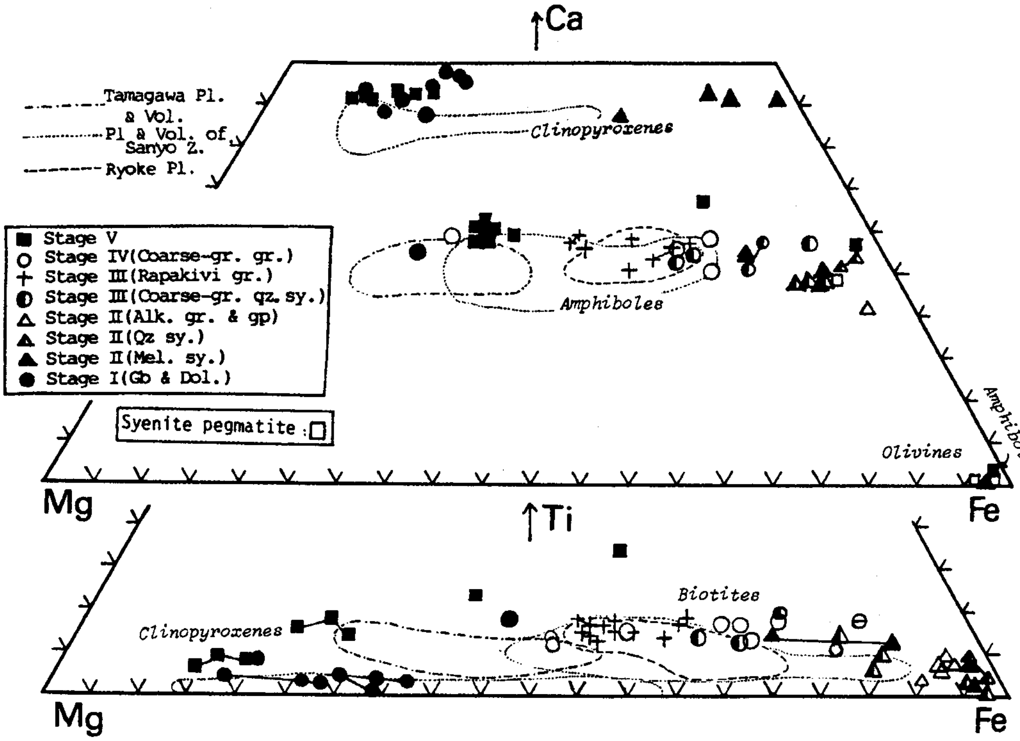


Fig. 6. Ca-Mg-Fe and Ti-Mg-Fe triangular diagrams for mafic minerals (olivines, clinopyroxenes, amphiboles and biotites). Data on the Ryoke, Sanyo and Tamagawa plutonic and volcanic rocks (Cretaceous to Paleogene) are shown together.

Discussion and conclusion

As is well known, A-type granites usually occur in anorogenic rift zones or related areas within cratones (Loiselle and Wones, 1979; Collins *et al.*, 1982). Recently, however, they are found also from the subduction or orogenic zoes (Ewart *et al.*, 1968; Smith, 1976).

During Miocene time, the Outer Zone of Southwest Japan was an active subduction zone. The Kula-Pacific plate subducted beneath the Shimanto accretionary terrain possibly in intimate connection with the southward drift of the Southwest Japan due to the opening of the Japan Sea. As already mentioned, S-type granites and related volcanic rocks occur sporadically along the Pacific coast of Southwest Japan. They might have been derived by melting and/or contamination of the subducted sedimentary materials during the subduction movement (Takahashi, 1986). The Cape of Ashizuri is not so far from the outcrops of S-type granites, but there is no prominent evidence suggesting the contamination by sedimentary rocks in the igneous rocks of the Ashizuri complex.

Judging from the major elements and isotope chemistry, especially low content of H_2O in ferro-magesian silicates and relatively low Sr initial ratios, the magma of Stage II of this complex is considered to have been led to the high level from the upper mantle or lower crust without much contamination by middle to upper crustal materials. On the Stages

IV and V, low to moderate amounts of contamination of crustal rocks are suggested from the relatively high Sr initial ratios and high H_2O contents in the component rocks.

This may mean the formation of deep vertical or near-vertical faults.

Our recent investigation reveals that the age of emplacement of the Ashizuri igneous complex range from about 14 Ma to 10 Ma, similar to the compiled age data on the granites from Outer Zone (Nozawa, 1968). This indicates that there is no great difference in age between Ashizuri igneous complex, and S- and I-type granites from Outer Zone. In addition to this, in remnant paleomagnetic directions too, no great difference can be detected between two. This seems to imply that any big movement leading to the variation of paleomagnetic latitude has not occurred in these granite masses after their emplacement.

Consequently, on the mechanism of emplacement of the Ashizuri igneous complex, there is a possibility that the deep faults have been formed between the volcanic front and trench during Miocene.

Adding to this, we cannot deny the possibility of the relatively high rate of descending of slab at a certain epoch in Miocene, as considered by Weissel ***et al***. (1982) in the northern Melanesia where the spatial and temporal changes in igneous activity are explained by the rapid changes in relative motion of plate. The further detailed investigations on the tectonics and radiometric ages will be needed.

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