Evolutional processes and geotectonic history of Maizuru Terrane, Southwest Japan

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Introduction

Middle to lower crustal section of Paleozoic oceanic island arc exposes in the Yakuno ophiolite of the Asago body, which consists of the first stage Yakuno rocks and the second stage Yakuno rocks. The first stage rocks are divided into metagabbro and schistose amphibolite corresponding to the basement of Yakuno paleo-island arc during Permian, on which the second stage rocks of arc granitoid are developed. Previous work by Suda (2004) indicated that mafic migmatites occur at the lower crustal level, which might be the evidence of an anatexis of mafic lower crust. Furthermore, morphological changing of the migmatites toward the upper crustal level represents the segregation and accumulation processes of the anatextic melts. Subsequently, on the basis of field occurrences, petrography and geochemical modeling, Suda and Hayasaka (2008; in press) demonstrate that the first stage rocks were derived from a basaltic magma of back arc basin affinities, then Yakuno paleo-island arc must had been developed on the paleo-back arc basin. Moreover, the high-K series of second stage rocks (quartz monzodiorite and granodiorite) were derived from the partial melts produced by a low degree of lower crustal anatexis, and the low-K series of second stage rocks (hornblende, quartz diorite and tonalite) were derived from the partial melts produced by a relatively high degree of lowermost crustal anatexis. Namely, the Asago body is just a ground-truth of crustal evolution by an anatexis of mafic lower crust under an oceanic island arc, which is a possible mechanism for the formation of andesitic continental crust.

The Yakuno ophiolite is composed, generally of metamorphosed ultramafic, and mafic rocks, and distributed among the Yakuno igneous complex in the Maizuru Terrane. Previous works indicate that at least three different segments, such as back arc, ocean floor, and island arc are recognized in the Yakuno ophiolite which was derived from a paleo- island arc and back arc system, and originated from the basements of the Yakuno paleo-island arc, and back arc basin during Permian. But, as for the geotectonic history of the Yakuno ophiolite itself, in other words, the geotectonic history before this island arc stage is poorly known. Although the geodynamic change from an oceanic crustal stage to an island arc stage are proposed for the geotectonic history of the Yakuno ophiolite itself, to verify this model, some questions still remains as problems. In this paper, focusing on the Yakuno ophiolite in this Asago area, I would like to discuss the question what is the origin of the pre-arc basement of the Yakuno paleo-island arc.

Geological setting and petrography

The rocks of Asago body are divided into the first stage rocks and the second stage rocks. The first stage rocks consist of metagabbros and schistose amphibolite, while the second stage rocks consist of tonalite, quartz diorite, grano-diorite and hornblende gabbro. And then, in the field we can see the occurrence that the first stage rocks had been intruded by the second stage rocks. Also, at this structurally lowermost area in this body, we can see the occurrence that the first stage rocks and the second stage rocks are mixing together on the macroscopic scale, forming so-called migmatitic structures. On the basis of these occurrences and these isotopic ages obtained from the second stage rocks, it consider that this body must represent the crustal section of the Yakuno paleo-island arc during Permian that was built on the basement comprising of this first stage rocks. Namely, the Asago body is the most suitable geological target to understand the geodynamic history of the Yakuno ophiolite.

Metamorphic grade of this body varies from amphibolite-facies to granulite-facies. The migmatite exposes at the high-grade amphibolite-facies and the granulite-facies areas. Occurrence of migmatites in this body will change in accordance with the metamorphic grade or structural level. At the granulite-facies area the migmatites containing veined and arrested leucosomes are typically observed. On the other hand, at the amphibolite-facies area, the migmatites containing enriched and segregated leucosomes are typically observed. Leucosomes in these migmatite are generally undeformed without any distinct foliation or gneissosity. On the basis of these occurrence, metamorphic grade and whole-rock geochemistry, Suda (2004) indicate that the migmatites in this body must have been formed by the partial melting of the first stage rock, namely the migmatites in this body must represent the lower crustal anatexis of Yakuno paleo-island arc. Moreover, the morphological changing of migmatite in this body must represent segregation and accumulation processes of the felsic magmas, and the second stage rocks at the middle to upper crustal level must be derived from the partial melts generated at the migmatite area.

The first stage rocks in the Asago body are composed of metamorphic mineral assemblage and texture. But, sometimes we can find the relics of their original textures under the microscope and in the field. In this study, as for the rocks considered to be gabbroic protolith, we referred to as metagabbro. On the other hand, as for the rocks without any relics of their original textures referred to as schistose amphibolite after the nomenclature of metamorphic rocks.

Geochemistry

On the Harker variation diagrams, the compositions of granulite-facies metagabbro, amphibolite-facies metagabbro and schistose amphibolites, are overlapping with each other, as a whole forming a definite trend, or cluster. Then, on the variation diagrams of Titanium, Vanadium, and Chromium, the trends that comparable to those of oceanic gabbros in the Indian ridge are observed. On the other hand, on the diagrams of Potassium and Strontium, the clusters of relatively enriched in these elements comparing with the concentrations of oceanic gabbros are observed. On the basis of these results, it will be considered that the concentrations of these HFS elements and Chromium must represent the protolithic condition, while these LIL elements are generally added from their protoliths. Concentrations of these elements do not represent the protolithic condition.

On the N-type MORB normalized spiderdiagrams for the first stage rocks, the profile of all these patterns are characterized by the enrichment of alkaline elements, and negative anomaly of Niobium. On the basis of the profiles of these patterns, the first stage rocks, are divided into the Mafic 1 rocks and the Mafic 2 rocks. The rocks named Mafic 1 are characterized by the positive anomaly of strontium, and downward convexity at HFS elements. On the other hand, the rocks named Mafic 2 are characterized by the negative anomaly of strontium, and upward convexity at HFS elements. The profiles of Mafic 1, and Mafic 2 rocks are almost in relation of symmetry. On the basis of this classification, next let me discuss the magmatic processes of the first stage rocks.

Discussion

Fractional crystallization process

On the diagram of mg-umber versus Silicon-Aluminum ratio, the compositions of the Mafic 1 rocks occupy the field of relatively lower Silicon-Aluminum ratio comparing with the ratio of the Mafic 2 rocks. On the N-type MORB normalized Lanthanum-Nickel ratio versus mg-number, the Lanthanum-Nickel ratios of the Mafic 2 rocks systematically increase with decreasing the mg-umber. This mean that the composition of the Mafic 2 rocks will increase in the incompatible elements, while decrease in the compatible elements with decreasing the mg-number. From these results, it will be assumed that the Mafic 1 and Mafic 2 rocks are derived from the same parental magma with the compositions approximated to the rock of the highest mg-number among the Mafic 2 rocks. Moreover, the Mafic 2 rocks have liquid compositions, while the Mafic 1 rocks have cumulatic compositions. From the direction of the mineral vectors in diagrams, fractional crystallization of plagioclase, must involves in the magmatic processes.

On the N-type MORB normalized spiderdiagrams, results of the calculations of Rayleigh fractional crystallization model for the first stage rocks are summarized. On this model calculations, firstly, we assumed the composition of the rocks of the highest mg-number among the Mafic 2 rocks, the sample number 16, as parental liquid, calculated the concentration of each element after removal of cumulate containing mainly of olivine, clinopyroxene and plagioclase. Consequently, the results indicate that the compositions of the modeled residual liquids are consistent with the compositions of Mafic 2 rocks, the compositions of the modeled cumulates 80% + modeled residual liquid 20% are consistent with the compositions of the Mafic 1 rocks. These results mean that Mafic 1 and Mafic 2 rocks are originated from the same parental magma with the compositions approximated to the rock of sample number 16. Moreover, the Mafic 2 rocks are originated from the parental liquid and residual liquid, i.e. solidified liquid, while the Mafic 1 rocks are generally originated from the cumulate with subordinate liquid component. Using whole-rock geochemistry of the Mafic 2 rocks let me discuss the tectonic setting of the fist stage rocks.

Tectonic setting

On the N-type MORB spiderdiagram, the first stage rocks are all characterized by the negative anomaly of Niobium indicating the arc affinity. On the other hand, on the discrimination diagrams of basalt, the first stage rocks are characterized by the MORB affinities. Accordingly, the first stage rocks in the Asago body have geochemical affinities both of MORB and Arc. This is the reason why the tectonic setting of the first stage rocks is still remained as s problem.

On the variation diagram of Titanium content with respect to the mg-number, the compositions of the oceanic island basalt, MORB, and island arc basalt are generally characterized by the different trends with different directions, furthermore the compositions of back arc basin basalts are generally characterized by both MORB-type, and island arc basalt-type trends. On this diagram, plotting the compositions of the Mafic 2 rocks in the Asago body, and the metabasalts and metadolerites of the Yakuno igneous complex in various areas, the compositions of the rocks that have been considered to be back arc basin origin are characterized by both MORB-type and island arc basalt-type trends, indicating the geochemical affinity of the back basin basalt. On the other hand, the compositions of the rocks that have been considered to be island arc and the ocean floor origins are generally characterized by the MORB-type trend, but some are characterized by the island arc basalt-type trend. Generally speaking, these rocks also have geochemical affinity of back arc basin basalt.

On the diagram of N-type MORB normalized Lanthanum and Niobium ratio versus Lanthanum and Ytterbium ratio the compositions of back arc basin basalts are characterized by the trend or cluster connecting the fields of MORB and Arc. Plotting the compositions of the rocks of Yakuno ophiolite in various areas, these rocks are also shown by the same geochemical chracteristics as the back arc basin basalt.

Summary and conclusions

Asago body of the Yakuno ophiolite consists of the first stage rocks originated from the back arc basin basalt, and second stage rocks of arc affinities. This means that the Yakuno paleo-island arc was possibly built on the earlier back arc crust. Pre-arc basements of the Cenozoic arcs are very variable, and vary from normal oceanic crust, arc rocks and intra-oceanic arc rocks to back-arc crust. Therefore, it is possible that the Yakuno paleo-island arc was built on an earlier back arc crust. The age data to constrain the formation of the mafic basement of the Yakuno paleo-island arc, i.e. first stage rocks, will be needed to construct the detail of geodynamic history of the Yakuno ophiolite itself, which remains to be investigated in future study.

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