Multi-Series Volcanic Rocks in the Oligo-Miocene Sequence of Anamizu Formation, Uchiura-Noto Area, Noto Peninsula

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Three rock series have been found in lavas from Anamizu Formation: tholeiitic, low Mg calc-alkaline (LMCA) and bronzite andesite.

Tholeiitic basalt and basaltic andesite contain augite phenocryst, and are FeO*-rich and MgO-poor. LMCA basalt and basaltic andesite, contain augite and bronzite phenocrysts, and are higher in MgO and K2O. Bronzite andesite is aphyric, phenocrystic bronzite-rich and has a glass-bearing groundmass.

Although tholeiitic and LMCA series exhibit quite different petrographical and chemical characteristics, their TiO2/K2O ratios are almost the same, indicating a similar magmatic source and relatively anhydrous condition. In contrast, bronzite andesite is lower in TiO2/K2O, indicating a different primary magma and hydrous condition.

In the Uchiura-Noto area, Anamizu Formation is composed of lavas and minor volcanic breccia and red mudstone. The base of the sequence is not exposed in the area. Three rock series have been found: tholeiitic, low magnesiam calc-alkaline (LMCA) and bronzite andesite.

Tholeiitic series rocks, represented by basalt (52 SiO2 wt.%) and basaltic andesite (53-57 SiO2 wt.%), contain phenocrysts of plagioclase, olivine (altered) and augite (Mg# 65 to 75), although sometimes aphyric. Quartz is present in the basaltic andesite groundmass as a trace component. The rocks are higher in FeO* (7-10 wt.%) and lower in MgO (especially in basaltic andesite: <2.8 wt.%) and K2O (<1.2 wt.%) than in LMCA rocks. Moreover, they are depleted in Rb (<25 ppm) and Sr. Tholeiitic rocks occur at lower stratigraphic levels in association with red mudstone.

LMCA rocks include basalt (52.5 wt%) and basaltic andesite (53-57 wt%), containing phenocrysts of plagioclase, olivine (less altered), augite (Mg# 75-80 in basalt and 72-77 in basaltic andesite) and bronzite (Mg# 79-80). They have intersertal and seriated textures. MgO (4-6 wt.%), K2O (0.7-1.8 wt.%) and Rb (<43 ppm) contents in the LMCA basaltic andesite are generally higher than those in tholeiitic basaltic andesite.

Bronzite andesite is distinctly aphyric (>90% groundmass) and shows trachytic texture. This series contains bronzite (Mg# 82-86) as the dominant phenocryst phase, with minor plagioclase and augite (Mg# 69-74). The groundmass consists of plagioclase, orthopyroxene, clinopyroxene, opaque minerals, and dark brownish glass (less than 30%). This andesite has 60-61 wt.% SiO2, and is higher in MgO (3.5-4.4 wt.%) than LMCA andesite so far reported from Noto Peninsula (Nakagawa, M., 1980, Yamada, H., 1985, Kanazawa University, Master Thesis). Sr contents (<375 ppm) and Sr/Y ratio (<19) of bronzite andesite are lower than those of adakite-like andesite (Sr: 1000 ppm and Sr/Y: 70) reported by Uematsu et al. (1995), from northwestern Noto Peninsula.

Bronzite andesite, in this area, is relatively richer in K2O (1.7-1.9 wt%) and Rb (66-68 p.p.m.) and poorer in Ni and Cr than other bronzite andesites of Noto Peninsula, like at Terabun (Hoshina, 1984), Shinobu (Uematsu, Shuto & Kagami, 1995), and Hegura-jima and Nanatsu-jima islands (Sato, 1989), all of which have K2O<1.6 wt.%.

In the area, bronzite andesite occurs at the higher levels of the sequence, overlying LMCA rocks.

Even though there are some different petrographical and chemical characteristics between tholeiitic and LMCA series (absence of orthopyroxene phenocryst and higher FeO* and FeO*/MgO ratio in the former), some of their trace element concentrations (Ba and Sr) are roughly the same. Moreover, TiO2/K2O ratios (tholeiite 0.8-1.1 and calc-alkaline 0.6-1.1) are very similar, suggesting not much different magmas and relatively anhydrous condition of their genesis (Okamura & Yoshida, 1989). However, more magnesian calc-alkaline andesite can not be produced from less magnesian tholeiitic basalt through fractional crystallization. Mixing of fractionated SiO2-rich tholeiitic magma or assimilation of granitic crustal material by the primitive tholeiitic magma may have produced the calc-alkaline rocks.

In contrast, bronzite andesite have petrographic and chemical characteristics (abundance of phenocrystic bronzite, absence of olivine, high MgO content and distinctive trace elements signatures) far different from tholeiitic and LMCA series. In addition, TiO2/K2O ratio of bronzite andesite (<0.6) is lower than in those series, indicating hydrous condition in the source mantle. Therefore, bronzite andesite may have evolved from a different primary magma or the magma may have considerably modified in the mantle.