

Abstract

Oki-Dogo, southwest Japan is one of the best fields to study the development of lower crust on the representative convergent margin, because mafic to ultramafic xenoliths composed of gabbro, pyroxenite and peridotite were transported by Pliocene alkaline basalt from the deep crust. In order to understand formation and evolution processes of the lower crust, petrological, geochemical and isotopic studies of more than 200 rock samples including basalts and exposed gneisses have been studied. Major classification of xenoliths is based on lithology: peridotite suites (modal olivine > ~ 40 %), pyroxenite suites and gabbro suites (modal plagioclase > 5 %). These suites can be also subdivided I-type and G-type xenoliths. I-type xenoliths are characterized by cumulus texture and exsolution lamellae in pyroxenes, and olivine and plagioclase are observed in all lithologies. On the other hand, G-type xenoliths are characterized by recrystallized granoblastic and equigranular texture and no lamellae in pyroxenes. G-type gabbros, moreover, consist of no olivine, and G-type ultramafic xenoliths are plagioclase absent. Thermometric calculations based on major element composition of pyroxenes indicate that the both I- and G-type xenoliths were equilibrated under the granulite facies condition at temperatures range as 950 - 1050°C. Co-existing mineral assemblage of G-type xenoliths also supports that G-type xenoliths underwent granulite-facies metamorphism at pressure range of 0.7 – 1.2 GPa.

Whole rock geochemistry of the both I- and G-type xenoliths shows that I-type xenoliths are relatively enriched in highly incompatible elements comparing with G-type xenoliths. Additionally, depletion of Zr and Hf of G-type xenoliths is significant. Correlation among the modal abundances of constituent minerals, major and trace element concentrations, suggest that both I- and G-type xenoliths would be formed by

crystal accumulation processes from basaltic magma(s). In order to investigate the origin of I- and G-type xenoliths, the author examined Sr, Nd, Hf and Pb isotopes for whole rock samples. As a result, I-type xenoliths have depleted in Sr, Nd and Hf isotope compositions ($^{87}\text{Sr}/^{86}\text{Sr}$: 0.70457 ~ 0.70498; ϵNd : -1.5 ~ +0.1; ϵHf : -0.1 ~ +2.7) and enriched in Pb isotope compositions ($^{206}\text{Pb}/^{204}\text{Pb}$: 17.86 ~ 18.50) compared with G-type xenoliths ($^{87}\text{Sr}/^{86}\text{Sr}$: 0.70578 ~ 0.70826; ϵNd : -5.4 ~ -2.9; ϵHf : -6.1 ~ -2.7; $^{206}\text{Pb}/^{204}\text{Pb}$: 17.72 ~ 17.93).

The Rb-Sr and Sm-Nd mineral isochron age cannot be defined from G-type gabbroic sample. This result is implied that these xenoliths underwent cryptic metasomatism after the accumulation and recrystallization processes. One of the evidences of this implication is that the xenoliths from Oki-Dogo generally include platy fluid inclusion trails in the constituent minerals. In order to examine the effect of metasomatic event for the geochemical signature of the xenoliths, separated plagioclase (PL) and clinopyroxene (CPX) grains (< 1 mm) from G-type gabbro and pyroxenite were sliced into 2 or 3 pieces (1 – 8 mg for each), and carried out Sr and Nd isotope analyses for the each slice. As a result, isotopic heterogeneities correlating with relative amount of fluid inclusions were observed in both separated PL and CPX grains. The isotopic variation, moreover, define as a mixing line among the inclusion-free mineral and inclusion-bearing minerals. The mixing lines converge in the direction of isotopic compositions of the late Cenozoic alkaline basalts, and alkaline magmas would be considered to be a source of the metasomatic agent. The leaching experiment by HBr + HNO₃ mixed acid for whole-rock powder also support that the lower crustal xenoliths, not only G- but also I-type, underwent the metasomatism by the Cenozoic alkaline basalts.

Based on these experiments, the author examined to estimate the metasomatic influence for trace element and isotopic compositions of the whole-rock samples. In

consequence, the extent of the metasomatism might be limited as a few percentages for the Sr, Nd and Hf isotopes. Even though the corrected isotope values are applied, therefore, systematic difference of the geochemical signatures between I- and G-type xenoliths still exists. The isotopic compositions of I-type xenoliths are plotted within late Cenozoic alkaline basalts around Japan Sea, and strongly suggest that I-type xenoliths were formed by crystal accumulation from underplating these alkaline magmas. On the other hand, isotopic variations of G-type xenoliths expand widely toward the isotopically enriched felsic gneisses field (Oki gneiss). These variations could be interpreted that assimilation of pre-existing felsic crust by basaltic magma played the important role to form the G-type lower crustal xenolith. Moreover, it is considered that the involved magma would be subduction-related rather than the late Cenozoic alkaline basalt, because significant depletion of HFSE is observed in G-type xenoliths.

The comprehensive geochemistry of xenoliths from Oki-Dogo reveals that the lower crust in convergent margin could be explained by two-stage underplating model of basaltic magma. In the first stage, cumulates from subduction-related arc type magma would be formed together with the assimilation of the pre-existing felsic crust. The existence of calc-alkaline type lava, Kori basalt, which has early Miocene of the eruption age, in Oki-Dogo also supports this model. These mafic to ultramafic cumulate had subsequently been underwent granulite-facies metamorphism and recrystallized. After evolving of this arc-type lower crust, back-arc magmatism has been created new magmatic lower crust by accumulation of underplated alkaline magmas. It could be considered that I-type xenoliths correspond with this back-arc type lower crust. In this study, the author elucidates the two-stage development history of the lower crust beneath Oki-Dogo. This type of crustal evolution process on the dynamic convergent margin would be essentially important to assess the geochemical evolution of the Earth,

because the geochemical structure developed by the multiple-stage model would differ from that by simple magma-underplating. The research scheme based on the comprehensive geochemical approach is inevitably important to reconsider the crustal evolution processes through the Earth's history.