Upwelling and melting of a hot mantle diapir beneath northwestern Kyushu, Japan

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General characteristics of back arc regions, such as active volcanisms, high surface heat flow, slow upper mantle velocity, and high temperature lithosphere, indicate efficient material and heat transportation into the upper mantle beneath back arc regions. The length and time scales and driving force of the upwelling including temperature and composition of the mantle are, however, still unknown.

Eastern margin of the Eurasian Plate is the extensive regions of the Cenozoic back arc volcanisms. We made systematic geological, petrological, geochemical, and chronological investigations on an intra-plate Cenozoic volcanism in the Kita-Matsuura area, northwestern Kyushu, to address the issue of mantle dynamics in back arc regions on the basis of temporal and spatial changes of the melting conditions on the time scale of ˜2.5 Myr and the horizontal scale of 35km.

In the central and western parts of the Kita-Matsuura area, chemical composition of the basalts shows a temporal variation: the volcanism initiated with mildly alkaline basalt (low- to medium-SiO_2 group) followed by major sub-alkaline basalt (medium- to high-SiO_2 group) at the later stage. The eastern area is characterized by the production of mildly alkaline basalt (low-SiO_2 group) almost all the way up to the uppermost horizon. Each SiO_2 group has a distinctive phenocryst assemblage and plots in a distinct region on a particular oxide-oxide diagram. The Zr/Y, Nb/Th, and Nb/Y ratios temporally decrease in each section and samples with low Zr/Y, Nb/Th, and Nb/Y ratios are dominant in the western sections. Reported Sr and Nd isotope ratios show negative and positive correlations with Zr/Y and Nb/Y, respectively. Such systematic variations of high field strength elements (HFSEs) and large ion lithophile elements (LILEs) cannot be explained by assimilation of crust materials in the vicinity of northern Kyushu.

Plausible ranges of primary melt compositions for the three basalt groups do not overlap each other. Water contents of primary melt estimated by MELTS calculation and plagioclase phenocryst composition are 0˜0.25, 0.3˜1.0, and 0.8˜2.0wt%, for the low-, medium-, and high- SiO_2 groups, respectively. By comparing the compositions of the primary melts to those of high pressure melting experiments of peridotites after careful evaluation of contribution of excess basaltic components in a source peridotite mantle and water content in the primary melt, the average segregation pressures and temperatures are estimated to be 3.0˜2.3, 2.7˜1.8, and 2.0˜1.3 GPa, and 1410˜1550, 1370˜1510, and 1290˜1400^{o}C for the low-, medium-, and high- SiO_2 groups, respectively.

The temporal decrease of melting temperature and pressure with increase of water content in the primary melt in a few Myr cannot be explained by melting of static mantle or melting of passively upwelling mantle but requires melting of actively upwelling mantle with progressive supply of water from the outside of the melting system. The temporal decrease of HFSE/LILE with decrease of HFSE abundances is accounted for by progressive melt extraction with continuous input of fluid/melt enriched in LILE with increase of melting degree and thus during the ascent (entrain model).

We conclude that chemically homogeneous hot mantle with potential temperature more than 1400^{o}C and diameter larger than 70km upwelled centering in the western part at the velocity of ˜2cm/yr, which induced progressive melting and melt segregation with entraining the ambient H_2O-rich mantle modified by an addition of fluid derived from subducted slab. The correlation between trace elements and isotope ratios suggests that the upwelled mantle was isotopically depleted while the entrained mantle occupying the shallow upper enriched. This study shows that the characteristic features of back arc regions mentioned above are attributed to an active upwelling of hot and depleted mantle, probably from the mantle transition zone.