The redox states of basaltic and boninitic magmas throughout the early stage of the Bonin arc formation; Fe-K edge XANES study

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One of the significant features of arc magmas is their relatively oxidized nature compared to those from other tectonic settings. Previous studies discussed that the nature is attributed to relatively high oxygen fugacity (fO_2) conditions in their source mantle region, and accession of subducting slab-derived fluid may have raised fO_2 of the MORB source-like mantle. However, it is unknown how the fO_2 condition of melting region in mantle wedge develops throughout the early stage of arc formation. In this study, we investigated the fO_2 conditions of basaltic and boninitic magmas erupted during the initial ca. 12 million years of the Bonin arc formation based on the Fe valence states of quenched silicate glasses, which is a sensitive indicator of magmatic fO_2, to examine how fO_2 of their source mantle region developed with time.

Fe-K edge micro-XANES (X-ray Absorption Near Edge Structure) measurements enable us to determine valence state of Fe in silicate glass with spatial resolution of several microns. In this study, Fe-K edge XANES spectra were measured for quenched silicate glasses included in pillow lavas and hyaloclastites of basalt and boninite from Bonin arc, using a X-ray micro-beam system at Beam Line 4A in Photon Factory, KEK, Japan. Mole ratios of ferric to total iron, Fe^{3+}/Fe_{total}, were determined from the spectra, and then the ratios were used to estimate fO_2 of silicate melts. Precision of our analyses was evaluated to be within standard deviation of 0.4 log unit in fO_2 using basaltic and andesitic standard glasses synthesized at controlled fO_2 conditions.

The measured samples include forearc basalt (FAB) collected at Bonin Ridge, which is the earliest volcanic product from Bonin arc and has MORB-like geochemical feature, erupted right after the initiation of subduction (ca. 51Ma), boninites from Chichijima, Otojima, and Mukojima, erupted at ca. 44-48 Ma, and arc basalts from Anejima and Hahajima, erupted at ca. 37-44Ma. The measured Fe^{3+}/ Fe_{total} ratios of quenched glasses are ca. 0.20 for FAB, 0.17-0.24 for boninites from Chichijima, Otojima, and Mukojima, and 0.20-0.22 for arc basalts from Anejima and Hahajima, respectively. All measured samples show Fe^{3+}/ Fe_{total} ratios higher than that of MORB. fO_2 of the measured glasses are estimated to be near Ni-NiO buffer which is consistent with the range of arc magmas. The results suggest that fO_2 of magmas erupted at Bonin arc has been higher than that of MORB since the initiation of arc volcanism. In addition, the similarity of fO_2 among MORB-like FAB, boninites, and arc basalts implies that the oxidation process may be independent of accretion of subducting-slab derived aqueous fluid.