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The redox states of volcanic glasses from Bonin islands, Japan, estimated by Fe-K edge micro XANES study

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The redox state of arc mantle is an important issue to understand processes of material cycle and generation of magma within mantle wedge. Previous studies on mantle xenoliths indicated that arc mantle is more oxidized relative to those of other tectonic settings and proposed that the oxidized nature is attributed to an influence of subduction-related fluid. However, it is unobvious that partially melted region within mantle wedge where arc magma is generated is actually oxidized because mantle xenoliths are fragments of cool, rigid, re-equilibrated lithospheric mantle. In addition, the role of subduction-related fluid on oxidization of arc mantle is still unclear.

Arc magmas might be a unique material having information about the redox state of their source mantle region. Among various arc magmas, we thought that boninite is the most suitable to examine both the redox state of arc mantle and the effect of subduction-related fluid on arc mantle. This is because boninite is undifferentiated rock quenched in seawater. They are expected to preserve information on redox state of sub-arc mantle. In addition, they were considered to be generated by partial melting of hydrous mantle which was highly influenced by subduction-related fluid. Therefore, the redox state of boninite is ecpected to give clue to above issues.

It is well known that valence state of Fe in silicate glass is a sensitive indicator of its oxygen fugacity (fO2). Recent advance in Fe-K edge micro-XANES (X-ray Absorption Near Edge Structure) study enables us to determine valence state of Fe in silicate glass with several microns order of special resolution. In this study, we investigated fO2 of quenched silicate glasses included in pillow lavas and hyaloclastites of boninite from Chichijima, Otojima, and Mukojima, Bonin islands, Japan. We also analyzed quenched basaltic glasses from Anejima and Hahajima for comparison. In addition, quenched glasses of AIST standard rock samples (JA-1a, JA-2, and JB-2) synthesized at fO2 near quartz-magnetite-fayalite (QMF) and Ni-NiO (NNO) buffers were analyzed to assess the reliability of this analytical method. We performed the measurements using Beam Line 4A in Photon Factory, KEK, which enables us micro analysis of XANES. The obtained spectra were analyzed using the method of Cottrell et al. (2009) to determine mole ratios of ferric to total iron, Fe3+/Fe. Oxygen fugacity of silicate glass was calculated from the Fe3+/Fe ratio using the method of Kress and Carmichael (1991). Reliability of our analyses is confirmed because controlled fO2 during synthesizing standard glasses is reproduced within standard deviation of 0.4 by the models of Cottrell et al. (2009) and Kress and Carmichael (1991).

The measured Fe3+/Fe ratios of quenched glasses are 0.17-0.24 for boninites from Chichijima, Otojima, and Mukojima. Basaltic glasses from Anejima and Hahajima are 0.20-0.22, which is identical to those of boninites. These values are larger than the average Fe3+/Fe value of MORB (ca.0.16). We estimated fO2 of the measured glasses is near NNO buffer based on obtained Fe3+/Fe ratios. Because the effects of crystallization of silicate minerals and dehydration during ascent on fO2 of silicate melt are thought to be small, the estimated fO2 of the glasses may inherit their genetic conditions. Our results suggest that (1) slab-derived fluid related to boninite genesis did not significantly affect the redox state of source mantle region and (2) the redox state of arc mantle was oxidized even at an initial stage of arc evolution. This is inconsistent with the results of Lee et al. (2005, 2010).

Keywords: XANES, Oxygen fugacity, arc mantle, volcanic glass, boninite, Bonin islands