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XANES study on the redox state of silicate glasses in: a preliminary result for boninites from Ogasawara Islands, Japan

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The redox state of arc mantle is not only of geochemical interest but also an important factor to understand processes of material cycle and generation of arc 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 most suitable to examine both the redox state of arc mantle and the effect of subduction-related fluid. This is because they are undifferentiated and their modification during ascent was minimal. 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 expected to have a key to clarify above issues.

It is well known that valence state of Fe in silicate glass is a sensitive indicator of its oxygen fugacity (fO2) and can be determined from pre-edge feature in Fe K-edge XANES spectrum. In this study, we investigated fO2 of silicate glasses included in three boninite pillow lavas from Chichijima and Mukojima, Ogasawara islands, Japan, using Fe K-edge micro X-ray absorption near-edge structure (XANES) spectroscopy. A natural glass included in pahoehoe lava from Kilauea volcano, Hawaii was also analyzed for comparison. 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). Two pre-edge peaks centered at ca. 7112eV (peak-1) and ca. 7114eV (peak-2), respectively, are commonly observed for silicate glass. The former and the latter are attributed to absorptions by Fe2+ and Fe3+ in silicate glass, respectively, and intensity ratio of peak-2 to peak-1 increases with increasing Fe3+/Fe2+ ratio. Therefore, the intensity ratio is a useful indicator of fO2 for silicate glass. We estimate fO2 of silicate glass using the relation between the intensity ratio and fO2 based on experimental dataset for basaltic glass (Cottrel et al. 2009).

We measured several points of groundmass glasses for each lava samples and confirmed that groundmass glass is homogeneous in terms of Fe3+/Fe2+ ratio for the studied samples. Delta QMF (Quartz-Magnetite-Fayalite) value [= log fO2(sample) ? log fO2(QMF buffer)] of +0.2 was obtained for Kilauea pahoehoe glass. This is consistent with previous studies, demonstrating reliability of this method. Delta QMF values are +0.7 for a samples from Chichijima and +0.5 and +1.3 for two samples from Mukojima, respectively. With considering the fact that the intensity ratio is higher for silicic glass than for basaltic glass at the same Fe2+/Fe3+ ratio and boninite is more enriched in SiO2 than basalt, the boninites may be more reduced than the estimated fO2 conditions. In addition, previous study showed that crystallization of mafic silicate minerals slightly oxidizes silicate melt and the effect of dehydration during ascent on fO2 of silicate melt is negligible. This suggests that the redox condition of primialy boninite melt, and hence of its source mantle, was at least more reduced that the estimated fO2 (near QMF buffer) whereas it was highly influenced by subduction-related fluid. Therefore, the effect of subduction-related fluid on the redox state of partially melted arc mantle is considered to be minor.

Keywords: XANES, arc mantle, boninite, redox state, oxygen fugacity, silicate glass