Systematic classification of kimberlites and their xenoliths using I/Br ratios

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The halogen elements (Cl, Br, I) have high partition coefficients in aqueous fluid (Bureau et al., 2000). Thus, they are enriched in pore fluid and difference in the partition coefficients results in distinct elemental ratios in seawater, pore fluid, sediment, oceanic crust and mantle. These characteristics are useful to trace water cycling in subduction zones (e.g., Fehn et al., 2003; Muramatsu et al., 2007).

Recently, subduction of seawater and marine pore fluid subducting into the mantle was suggested (Holland and Ballentine, 2006; Sumino et al., 2010). However, only a little is known about the behavior of halogen elements during subduction processes and their fate in the earth's mantle.

Kimberlite is an igneous rock originated from deep mantle. Compared to ordinary ultramafic rocks, kimberlite is rich in volatile components. In addition, studies on the noble gas isotopes in kimberlites showed that kimberlite magmas have similar noble gas characteristics to those of ocean island basalts derived from deep mantle plume (Sumino et al., 2006).

In this study, we analyzed concentrations of Cl, Br, and I in kimberlites and their mantle-derived xenoliths from six localities to investigate the halogen characteristics and their origins in the kimberlite source regions.

Samples analyzed are 35 kimberlites collected from South Africa, China, Greenland, Brazil, Russia and Canada, and 4 xenoliths collected from South Africa and Russia. For the analyses of Cl, Br and I, we used the pyrohydrolysis method (Muramatsu et al., 2008) combined with ICP-MS and ion chromatography.

The result shows that the kimberlite samples are classified into two groups with respect to I/Br ratios. The first group (Group S) shows high I/Br ratios (about 1 x 10^{-1}), which are distinctively observed in the kimberlites from South Africa, Greenland, Canada and Brazil. The xenolith from South Africa is also classified into the Group S. The I/Br ratio of the Group S is fairly similar to that of CI chondrite (I/Br ratio: about 1 x 10^{-1}, Anders and Ebihara, 1982). These suggest that these kimberlites preserve the primordial characteristics of halogens in the mantle from which the kimberlite magmas formed. On the other hand, the other group (Group C) composed of Chinese and Russian kimberlite samples shows markedly low I/Br ratios (about 6 x 10^{-3}). Similar low I/Br ratios have been observed in fluid inclusions in eclogites derived from seawater-altered oceanic crust (Svensen et al., 2001) and in seawater associated with halite precipitation (Zherebtsova and Volkova, 1996). This suggests an involvement of seawater-derived halogens having low I/Br ratios in the source regions of the Group C kimberlites. In Russian xenolith, one is classified into the Group S and the other two samples are Group C. This suggests the heterogeneous involvement of the Group C component in the mantle beneath this region.