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Noble gas isotopic compositions of diamonds in the Udachnaya kimberlite pipe, Siberia

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Noble gas isotopes trapped in fluid/melt inclusions in diamonds can constrain the origin of such deep-mantle-derived materials because they show completely different values between the more primordial source, which contributes OIBs and which is possibly stored in the deep mantle, and the depleted MORB source in the convecting mantle. In contrast, in situ radiogenic/cosmogenic noble gas isotopes might be distributed homogeneously in the diamond lattices. In vacuo sequential dynamic crushing extraction-by which diamond stones are crushed mechanically in vacuum-is a powerful tool for selective noble gas extraction from the inclusions. This report presents a noble gas study, conducted using a combination of several non-destructive micro-spectroscopic methods, of inclusions in diamonds in Udachnaya kimberlite (Siberia).

Sumino et al. (2006) [1] analyzed noble gases in olivine phenocrysts in the Udachnaya kimberlite and obtained $^{3}He/^{4}He$ of kimberlite magma of ca. 5.7 R_A which resembles that of subcontinental lithospheric mantle (SCLM) and a less-nucleogenic feature in neon isotopes of the magma than in the MORB source. The He?Ne systematics revealed that helium and neon in the Udachnaya kimberlite magma are explainable by a mixing between a plume-like and the SCLM-like components. The results indicate that the source of the Udachnaya kimberlite has similar noble gas characteristics to those of OIBs, and constrain a depth of its origin to be deeper than the MORB source mantle. To clarify the origin of the Udachnaya diamonds and their genetic relation to the host kimberlite, diamond crystals of cubic habit with abundant micro-inclusions and of 1-3 mm were investigated in this study.

The individual micro-inclusions are usually smaller than several micrometers, with some exceptions reaching 10-15 micrometers [2]. According to the distribution of carbonates (i.e., inclusions) obtained by FT-IR investigation, doubly polished plates of the samples were cut into several pieces. Noble gases in the sample pieces (less 0.5-1 mg each) were extracted using in-vacuo stepwise heating or crushing. Although the samples released helium that was dominated by radiogenic ^{4}He at their graphitization (2000 degree C) during stepwise heating, the crush-released helium exhibited $^{3}He/^{4}He$ of 3.5-7.4 R_A, indicating that the inclusion-hosted helium has similar $^{3}He/^{4}He$ to that of the host kimberlite magma. This similarity implies diamond formation in a SCLM environment. A correlation between $CO_3{}^{2-}$ content and ^{3}He suggests that mantle-derived noble gases are trapped in the carbonate-rich inclusions. In contrast, diamond-lattice-hosted helium is dominated by radiogenic ^{4}He, possibly produced in situ from trace amounts of U and Th after diamond formation.

Because the scarcity of neon released by stepwise heating and crushing of the sample pieces made it impossible to determine neon isotope ratios precisely, we extracted noble gases by crushing several diamond stones together which exhibits similar volatile compositions each other based on FT-IR investigation. The result showed that crush-released inclusion-hosted neon isotope ratios form a trend in a neon three-isotope plot which is almost identical to that of the host kimberlite magma reported by [1], suggesting a common source of the diamonds and host kimberlite magma. The diamond-forming fluids and incipient carbonatitic fluids/melts of the kimberlite magma may originate from partial melting of SCLM peridotite previously metasomatised by a plume.

[1] Sumino et al. (2006) Geophys. Res. Lett. 33, L16318. [2] Zedgenizov et al. (2004) Mineral. Mag. 68, 61-73.

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