Noble gas evidence for the common origin of diamonds and their host kimberlite from Udachnaya-east pipe kimberlite, Siberia

*Hirochika Sumino[1], Syuya Tago[2], Hiroyuki Kagi[2], Dmitry A Zedgenizov[3]

1. Department of Basic Science, Graduate School of Arts and Sciences, The University of Tokyo, 2. Geochemical Research Center, Graduate School of Science, The University of Tokyo, 3. Sobolev Institute of Geology and Mineralogy, SB, RAS

Mysterious origin of diamonds has attracted not only public interest but also those of scientists. Whether diamonds and their host kimberlite are completely stranger just come along to the surface accidentally at the last moment of their long journey in the Earth's interior, or they have a genetic link, is unclear [1,2]. Whereas gem-quality octahedral diamonds exhibit significantly old crystallization ages up to several billion years old [3-7] compared to their host kimberlites (several hundred million years old [6,8]), some diamonds with cubic habit show fibrous texture and contain numerous micron-sized inclusions suggesting their rapid growth just before being captured by the host kimberlite magma to erupt [9-12]. Here we show that noble gas isotope data combined with micro-spectroscopic investigation provide the first strong evidence of cogenetic origin of such diamonds and their host kimberlite from Udachnaya east pipe, Siberia.

Noble gas isotopes trapped in fluid/melt inclusions in diamonds and kimberlitic olivines have a potential to constrain the origin of such deep-mantle-derived materials because they show completely different values between the more primordial source (represented by OIBs), which is possibly stored in the deep mantle, and the depleted source (MORBs) in the convecting mantle [13]. The in vacuo sequential dynamic crushing extraction, in which sample grains are mechanically crushed in vacuum, is a powerful tool for selective noble gas extraction from the inclusions.

Fresh olivine phenocrysts in kimberlite collected from the deep levels (~500 m) of the Udachnaya kimberlite pipe have been revealed to preserve magmatic noble gases possibly in low density CO_2 fluid inclusions associated with carbonate-chloride inclusions [14]. Based on He-Ne systematics, it is revealed that helium and neon in the Udachnaya kimberlite magma can be explained by a mixing between plume-like component, which would be the original characteristic of the source of kimberlite magma, and SCLM-like one, which would be acquired from the surrounding materials in the SCLM. The results indicate that the source of the Udachnaya kimberlite have similar noble gas characteristics to those of OIBs, and constrain a depth of its origin to be deeper than the upper mantle.

The diamond crystals of cubic habit with abundant micro-inclusions and of 1-3 mm in size were collected from the Udachnaya kimberlite pipe. Because the scarcity of neon in the individual diamond stones 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 helium and neon isotope signatures are quite similar to that of the host kimberlite magma [14]. The striking similarity in He–Ne isotope systematics of the Udachnaya diamonds and their host kimberlite strongly suggests a common source of the diamonds and kimberlite magma. During the ascent in the SCLM, an incipient carbonatitic melt of kimberlite magma consumes silicate minerals (orthopyroxene) in surrounding mantle peridotite to evolve to silica-rich composition [15,16]. Therefore, the plume-like noble gas could have been inherited from the incipient melt derived from a plume tap from deepest region of the mantle, and mixed with

SCLM-derived noble gas during the magma evolution. The low nitrogen aggregation states in the diamonds suggest their rapid growths in the C-O-H fluids progressively changing its noble gas isotope composition.

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