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Origin of sublithospheric diamonds: clues from Fe and Mg isotopes

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Sublithospheric diamonds, identified by inclusions that indicate formation beneath the lithosphere, make up only about 1% of natural diamonds in kimberlite. Unlike lithospheric diamonds, for which mineralogical and geochemical criteria are well established to divide them into peridotitic and eclogitic suites, the origin of sublithospheric diamonds is less well understood. Yet these diamonds and their inclusions represent the deepest samples of Earth's interior that we can directly study. Understanding the origin of sublithospheric diamonds provides vital constraints on Earth's deep geochemical cycles and the plate tectonic processes that drive them.

Non-traditional stable isotope systems, such as Fe and Mg, have emerged as powerful tools for studying geochemical processes on Earth. Their distinct behaviors often provide complementary constraints. A combination of Fe and Mg isotopes with traditional stable isotope systems (e.g. C, N, and O) and radiogenic isotope systems (e.g. Re-Os) provides a more comprehensive perspective on the origin of inclusions hosted in sublithospheric diamonds.

To measure Fe and Mg isotopic compositions of these minuscule inclusions in sublithospheric diamonds, we developed a dedicated protocol involving host-diamond cleaning, inclusion extraction, and micro-chromatographic purification. Analyses of metallic inclusions in a subset of sublithospheric diamonds–the so-called CLIPPIR diamonds (Cullinan-like, Large, Inclusion-Poor, Pure, Irregular, and Resorbed) reveal strong enrichment in the heavy isotopes of iron that extend far beyond the typical mantle range [1]. On the other hand, Fe and Mg isotope analyses of ferropericlase [(Mg,Fe)O] inclusions, the most common inclusion type in non-CLIPPIR sublithospheric diamonds, divide these inclusions into two groups that correlate with their Mg number and crystal orientation relative to the host diamond [2].

In both cases, the magnitude and systematics of Fe and Mg isotope fractionation link diamond-forming fluids to surface-derived protoliths, where low-temperature environments allow for larger isotopic fractionation. The involvement of surface-derived lithologies in forming these sublithospheric diamonds bears direct witness to Earth's deep geochemical cycle, which transports volatiles to Earth's interior and contributes to sustaining long-term geochemical heterogeneities in the mantle.

[1] Smith E.M. et al. (2021) *Sci. Adv.*, 7, eabe9773.

[2] Ni P. et al. (2025) *Sci. Adv.*, 11, eadt9106.