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Ni-rich inclusions in diamonds and the enrichment of nickel in the Earth's mantle

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Nickel is a major constituent of the Earth's core and an important trace element in the mantle, where it follows Mg, Fe and S. Here we report the first coexisting Ni-rich carbonate and Ni-rich metal-bearing inclusions in sublithospheric diamonds from the Voorspoed mine, South Africa. The $(Ni,Fe)CO_3$, with Ni/(Ni+Fe)=0.89±4 resides in microinclusions (<1µm) forming a central cloud in diamond ON-VRS-664. The Ni-Fe metal (Ni/(Ni+Fe)=0.89) resides in the apex of molecular d-N_2 nanoinclusions in both ON-VRS-664 and 866. Coesite, a K-NAL phase, ulvospinel, Na-Al pyroxene and olivine were found in larger mineral inclusions (1-20 µm) surrounding the cloud. Raman and X-ray data for the d-N_2, NAL and coesite suggest trapping at 9-16 GPa. The mutual occurrence of carbonate and metal and their very high Ni content call for an explanation. We suggest they record the interaction of a carbonatitic fluid with metallic melt at depth below the Ni-precipitation curve in the sublithospheric upper mantle.

We propose the following scenario: Upon the introduction of the oxidized carbonatitic melt into a metal-bearing peridotite, the local fO_2 increases and Fe in the metal is reduced preferentially to ferrous iron that enters into olivine. The remaining Ni-rich melt and carbonate remain in the rock. Diamonds form as the carbonate is reduced and trap the two phases.

Our findings corroborate the presence of a Ni-rich metallic phase at depths below 290-450 km, in accordance with predictions based on thermodynamic modelling.

The storage of Ni in more labile phases facilitates its transport and may provide an explanation for Ni-enrichment in basalts. When a rock that carries the carbonate and melt joins an ascending plum, these less refractory phases may contribute to formation of basalts that are enriched in Ni. In turn, the basalts precipitate Ni-rich olivines, as found in Hawaii, Baffin Island, Greenland and a few more localities.