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Corundum inclusions in diamonds: implications for multi-stage diamond formation beneath the Kaapvaal Craton

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Corundum inclusions in natural diamonds are extremely rare, only five occurrences are reported in literature, one of unknown origin, one from Canada (Fort à la Corne) and three from Brazil (São Luiz and Juina). So far, their occurrence has been related to eclogitic parageneses and their high Cr_2O_3 and NiO contents to a sublithospheric origin, but the extent of geological information that can be extracted from corundum inclusions is not completely understood. The connection between diamond formation and the mantle lithologies compatible with corundum, and the depths at which they form, remain largely unknown.

We present the first geochemical, spectroscopic and single-crystal X-ray diffraction characterization of corundum inclusions in four diamonds from the Premier mine (or Cullinan mine - Kaapvaal Craton, Africa). Raman, SEM-EMP and LA-ICPMS analyses highlighted homogeneous compositions for all the corundum inclusions, showing low Cr_2O_3, LILE, HFSE and Pb contents and high Ni. FTIR spectroscopy revealed variable N-aggregation states and, for one diamond, core-to-rim zonation.

For the first time, elastic geobarometry was applied to the diamond-corundum system to determine the minimum pressure of formation. Combining the FTIR-thermochronometric and X-ray diffraction-elastic barometric data, we reconstructed the pressure (8.3-12.3 GPa), depth (250-370 km) and temperature (1220-1390 °C) of corundum entrapment and diamond formation.

The low Cr content of corundum accords with an eclogitic paragenesis. Thus, the bulk composition of subducted materials is Al-rich and Cr-poor, with troctolitic protoliths being sufficiently Al-rich to form corundum and other aluminous phases. We propose several eclogitic diamond-forming episodes beneath the Kaapvaal Craton, during the Mesoproterozoic, not limited to the lithospheric mantle, but extending to sublithospheric depths, at different temperatures and pressure conditions, along the subducting slab. Variable partial melting temperatures of different carbonate-rich slab lithologies, as well as locally heterogeneous redox conditions, may explain the variable N content and aggregation state recorded in the Premier diamonds. The formation of these corundum-bearing diamonds can be related to deep subduction associated with the Namaqua-Natal Orogeny.

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