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Nanometric mineral inclusions in fluid-rich diamonds

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A particularly interesting type of diamond, known as *fluid-rich* or *fibrous diamond,* can provide crucial information about diamond-forming fluids and the recycling of volatiles in the deep Earth through the study of the fluid inclusions they contain. However, the minerals found within fluid-rich diamonds are often nanometric in size and thus not amenable to study using standard instrumentation, preventing application of chemical or elastic thermobarometry. Consequently, determination of the depths at which they form is extremely challenging and researchers have been unable to link information from fluid-inclusions to specific mantle environments associated with diamond formation. The MADAM research group (Discovering **M**ineral n**A**noinclusions in **D**i**AM**ond - ERC Advanced Grant - 2024) is working to solve this problem.

Using new micro-electron diffraction (MED) instrumentation and a custom device for crushing and extracting nanometric mineral inclusions, we can now structurally characterize, and thus rigorously identify, nanometric inclusions from different types of fluid-rich diamonds. A preliminary study of a fluid-rich diamond from the Kaapvaal craton (Kimberley region, South Africa) revealed nanometric inclusions of Sr-rich åkermanite ($Ca_2MgSi_2O_7$), unusual carbonates (norsethite – $BaMg(CO_3)_2$, monoclinic Ca-rich strontianite - $SrCO_3$ and nyerereite - $Na_2Ca(CO_3)_2$), sellaite (CaF_2) and anatase (TiO_2). We completed a crystal structure refinement with full anisotropic displacement parameters of one åkermanite crystal (100 × 40 × 10 nm) marking a milestone, the first complete structural characterization of a nanometric mineral inclusion in diamond. Åkermanite and monoclinic Ca-rich strontianite have not been previously observed as inclusions in diamonds and no natural analogue of monoclinic Ca-rich strontianite is known. FTIR data from fluid inclusions, along with MED data, suggest this diamond formed from an alkali-silico-carbonatitic parental melt, related to recycling of crustal material into the lithospheric mantle beneath the Kaapvaal Craton. Using the experimental formation temperatures of synthetic åkermanite, combined with N-aggregation thermochronometry, the minimum diamond formation temperature was constrained to 1000 °C, at ~140 km depth (~4.6 GPa) along a typical 40 mWm^{-2} geotherm.

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