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# TEM imaging and analysis of microinclusions in diamonds: A close look at diamond-growing fluids

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## Abstract

Fluid-bearing microinclusions in diamonds (<1 μm) provide a unique source of information on the diamond-forming medium. Transmission electron microscopy (TEM) investigation of such microinclusions enables the detailed study of their size, external habit, internal morphology, and mineralogy, and yields information on the chemical composition and crystallography of the included phases. Here we present a detailed TEM examination of microinclusions in four fibrous diamonds from Canada and Siberia, each with a distinctive inferred original fluid composition. Most microinclusions contain multi-phase assemblages that include carbonate, halide, apatite, possible pyroxene, and high-silica mica (6.8–7.7 Si atoms per formula unit) whose composition lies along the phlogopite–Al-celadonite join. The TEM results, together with the tight range of composition detected by electron probe microanalysis (EPMA) and the volatiles detected by infrared (IR) spectroscopy, suggest that the microinclusions trapped a uniform, dense, supercritical fluid and that the crystallized minerals grew as secondary phases during cooling.

Carbonates appear in all assemblages, together with either halides or silicates, indicative of the importance of carbonatitic high-density fluid during diamond growth and fluid evolution. The presence of halide-carbonate or silicate-carbonate assemblages is in agreement with the bulk composition of the microinclusions as detected by EPMA. The high K content of some microinclusions detected by EPMA cannot be accounted for by the solid phases analyzed by TEM. This discrepancy suggests that K is concentrated in the residual fluid that is lost during TEM sample preparation. In addition to microinclusions, large cavities containing amorphous phases were found in the inner parts of one Siberian and one Canadian diamond. An Al-rich phase is the most abundant, and it is accompanied by Ca-rich and Si-rich phases. These phases may be explained by amorphization of crystalline phases. A breakdown of a single melt into three immiscible components is less likely.

**Keywords:** Crystal structure, high-density fluid, high-silica mica, carbonate, halide, secondary minerals, multi-phase assemblage