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Macle Diamonds: Primary Fluid Inclusion Entrapment Along the Twinning Plane

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Diamond growth in the mantle is mediated by carbon-bearing fluids, but this process remains challenging to study because of the rarity of fluid inclusions. Most previous studies of diamond-forming fluids are restricted to a subset of diamonds called fibrous diamonds, specifically because they contain abundant fluid micro-inclusions that give them their characteristic opaque or translucent appearance (Weiss et al., 2022). Relatively recently, sparse micro-inclusions with similar chemical compositions were identified directly along the twinning plane of macle diamonds (Jablon & Navon, 2016). This provided a crucial link between the primary fluids of fibrous diamonds and non-fibrous, gem-quality diamonds.

Our analysis further demonstrates the scientific value of macles as a host of fluid. We have identified a previously unappreciated reservoir of fluid inclusions in non-fibrous, gem-quality diamonds, trapped in so called "twinning wisps" found in macle diamonds (Fig. 1). These are groups of many small inclusions that appear to be remnants of the diamonds' primary growth fluids, making them unique resources for learning about growth conditions and the deep earth carbon cycle.

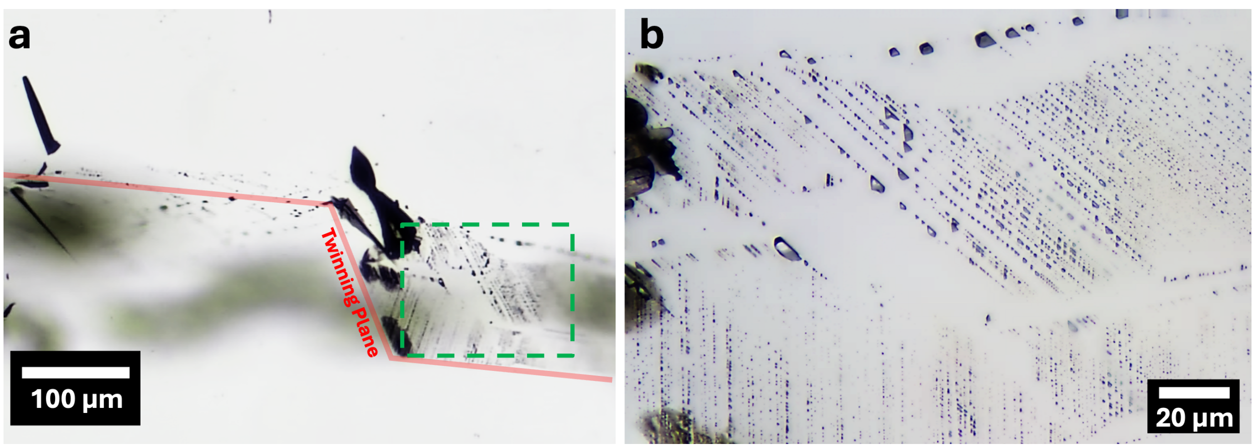

Figure 1: a) Twinning wisp seen in cross section (110) of a 1.9 ct macle diamond. The twinning plane extends into the depth of the image and is marked by the red line. The wisp is found at a step in the twinning plane and dips to the right, into the center crystal. b) Focus-stacked photomicrographs of twinning wisp inclusions (green inset panel a). Inclusions range in diameter from 0.1-10 µm.

Twinning wisps are often visible with 10x magnification. They are made up of chains or ribbons of micro-inclusions, each up to several micrometers in diameter. They are associated with the twin plane in macle diamonds, presumably being trapped along steps or other morphological imperfections that trap material during crystallization. Raman spectroscopy of twinning wisp inclusion suites in several diamonds reveals the presence of hydrous silicic fluids (Fig. 2), similar to those previously identified surrounding mineral inclusions in diamonds (Nimis et al., 2016). Fourier Transform Infrared Spectroscopy has also revealed that the diamond growth nearest to the twinning plane is enriched in hydrogen-related defects (N_3VH defects as measured by the area of the 3107 cm^{-1} peak [Goss et al., 2014]) consistent with the hydrous nature of the fluid inclusions. Our work combines imaging of growth banding along the twinning plane and Raman analysis of inclusions to learn about how these inclusions are entrapped during diamond growth and what they might reveal about the diamond-forming medium. Imaging techniques include fluorescence and cathodoluminescence, as well as advanced 3D fluorescence lifetime mapping of nitrogen defect concentrations. We plan further analyses by electron microprobe and mass spectrometry to determine the specific chemical compositions of the inclusions and the surrounding diamonds.

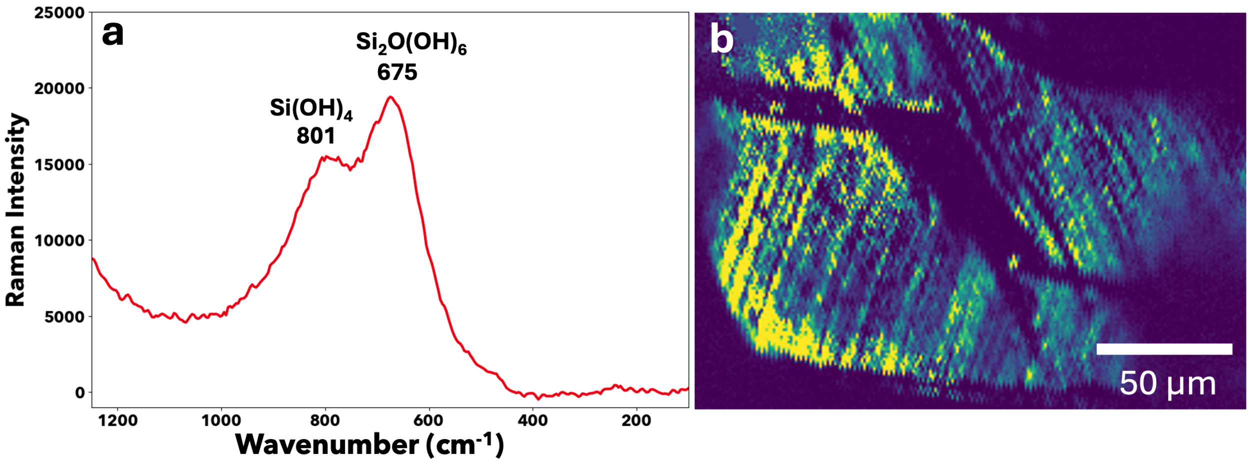

Figure 2: Raman spectrum (a) and map (b) of hydrous silicic fluid found in the twinning wisp shown in figure 1. b) Map is a 2D projection of 3D data; yellow and green color indicate the presence of hydrous silicic fluid but are not scaled for concentration due to changes in Raman intensity with depth in sample. Raman analysis also indicates the presence of olivine and enstatite mineral inclusions, not presented in this image.

References

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