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Rare {110} cleavage in sublithospheric diamonds and deep mantle deformation events

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Diamond exhibits excellent cleavage on {111}, or octahedral, planes. Cleavage along {110}, or dodecahedral, planes is theoretically possible but energetically unfavorable. It can be produced in point-loading deformation experiments and in diamond anvil cells, but {110} cleavage is rarely observed in nature. However, three diamonds have been found to contain planar arrays of metallic melt inclusions that document localized {110} cleavage and subsequent healing of the host diamond. These examples are CLIPPIR diamonds (Cullinan-like, Large, Inclusion-poor, Pure, Irregular, Resorbed), whose formation has been linked to subducted altered oceanic lithosphere at depths of 360-750 km [1-3].

CLIPPIR diamonds often contain linear chains of melt inclusions aligned along <111> directions (i.e., perpendicular to an octahedral plane). In the favored hypothesis, these chains form during extreme mantle deformation events, such as deep focus earthquakes [4], when high deviatoric stresses enables two or three {110} cleavages to open around melt inclusions, oriented parallel to the maximum resolved compressive stress [1,2,5]. These stress-controlled fractures intersect along a <111> direction and open a transient channel along which the melt can redistribute. In cathodoluminescence and deep-UV luminescence imaging, the metallic inclusion chains are indeed surrounded by luminescent features interpreted as healed {110} cleavages [2].

The present observations of {110} planar arrays of metallic melt inclusions nicely demonstrate {110} cleavage in the mantle. Encountering several examples of natural {110} cleavage in CLIPPIR diamonds lends support to the model above, which relies crucially on the operation of {110} cleavage to explain inclusion chains as a deformation feature. It implies that CLIPPIR diamonds in general have witnessed a pronounced transient stress event, sufficient to fracture diamond despite its typically plastic behavior at mantle temperatures. This deformation history may apply more broadly to all sublithospheric diamonds, which have conspicuously fractured and irregular morphologies compared to lithospheric diamonds.

[1] Smith *et al*. (2016) *Science* **354**, 1403-1405. [2] Smith *et al*. (2017) *Gems & Gemology* **53**, 388-403. [3] Smith and Ni *et al.*, (2021) *Science Advances* **7**, eabe9773. [4] Shirey et al. (2021) *AGU Advances* **2**, e2020AV000304. [5] Smith *et al*. (2025) *Mineralogy and Petrology* **119**, 305-325.