Polycrystalline diamonds and their mantle-derived mineral and fluid intergrowths

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Polycrystalline diamond aggregates (framesites, boart, diamondite) are an understudied variety of mantle diamond, but can make up 20% of the production in some Group I kimberlites. Their polycrystalline nature indicates rapid precipitation from carbon-oversaturated fluids and individual PDAs often contain a chemically heterogeneous suite of websteritic and pyroxenitic inclusions and minerals intimately intergrown with the diamond crystals. Geochemical and microstructural evidence suggests that fluid-driven redox reactions with lithospheric material occurring episodically over millions of years play a major role in freezing carbon in the subcratonic lithosphere (Jacob et al., 2000; 2016; Mikhail et al., 2014).

A suite of 39 samples from the Venetia kimberlite pipe in South Africa allows a more detailed look at the diamond-forming fluids. $\delta^{13}C$ values in the diamonds measured by secondary ion mass spectrometry range from +2 to -28‰ and cover the entire range for PDA from the literature. Nitrogen concentrations are mostly very low (less than 100 at ppm), but reach up to 2660 at ppm in individual samples. These high nitrogen concentrations in concert with mostly positive $\delta^{15}N$ values of up to +17‰ and some very negative $\delta^{13}C$ values suggest crustal material as the source of the nitrogen and the carbon.

However, detailed analysis of the sample provides evidence for a more complex growth history followed by alteration. Individual diamond crystals show complex growth zonations by cathodoluminescence imaging that can be related with the carbon and nitrogen isotopic compositions and points to growth incorporating several pulses of carbon-nitrogen fluid with distinct isotopic compositions. Most of these growth events show decoupled carbon and nitrogen systematics. In addition, EBSD identifies deformation and recrystallization and nitrogen aggregation states range from pure IaA to pure IaB, supporting a heterogeneous and episodic growth history.

Jacob et al. (2000) Science 289, 1182; Jacob et al. (2016), Nat. Comm 7:11891; Mikhail et al. (2014) Am Min 99, 1537.