Fast ascent of diamonds from transition zone to surface: δ-N_2 inclusions in Juina diamonds.

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The exsolution of nitrogen and the formation of small (~20 nm) inclusions of solid nitrogen in diamonds is the ultimate stage in the aggregation of nitrogen in diamonds. We report the finding of such exsolutions in diamonds from Juina, Brazil. IR spectroscopy of four diamonds revealed high concentrations of fully aggregated nitrogen (average of 900 ppm, all in B centers). The platelets which accompanied the formation of B centers have all been degraded and disappeared. Bimodal population of inclusions comprised microinclusions (average size: 150 nm, average concentration: 100 ppm) and nanoinclusions (20-30 nm, 350 ppm), suggesting two distinct nucleation events. Raman spectroscopy indicated the presence of solid, cubic δ-N_2 at 10.9±0.2 GPa (Density=1900 kg/m^3). This is the highest pressure ever measured in a natural inclusion. Transmission electron microscopy also indicates the presence of a fully crystalline phase and EELS detects the presence of nitrogen. A single diffraction pattern suggests a tetragonal phase, which resembles γ-N_2 at 1400 kg/m^3 (P~2.7 GPa at room temperature). Atomic force microscopy revealed up-warping of small areas (~150 nm in size) on the polished surface of one diamond. The ~2 nm rise is explained by a pressurized shallow subsurface microinclusion, with P>10 GPa.

Using equations of state for nitrogen and diamond and assuming no plastic relaxation and formation at near geotherm conditions, we estimate origin at the deepest part of the transition zone at pressures of ~22 GPa (630 km) and temperatures of ~1640°C. We suggest that both generations of inclusions are the result of exsolution of nitrogen from B centers and that growth took a few million years. The microinclusions nucleated first, followed by the nanoinclusions. Shortly after the exsolution events, the diamonds were trapped in a plume or an ascending melt and were transported to the base of the lithosphere and later to the surface. This conclusion joins earlier studies that advocated a fast ascent from depth to surface.

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