Boron-Bearing, Type IIb Diamonds from Superdeep Subduction

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Type IIb diamonds, such as the Hope diamond, contain trace amounts of boron and are prized for their blue colors. Since boron is a quintessential crustal element, it is completely unexpected in diamond-forming fluids at mantle depths. Despite the mineralogical/geochemical interest in type IIb diamonds, almost nothing is known about how they form chiefly because of their rarity (≤0.02% of all diamonds) and high gem value.

To investigate the type of mantle host rock, the depth of origin (lithospheric vs. convecting mantle), and the source of boron, the high-volume diamond grading stream of the Gemological Institute of America was systematically screened to find type IIb diamonds with inclusions. Over a period of about two years, 46 prospective samples were identified and examined optical microscopy, X-ray diffraction, and infrared/Raman spectroscopy; a few diamonds were also analyzed for carbon isotopic composition and polished for electron probe microanalysis of inclusions.

The examined inclusions represent retrogressed high-pressure minerals, from metabasic to metaperidotitic hosts in the lowermost mantle transition zone (MTZ) to lower mantle (LM). These include former $CaSiO_3$-perovskite, majorite, bridgmanite, stishovite, calcium-ferrite-type phase, and ferropericlase. The variably light carbon isotope compositions and inclusion mineralogy indicate diamond growth in deeply subducted oceanic lithosphere (crust and mantle). Some inclusions are found to have coexisting fluid ($CH_4 \pm H_2$) that suggests the original high-pressure minerals interacted with hydrous media. We propose that the boron resided in serpentinized oceanic lithosphere. During subduction, the serpentine was metamorphosed to dense hydrous magnesium silicates (DHMS) that retained some boron. Upon breakdown in the MTZ/LM, these DHMS yielded boron-bearing hydrous fluids conducive to diamond growth.