A geological overview of large, high-quality diamonds

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It has long been recognized that many of the world's largest, high-quality gem diamonds have an unusual set of characteristics. Most often noted is their very low nitrogen content, which classifies them as type II, an otherwise rare designation. In addition to this striking chemical purity, diamonds such as the 3,106 carat Cullinan (type IIa) and the famous blue Hope (type IIb, boron-bearing) tend to have very few or no inclusions, and in their rough state they are found as irregular shapes rather than as sharp octahedral crystals. Over the past three years, systematic investigation of both type IIa and IIb diamonds at the Gemological Institute of America has now revealed the unique geological origins of these high-value gem diamonds. Examination of more than 130 inclusion-bearing samples has established recurring sets of inclusions that clearly show many of these diamonds originated in the sublithospheric mantle, several times deeper in the Earth than more common diamonds from the cratonic lithosphere. We now recognize that type IIa diamonds, or more specifically, diamonds with characteristics akin to the historic Cullinan diamond (dubbed CLIPPIR diamonds), are distinguished by the occurrence of iron-rich metallic inclusions. Less frequently, CLIPPIR diamonds also contain inclusions of majoritic garnet and former $CaSiO_3$ perovskite that constrain the depth of formation to within 360–750 km. The inclusions suggest that CLIPPIR diamonds belong to a unique paragenesis with an intimate link to metallic iron in the deep mantle. Similarly, findings from type IIb diamonds also place them in a "super-deep" sublithospheric mantle setting, having inclusions of former $CaSiO_3$ perovskite and other high-pressure minerals, although the iron-rich metallic inclusions are generally absent. Altogether, these findings show that high-quality type II gem diamonds are predominantly sourced from the sublithospheric mantle, a surprising result that has refuted the notion that all super-deep diamonds are small and non-gem quality. This has significant implications for mining and exploration because these large, high-quality diamonds are disconnected from traditional lithospheric diamond indicator minerals. It is important to recognize that any given diamond deposit may contain varying mixtures of distinct diamond populations sourced from disparate mantle origins.

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