

# What makes diamonds blue? Boron from oceanic crustal remnants in Earth's lower mantle

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A blue, boron-bearing diamond with dark inclusions of a mineral called ferropericlase, which were examined as part of this study. This gem weighs 0.03 carats. Credit: Evan Smith/GIA

Blue diamonds—like the world-famous Hope Diamond at the National Museum of Natural History—formed up to four times deeper in the Earth's mantle than most other diamonds, according to new work published on the cover of *Nature*.

"These so-called type IIb diamonds are tremendously valuable, making them hard to get access to for scientific research purposes," explained lead author Evan Smith of the Gemological Institute of America, adding, "and it is very rare to find one that contains inclusions, which are tiny [mineral](#) crystals trapped inside the diamond."

Inclusions are remnants of the minerals from the rock in which the diamond crystallized and can tell scientists about the conditions under which it formed.

Type IIb diamonds owe their blue color to the element boron, an element that is mostly found on the Earth's surface. But analysis of the trapped mineral grains in 46 blue diamonds examined over two years indicate that they crystallized in rocks that only exist under the extreme pressure and temperature conditions of the Earth's lower mantle.

The research group—which included Carnegie's Steven Shirey, Emma Bullock, and Jianhua Wang—determined that blue diamonds form at least as deep as the transition zone between the upper and lower mantle—or between 410 and 660 kilometers below the surface. Several of the samples even showed clear evidence that they came from deeper than 660 kilometers, meaning they originated in the lower mantle. By contrast, most other gem diamonds come up from between 150 and 200 kilometers.



A blue, boron-bearing diamond containing mineral inclusions that were examined as part of this study. This gem is 3.81 carats and 1.26 centimeters long. Credit: Robison McMurtry/GIA.

So how did the boron get down there if it is an element known for residing predominately in the shallow crust?

According to the hypothesis put forth by the research group, it came from seafloor that was conveyed down into the Earth's mantle when one tectonic plate slid beneath another—a process known as subduction.

The new study proposes that boron from the Earth's surface was incorporated into water-rich minerals like serpentine, which crystallized during geochemical reactions between seawater and the rocks of the oceanic plate. This reaction between rock and water is a process called serpentinization and can extend deep into the seafloor, even into the oceanic plate's mantle portion.

The group's discovery reveals that the water-bearing minerals travel far deeper into the mantle than previously thought, which indicates the possibility of a super-deep hydrological cycle.

"Most previous studies of super-deep diamonds had been carried out on diamonds of low quality," Shirey said. "But between our 2016 finding that the world's biggest and most-valuable colorless diamonds formed from metallic liquid deep inside Earth's [mantle](#) and this new discovery that blue diamonds also have super-deep origins, we now know that the finest gem-quality [diamonds](#) come from the farthest down in our planet."

**More information:** Evan M. Smith et al, Blue boron-bearing diamonds from Earth's lower mantle, *Nature* (2018). [DOI: 10.1038/s41586-018-0334-5](#)

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