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Nitrogen content of diamond and subduction changes through time

STEVEN B. SHIREY AND MICHAEL J. WALTER
Carnegie Institution for Science

Many lithospheric and sublithospheric diamonds contain isotopic evidence for the recycling of surficial components equilibrated at low temperatures in ocean floor hydrothermal systems. Diamond N content constrains the petrogenesis of these different diamond types and the subduction style of their source fluids through geologic time.

Sublithospheric diamonds derived from supercritical aqueous fluids/melts or carbonatitic liquids, have low N content by crystallizing from low-N-content diamond forming fluids. These fluids are produced once N has been largely devolatilized or from N-free rocks deeper in the slab. For lithospheric diamonds, higher N content comes from diamond forming fluids created by devolatilization nearer the more N-rich slab surface.

To explain sublithospheric diamonds, thermal modeling, petrology, and seismology of typical subduction in modern arcs show that cold slabs avoid devolatilization and carry their volatiles into the deep upper mantle, mantle transition zone (MTZ), and uppermost lower mantle. In the upper mantle and MTZ, crust near the slab surface devolatilizes by melting when it intersects its carbonated solidus. Colder stockworks of serpentinized mantle in the deeper slab interior will devolatilize later to melt or evolve fluids. For both scenarios, fluids in cracks and faults get reduced and become diamond-forming when they react with mantle rocks in the slab or nearby ambient mantle.

Lithospheric diamonds form from fluids derived near the surface of slabs where N resides. Devolatilization of these warmer slabs occurs shallower than 300 km. The high N content of most lithospheric diamond forming fluids comes from a setting where subduction occurs against the dipping edge of the subcontinental mantle keel. This setting allows for mantle-wedge-free transfer of diamond-forming fluids from the subducting plate to the “hanging wall” of the reducing subcontinental mantle keel.

Scant ages of sublithospheric diamonds show their onset of crystallization in the Paleoproterozoic whereas the onset of lithospheric diamond crystallization is Paleoarchean. These age differences may preserve a temporal change in the style of Earth’s volatile geochemical cycles. Shallower, hotter, keel-adjacent, mantle-wedge-free subduction favoring diamond crystallization in the continental lithospheric mantle starts earlier followed by deeper, colder, mantle-wedge-avoiding subduction that favors diamond crystallization in the sublithospheric mantle.