Subducted serpentinite water, superdeep diamonds, and deep focus earthquakes

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The mechanism for “deep-focus” earthquakes (those with focal depths in the mantle between 350 to 700 km and occurring in subducting oceanic slabs) remains unresolved despite these earthquakes being among the most energetic events in the Earth. Hydration-related embrittlement, the cracking of rock facilitated by fluid flow, is thought to be the cause of “intermediate-depth” earthquakes to depths of ~350 km but remains controversial for deep focus earthquakes because evidence for the existence of free fluids at these depths has been missing. Instead, deep focus earthquakes have been postulated to be caused by a wedge of metastable nanocrystalline olivine and/or shear heating.

Superdeep diamonds have high pressure mineral inclusions formed up to 700 km deep, whose geochemistry indicates derivation from subducted oceanic lithosphere. Superdeep diamonds provide a unique window into deep focus earthquake processes that could help resolve the earthquake mechanism question. The mode of formation of superdeep diamonds involves melts, fluids, or supercritical liquids and thereby documents the existence of free fluids at deep focus earthquake depths. Modeling of the thermal structure of slabs indicates that in colder slabs the mantle portion can transport water in hydrous minerals to up to ~700 km depth and that there is a remarkable correlation between cool slab temperatures and the occurrence of deep focus earthquakes. Once slabs reach the transition zone, stalling and heating leads to fluid release, hydration-related embrittlement, superdeep diamond formation, and earthquake rupture. Fault rupture could provide space to account for the frequently blocky shape of the largest superdeep diamonds whose growth may be a spectacular record of the triggering and propagation of deep-focus earthquake faults.