Effects of tectonic history of subduction upon deep-focus earthquakes: application to Pacific plate under Eastern Asia

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Abstract

Deep seismicity in subduction zones provides invaluable information that helps to constrain geodynamic subduction models. While spatial distribution of deep-focus earthquakes may delineate slab geometry, seismogenic stresses indicate the directions of tectonic stress in the subducting plate which reflects the thermal and petrological (phase transitions-related) buoyancy and viscous resistance of the mantle.

Several seismic analyses of deep-focus earthquakes in the Pacific slab under Eastern Asia identified subhorizontal fault planes near to slab bending above the 660-km discontinuity. The most commonly proposed mechanisms of deep seismogenic shear instability include polymorphic transformational faulting in metastable olivine, high-pressure dehydration embrittlement, and thermal runaway of localized shear heating. Here we show that these Pacific slab earthquakes can be associated with the boundary of a metastable olivine wedge (MOW). We construct an evolutionary numerical model of subduction that reflects realistic mineralogy and rheology of mantle material. Our explanatory model accentuates the role of non-uniform plate aging and subduction disruption due to the sinking of the Izanagi–Pacific ridge in the early Cenozoic. We show that this process likely resulted in a present-day seismoactive slab tip, which is bent at the endothermic phase boundary at 660-km depth in agreement with the shape of a seismic high-velocity anomaly reported by seismic tomography. Thermal conditions in the deep transition zone with temperatures ~1000 K allow for the presence of metastable olivine. We therefore argue that a bent MOW at the base of the transition zone provides a plausible explanation of the seismogenic mechanism of deep seismicity in this region and might suggest a transformational faulting nature of the events.

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