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Metamorphic dehydration reactions control the location of intermediate-depth seismicity

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The cause of intermediate-depth seismicity in subduction zones is not well understood. The viability of proposed mechanisms, that include dehydration embrittlement, shear instablities, and the presence of fluids in general, depends significantly on local conditions, including pressure, temperature, and composition. A number of high resolution seismic studies have improved the location of earthquakes within the slab in Japan, Alaska and Cascadia. Intriguingly, the warm subduction zones of Nankai and Cascadia show that intermediate depth seismicity is located below the oceanic crust. In contrast, the colder subduction zones Alaska, Tohoku and Hokkaido have the upper plane of seismicity confined to the subducting crust, with a systematic deepening of the seismic belt with respect to the top of the slab with depth.

We use high resolution thermal-petrological models to determine the metamorphic facies in the downgoing slab and to identify the main phase changes that cause dehydration. In Alaska and Northern Japan, the seismicity occurs at, or at shallower depths than, the blueschist-out boundary. In Nankai and Cascadia the seismicity disappears above the antigorite-out boundary. Seismicity in the lower plane of the double seismic zone in Northern Japan also occurs at pressures and temperatures below the antigorite-out boundary. These observations strongly suggest that intermediate-depth seismicity is limited by the first major dehydration reaction in the crust and mantle and that fluids liberated by this phase change are primarily responsible for causing the earthquakes.