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Dynamics of subducting slabs and origin of deep-focus earthquakes

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Most earthquakes are associated with subduction zones. While earthquakes occur on very short time scales, they reflect thermal conditions and stress state attained in the subducted slab during its long term evolution. The source models of deep earthquakes thus might provide unique information about stress distribution in subduction zones which could be used to constrain geodynamic models.

In the Tonga region, ordinary deep (620-680 km) earthquakes exhibit down-dip compressional stresses as expected, but unusually deep (≥680 km) earthquakes have unique focal mechanisms with vertical tension and horizontal compression. Here we employ geodynamic slab models to investigate the effects of the phase transitions and rheology on the stress and thermal state in Tonga slab in the transition zone and shallow lower mantle and we discuss its relation to deep earthquakes. We show that the direct buoyancy effects of the endothermic transition at 660 km depth are overprinted by bending-related forces and resistance from the more viscous lower mantle transmitted by a strong slab up-dip. The stress pattern that best fits seismogenic stresses is found for the cold plate (150 Myr old) and a viscosity increase at 1000 km depth. An abrupt change in stress orientations occurs as the slab temporarily deflected by the endothermic phase transition penetrates the shallow lower mantle while the fold in the flat-lying part tightens.