Magali Billen
Professor; Director, Computational Infrastructure for Geodynamics (CIG)
Earth and Planetary Sciences
University of California, Davis

A Plate Tectonic Perspective on Earthquakes Occurring 600 km Beneath the Earth's Surface

Within tectonic plates earthquakes occur near the Earth's surface at depths up to about 30 km. These earthquakes occur through brittle fracture and frictional sliding. As depth increases this familiar type of brittle failure is inhibited by increasing pressure and temperature and deformation transitions to ductile and viscous processes. However, in subduction zones, sinking tectonic plates (slabs) remain cold (<1000 C) to depths exceeding 660 km and there are earthquakes occurring within these cold slabs. Several different failure mechanisms have been proposed to explain the occurrence of deep earthquakes including transformational faulting of metastable olivine, dehydration embrittlement and thermal shear instability. The global depth-dependent seismicity rate can be explained by considering that each of these mechanisms will be viable over different depth (temperature) ranges in slabs. However, there is considerable variation in the depth-dependent seismicity both between different subduction zones and along strike within individual slabs. In particular, there are significant gaps in seismicity where one would expect thermally-controlled conditions to be appropriate for earthquakes to occur. This suggests that there is another physical factor that must be taken into account to explain the observed variation. At the Earth's surface, the cold interior of plates are mostly aseismic because the strain-rate is very low, while seismicity is concentrated at the plate boundaries where strain-rates are high. Using numerical models of subduction, I show that slabs also have regions of high and low strain-rate. Accounting for this variation in strain-rate can explain the regional variations in deep slab seismicity and provides another important constraint on the conditions required to cause deep earthquakes.