Geophysical Research Abstracts
Vol. 15, EGU2013-12381, 2013
EGU General Assembly 2013

Subduction Channel Thickening and Thinning: Implications for Interplate Seismicity

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Reconciling the viscous behavior inferred along the plate interface zone in the subduction channel model with the global variations in subduction zone seismicity is a matter of geodynamic importance. Thermal modeling indicates that where subduction is slow (<2 cm/yr) or the incoming plate is very young (<5 Ma), 300°C temperatures are present at depths as shallow as 20 km. Consequently, intracrystalline creep dominates in the shear zone and earthquakes are limited to shallow depths. Where subduction is fast (> 4 cm/yr), the plate interface zone cools to great depth and interplate earthquakes occur to depths as great as 60 km. Thermal modeling and many petrological observations indicate temperature/depth trajectories near the plate interface can become as cold as 6°C/km.
As first emphasized by Uyeda and Kanamori (1979), there is a wide range in the fraction of the plate convergence that manifests itself as thrust-type seismicity at rapidly convergent plate margins. They characterized the end-member behaviors as Mariana-type where only a small fraction of the plate convergence is evident from seismogenic movements and Chilean-type where a large fraction of the plate convergence is accomodated by slip during large earthquakes (M>7.5).
Mariana-type margins are sites of subduction erosion because sediment supply is less than channel capacity, the shear zone is thin and shear stresses are high near the inlet. The long-term mechanical behavior of Chilean-type margins is accretionary because sediment supply is greater than channel capacity. Shear stresses are lower where the shear zone is thicker. The association of infrequent large earthquakes with thicker zones of subducting sediment is especially problematic if the build up of large elastic strains is attributed to friction along a planer interface (decollement) within compacting and metamorphosing sediments. The subduction channel concept postulates that the shear from convergence becomes distributed in the subducting layer of fluid-rich (10-20 volume % pore water), highly overpressured (Pf ∼Pl) sediment. Such materials have limited ability to accumulate elastic strain energy. Large, M7.5 to 9+ events require strong mechanical interactions across which elastic strain energy can accumulate over century timescales. A common mechanical irregularity in subduction channels must be the volcanic seamounts that are welded to the top of descending plates. They can become highly seismogenic asperities where they abut crystalline materials in the overriding plate.
The dichotomy of subduction zone seismicity is explainable. Where subduction accretion occurs by underplating, subduction channels thin downdip. Where subduction erosion abrades the hanging wall block, subduction channels thicken downdip. Subducting seamounts will become truncated at low confining pressures near the inlet of tectonically erosive margins and their impingement may enhance the removal of material from the hanging wall. Where this occurs, interplate seismicity is limited in magnitude because these mechanical irregularities become truncated and shorter than the downdip thickness of the shear zone. In striking contrast, incoming seamounts at accretionary margins can subduct largely intact until they become jammed against the roof of the subduction channel, commonly at depths of 20 to 30 km. Distinct seismic fronts demark where shear zones abruptly thins.