Outer-Rise Faulting, Abyssal Fabric and the Structure of Double Seismic Zones

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Where fast-to-intermediate spreading abyssal fabric approaches the trench at a sub-parallel angle, crustal fault systems with spacing of only a few kilometers may be reactivated and extend down into the underlying mantle (e.g., Middle America). Elsewhere, when the relic abyssal fabric lies at an oblique angle to the trench, new trench-parallel fault systems are formed with much greater spacings and little-to-no reactivation of the abyssal structures (e.g., northern Chile). These two scenarios for fracturing the slab result in much different fault densities at sub-Moho depths, influencing fluid diffusion and the degree of mantle serpentinization.

Within the outer rise of the northern Chile trench, a low relief set of abyssal hill faults (0.1-0.2 km throw, spacings 1-4 km) trends to the northwest, being subducted at an oblique angle to the north-striking trench axis. This abyssal fabric is cut by a larger set of bending-induced horsts and grabens (0.3-0.9 km throw, 5-10 km spacing) that strike parallel to the trench axis. Double-difference earthquake locations reveal two bands of seismicity within the subducting slab; they are located within the crust and mantle, being separated by a ~10-km thick sparsely-seismic region [Rietbrock and Waldhauser, 2004 GRL]. FPFIT- and HASH-derived focal mechanisms for these intraslab earthquakes are rotated to horizontal for comparison with the outer-rise fault populations. The orientations of nodal planes within upper (crustal) band show evidence for slip events on both the oblique abyssal and trench-parallel fault systems that were formed pre-subduction. Below the crustal layer, earthquakes appear to be restricted to planes having strikes similar to the trench-parallel structures on the outer-rise. This indicates that bending-induced reactivation on the outer-rise has not caused the oblique abyssal fault systems to extend to mantle depths. Within portions of the sparsely seismic zone, earthquake clustering is observed along through-cutting planes with spacings similar to the trench-parallel fault systems on the outer rise. Such features likely would not have been resolved within a setting where reactivated abyssal fault systems produced more densely faulted and pervasively serpentinized mantle. As many prominent double seismic zones in the world involve slabs with a fracture history similar to that in northern Chile, we suggest that the pattern of hydration may be an important contributing factor in their development and appearance.