Constraints on composition and flow in the oceanic mantle from a high-resolution estimate of seismic velocities and electrical conductivity in the central Pacific

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Recent theoretical models of the seismic properties of mantle rocks predict seismic velocity profiles for mature oceanic upper mantle that are fundamentally inconsistent with the best observations of seismic velocities in two ways. Observations of strong positive velocity gradients with depth, and a very sharp and very shallow low-velocity asthenosphere boundary (LAB), both suggest that non-thermal factors such as bulk composition, mineral fabric, grain size, and dehydration play important roles in controlling the formation of the lithosphere, and thus the underlying LAB. There is little consensus on which of these factors are dominant, in part because high-resolution observations of detailed lithosphere and asthenosphere structure are limited. To address this discrepancy, we conducted the NoMelt experiment on ~70 Ma Pacific lithosphere between the Clarion and Clipperton fracture zones. The experiment consists of a 600x400 km array of broad-band (BB) ocean bottom seismometers (OBS) and magnetotelluric (MT) instruments, and an active-source reflection/refraction experiment.
The combined results from MT, surface-wave, and P-wave refraction data suggest that the central Pacific upper mantle can be characterized by a cold, dry lithosphere overlying a damp asthenosphere, with no melt required. P-wave velocity increases rapidly in the shallow mantle, with evidence for a distinct, high-velocity reflector at mid-lithosphere depths suggestive of a possible phase change. Seismic anisotropy is extremely strong in the lithosphere with fast direction aligned with fossil spreading. Strength of the fabric increases with depth in the shallow lithosphere, before systematically decreasing with depth into the asthenosphere. Minimum azimuthal anisotropy occurs within the middle of the low-velocity zone, and then it increases with depth, achieving a secondary maximum at about 250 km depth, below the weakest portion of the asthenosphere. Fast directions rotate from fossil-spreading direction within the lithosphere, to a more east-west direction at depth. In no depth range does the direction correspond to apparent plate motion. We interpret the anisotropy as arising from the combination of two processes: shear-strain during corner flow at the ridge axis, and pressure- and/or buoyancy-driven flow within the asthenosphere, perhaps in a non-Newtonian viscous channel. Shear associated with motion of the plate over the underlying asthenosphere, if present, is weak compared to these processes.

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