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Marine electromagnetic constraints on lithosphere/asthenosphere structure

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Marine controlled-source electromagnetic (CSEM) experiments long ago showed that the oceanic lithosphere is highly resistive, but deeper, conductive asthenospheric structure is beyond the resolution of this method. The development of a "broadband" marine magnetotelluric (MT) instrument allowed deepwater MT data collection down to about 20 second periods, overlapping in sensitivity with CSEM data and capturing the peak sensitivity of the asthenosphere in MT data at around 100 seconds. In two end-member experiments, one at the Pacific mid-ocean ridge at 9.5 degrees north, and one where the same, now 23 Ma, Cocos plate subducts beneath Nicaragua, we carried out joint CSEM and broadband MT data collection. At the mid-ocean ridge, symmetric melting above the wet solidus is consistent with passive upwelling of hydrated mantle. Deeper, carbonate-induced melting shows asymmetry that is consistent with upwelling due to viscous coupling across the nearby Clipperton transform offset. At 100 km off-axis, a 70 km thick resistive layer is consistent with melt-depleted lithosphere and asthenosphere. By the time the plate has migrated to the subduction zone, an anisotropic and conductive asthenosphere 25 km thick has developed at a depth of 45-70 km, again inferred to be melting of hydrated mantle. The nature of the anisotropy is consistent with shearing and alignment in the plate motion direction, suggesting viscous decoupling of the lithosphere and asthenosphere. We observe conductivities consistent with a smaller fraction of isotropic melt in the deeper mantle, suggesting that the melt at the lithosphere-asthenosphere boundary (LAB) is a result of upward migrating melt accumulating beneath a thermal and/or dehydration boundary. At both the ridge and subduction zone we estimate several hundred ppm water in the mantle, but this is dependent on laboratory data and any additional impact from carbon dioxide on the solidus.