Electromagnetic detection of partial melts and volatiles across the Middle America Trench offshore Nicaragua

Samer Naif[1], Kerry Key[1], Steven Constable[1], Rob L Evans[2]

[1]Scripps Institution of Oceanography, University of California, San Diego, USA, [2]Woods Hole Oceanographic Institution, USA

E-mail: snaif@ucsd.edu

In April 2010 we conducted a large-scale marine electromagnetic (EM) experiment along a 280 km profile across the Middle America Trench offshore Nicaragua in order to image the electrical conductivity of the incoming plate and asthenosphere before and during the early stages of subduction. The 50 seafloor EM stations were deployed onto the Cocos plate extending from the abyssal plain, across the trench and continental rise and onto the shelf. The instruments recorded controlled-source electromagnetic (CSEM) and magnetotelluric (MT) data that are sensitive to crustal and upper mantle structure, respectively. We inverted the data for 2D electrical conductivity using nonlinear regularized inversion implemented with a newly developed adaptive finite element forward algorithm; this code employs unstructured grids to readily handle the rugged seafloor bathymetry and uses automatic adaptive mesh refinement to ensure numerical accuracy.

The MT data were inverted to yield the triaxially anisotropic resistivity tensor aligned with the trench axis, revealing the existence of a 30 km thick, horizontally extensive low-resistivity layer that extends from the trench outer rise to 200 km into the interior of the plate. The onset of this layer is consistent with seismically observed lithosphere-asthenosphere boundary (LAB) depths. The layer resistivity (4-6 ohm-m) is 2 times more conductive in the direction of plate motion than perpendicular to it. While the low resistivity is compatible with both hydrous olivine and partial melt, we rule out hydrous olivine as it requires unrealistic mantle water contents to account for our observed resistivity. The solidus of wet peridotite suggests that a low degree of partial melt is stable, while the layer anisotropy suggests it is being actively sheared, such that the lithosphere is being decoupled from the deeper mantle over a 30 km depth interval.

The CSEM data image a resistive oceanic crust beneath the abyssal plain, but which decreases by a factor of 2-4 directly with the onset of bending faults at the trench outer rise. A strong azimuthal anisotropy is observed only on the densely faulted outer rise, with crustal conductivity highest in the trench parallel direction. The observed resistivity decrease and anisotropy can be explained by a porosity increase along vertical fault planes, which we interpret as evidence that the bending faults provide fluid pathways allowing for the deeper serpentinization of the uppermost mantle. We infer that the width of the faulting region and the density of fractures are primary controls on the extent of upper mantle serpentinization prior to subduction. Hence, the heavily faulted outer rise offshore Nicaragua is the culprit of the anomalously wet slab. By comparison, other sections of the Middle America Trench contain fewer bending faults and thus lower degrees of serpentinized upper mantle, perhaps resulting in a direct impact on arc volcanism.