1. Introduction

Water that cycles through subduction zones regulates fundamental tectonic processes, including the stress state of the megathrust fault at the plate interface, but the volume of pore and mineral-bound water that is subducted with the downgoing oceanic plate is poorly constrained. Here, we use seafloor electromagnetic data to create a comprehensive electrical conductivity image that illuminates a complex system of water-rich faults at the Middle America Trench offshore of Nicaragua.

2. Why EM?

Electrical conductivity is a physical parameter that is primarily sensitive to the presence of fluids and partial melts. With models of conductivity, we can detect fluid migration pathways and estimate porosity of the subsurface to constrain the cycling of water between the surface and the deep Earth.

3. Marine electromagnetic methodology

- EM receivers are deployed onto the seafloor and record horizontal electric and magnetic fields
- Natural oscillations of passive EM fields provide low frequency energy to probe deep crustal and upper mantle structure (magnetotelluric method)
- High frequency energy attenuated by seawater is injected through a towed EM transmitter with a dipole source (controlled-source EM method)

Marine EM survey operations. Broadband ocean bottom EM receivers (OBER) are deployed from a ship and record electric and magnetic fields on the seafloor. An EM transmitter is towed behind the ship to collect controlled-source data. A typical survey is performed in a single month-long voyage.

4. Marine EM Survey of the MAT

- EPR-sourced Cocos plate (4 Ma) subducts offshore Nicaragua
- Spreading fabric parallel to trench; trench flexure reactivates abyssal faults
- Total of 30 Rx deployed along 280 km transect spaced 10 and 4 km apart

Map of EM survey. Black squares show OBER receivers. Solid orange line is the Tx tow path. A total of 24 receivers recorded CSEM data, and all 30 recorded MT data. The red line presents here consider receivers deployed on the incoming plate and trench.

5. 2D Inversion Results

Close up of outer rise electrical structure. a, showing significant advective conductive channels below fault scarp. b, crustal bulk porosity estimates from Archie’s law (rev).

6. Porosity

- Fluid resistivity is strongly temperature dependent
- Cementation exponent is related to pore geometry

While, dikes, rocks in CSEM model Depth (km) 100-60 km 60-40 km 40-20 km 20-10 km 10-5 km 5-2.5 km 2.5-1 km 1-0.5 km 0.5-0 km 0.001 0.01 0.1 1 10 100 1000 10000 100000 Resistivity (\Omega m) Porosity (%)

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7. Synthetic tests

- Model responses w/ and w/o faults are inverted; demonstrate sensitivity of CSEM data
- Porosity inferred from forward and inverse models demonstrate resolution of CSEM data
- Data sensitivity good to 6-8 km depths; Resolution begins to fade around 8.5 km below seafloor
- Mean porosity is conserved

Conclusions

- Outer rise faults provide porous/permeable pathways that hydrate the incoming oceanic crust
- Lower crust porosity is doubled. Significantly more pore water is subducted than previous estimates
- Mantle stays resistive, suggests less than 20% serpentinitization. Favors a closed, low-fluid-flux system