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Triple seismic source, double research ship, single ambitious goal: integrated imaging of young oceanic crust in the Panama Basin

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Understanding geothermal heat and mass fluxes through the seafloor is fundamental to the study of the Earth's energy budget. Using geophysical, geological and physical oceanography data we are exploring the interaction between the young oceanic crust and the ocean in the Panama Basin. We acquired a unique geophysical dataset that will allow us to build a comprehensive model of young oceanic crust from the Costa Rica Ridge axis to ODP borehole 504B. Data were collected over two 35 x 35 km^2 3D grid areas, one each at the ridge axis and the borehole, and along three 330 km long 2D profiles orientated in the spreading direction, connecting the two grids. In addition to the 4.5 km long multichannel streamer and 75 ocean-bottom seismographs (OBS), we also deployed 12 magnetotelluric (MT) stations and collected underway swath bathymetry, gravity and magnetic data.

For the long 2D profiles we used two research vessels operating synchronously. The RRS James Cook towed a high frequency GI-gun array (120 Hz) to image the sediments, and a medium frequency Bolt-gun array (50 Hz) for shallow-to-mid-crustal imaging. The R/V Sonne followed the Cook, 9 km astern and towed a third seismic source; a low frequency, large volume G-gun array (30 Hz) for whole crustal and upper mantle imaging at large offsets. Two bespoke vertical hydrophone arrays recorded real far field signatures that have enabled us to develop inverse source filters and match filters.

Here we present the seismic reflection image, forward and inverse velocity-depth models and a density model along the primary 330 km north-south profile, from ridge axis to 6 Ma crust. By incorporating wide-angle streamer data from our two-ship, synthetic aperture acquisition together with traditional wide-angle OBS data we are able to constrain the structure of the upper oceanic crust. The results show a long-wavelength trend of increasing seismic velocity and density with age, and a correlation between velocity structure and basement roughness. Increased basement roughness leads to a non-uniform distribution of sediments, which we hypothesise influences the pattern of hydrothermal circulation and ultimately the secondary alteration of the upper crust.

A combination of the complimentary wide-angle and normal incidence datasets and their individual models act as a starting point for joint inversion of seismic, gravity and MT data. The joint inversion produces a fully integrated model, enabling us to better understand how the oceanic crust evolves as a result of hydrothermal fluid circulation and cooling, as it ages from zero-age at the ridge-axis to 6 Ma at borehole 504B. Ultimately, this model can be used to undertake full waveform inversion to produce a high-resolution velocity model of the oceanic crust in the Panama Basin.

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