



Intermediate oceanic crust is created by alternating periods of magma-rich and magma-poor spreading: evidence from a 7 Myr transect from the Costa Rica Ridge to ODP borehole 504B

Dean Wilson, Richard Hobbs, Christine Peirce, Emma Gregory, and Adam Robinson
Durham University, Earth Sciences, United Kingdom

We show that the accretion of oceanic crust at intermediate spreading rate ridges is highly variable. It alternates between styles typical of both fast and slow spreading rates, depending on the balance between magmatic supply rate and tectonic stretching. The resulting range of crustal structure, in addition to the thickness of sediment cover, strongly affects the pattern of permeability at the interface between the crust and the overlying ocean. Hence, the degree to which one of these accretion processes dominates over the other will influence the extent of hydrothermal fluid flow, leading to variability in crustal alteration, which drives changes in the primary porosity and permeability. Here, we present results from a study of the oceanic crust generated at the Costa Rica Rift, which is presently spreading in a N-S direction at a half-spreading rate of 30-36 mm yr⁻¹.

A tomographic approach is applied to wide-angle seismic refraction data collected on 72 OBSs during a multidisciplinary geophysical experiment conducted aboard RRS James Cook (JC114) and FS Sonne (SO₂38) in the Panama Basin of the equatorial East Pacific. Two grids of 25 OBSs were deployed for 3D acquisition, centred on the Costa Rica Rift and on borehole 504B, located 230 km to the south. Long-offset (4.5-8.5 km) multichannel streamer data acquired along the 330 km 2D flow-line profile connecting the grids using a two-ship synthetic aperture approach supplements the OBS data to improve imaging of the shallow structures.

The analyses of layer 2 along the flow-line profile reveal that the magma supply and resulting style of accretion at the ridge axis has alternated on a timescale of ~2-3 Myr. The smooth basement accreted 1.2-2.8 Myr and >5.7 Myr ago, including around 504B, is typical of magmatically accreted crust. In contrast, the crust accreted <1.2 Myr and 2.8-5.7 Myr ago is more heavily faulted. These variations in basement roughness also correspond to changes in the crustal P-wave velocity, being up to 0.5 km s⁻¹ slower than the 1D velocity structure at the ridge axis in more tectonically accreted regions, and up to 1.0 km s⁻¹ faster in more magmatically accreted regions. Overall, therefore, the observed P-wave velocity of layer 2 is not consistent with a gradual increase with time since accretion, and thus may provide an additional indicator for the mode of crustal formation.

We propose that the correlation between basement roughness and P-wave velocity can be applied generically to determine the accretionary mode of oceanic crust formed in all settings, across the full range of spreading rates between the magma-rich (e.g. East Pacific Rise) and magma-poor (e.g. South-West Indian Ridge) end-members. Possible processes that may govern the style of accretion, and thus warrant further investigation, include the supply rate and asymmetry of the magma source and the dip and direction of detachment faults at the ridge.

This research is part of a major, interdisciplinary NERC-funded collaboration entitled: Oceanographic and Seismic Characterisation of heat dissipation and alteration by hydrothermal fluids at an Axial Ridge (OSCAR) (NERC grant number: NE/I027010/1).