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Mid-Atlantic Ridge at 13°N: a 3D tomographic view of complex crustal structure and time-varying tectonic and magmatic spreading processes

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We present a 3D velocity model for the 13°10'N-13°40'N region of the Mid-Atlantic Ridge (MAR), a region well known for the presence of a number of active/recently-active oceanic core complexes (OCCs) at the ridge axis. This study focuses on the area surrounding two such massifs on the west ridge flank, at 13°20'N and 13°30'N, and aims to test conflicting hypotheses for the spatial and temporal extent of oceanic detachment faults. Previous studies have suggested either that the OCCs represent individual detachments initiated and terminated by local magma supply variations or, alternatively, that detachments are long-lived, spatially extensive structures that continue in the sub-surface only to emerge at the OCCs. Are the 13°20'N and 13°30'N discrete features, or one huge detachment fault that is linked at depth?

We find the region to have a highly variable and complex crustal structure at and adjacent to the ridge axis. A relative low velocity ($Vp < 5$ km/s) layer is present between the 13°20'N and 13°30'N OCCs extending to ~2 km depth below the seafloor. This supports the hypothesis that, in this region, the OCCs are individual features without a lateral connection at depth. The observed velocity-depth profile between the OCCs is consistent with that expected for magmatically accreted crust, and extends eastward into the neo-volcanic zone and follows the eastward bathymetric expression of the OCCs adjacent to the ridge-axis and westwards between relict OCCs preserved off-axis. Tomographic results also show that the 13°30'N OCC lies at the inside corner of an evolving left-stepping ridge offset that marks the northern limit of the MAR segment, in which the two OCCs sit. The 13°30'N OCC has a geometry and crustal structure distinct to the OCC at 13°20'N, which sits in the middle of the segment between two neo-volcanic centres. To the west of the ridge-axis, the OCC-dominated crust is significantly thinner than its eastern lineated seafloor counterpart, which suggests a strong asymmetry in spreading within the segment. Considered jointly with analysis of coincident gravity, magnetic, swath bathymetry and micro-seismicity datasets, our results suggest that, for at least the last ~3 Myr, western flank crustal accretion occurred through multiple periods of detachment faulting interspersed with phases of magmatism, and reveal a complex pattern of regional crustal structure and time varying tectonic and magmatic spreading processes prevail.