Anisotropy of the upper mantle beneath Mid-Atlantic Ridge: Results from the PiLAB experiment

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The mantle beneath oceanic spreading centres is anisotropic, holding the signature of the formation of new oceanic lithosphere and its coupling with the underlying convecting asthenosphere. Numerical studies have suggested that there should be significant differences between the anisotropy at the lithosphere-asthenospere boundary at slow versus fast spreading centres, but there is little observational evidence to calibrate these simulations, especially at slow spreading centres. Near the ridge axis, the anisotropic effects of aligned melt versus the lattice-preferred-orientation of minerals is not well understood. Finally, the mantle flow near ridge-transform interactions is also poorly understood.

Here we present observations of SKS splitting and surface-wave anisotropy in a region of the Mid-Atlantic Ridge (MAR) near the equator and offset by the Romanche and Chain Fracture Zones. An array of 37 ocean-bottom seismometers were deployed for a year in depths of up to nearly 6000m, with the aim of studying the nature of the lithosphere-asthenosphere boundary as it forms (the PiLAB - Passive Imaging of the lithosphere-asthenosphere boundary - experiment). Stations were deployed on crust that varies from newly formed to 80 My old.

We analyse SKS- splitting in 40 teleseismic events of magnitude greater than 5.8 and with epicentral distances between 88 and 130 degrees. The ocean-bottom is a noisy environment and a range of filters are used to isolate the SKS, SKKS, and related signals. Furthermore, splitting error envelopes are stacked to improve confidence in the splitting parameters. Many of the splitting measurements show an orientation parallel to the direction of absolute plate motion and not the direction of plate spreading, but variability in the orientation of the anisotropy increases towards the ridge axis. The magnitude of the anisotropy largest nearest the ridge axis (~2 seconds) and is relatively small (0.5-1.0 secs) away from the ridge.

We have also analysed Rayleigh wave dispersion at 18–143s periods using teleseismic events and Rayleigh wave and Love wave dispersion from 5–22s periods derived from ambient noise. We observe both fundamental-mode and first higher-mode Rayleigh waves at 5–18s periods, with average phase velocities that range from ~1.5 km/s at 5s period to 4.31 km/s at 143s, and fundamental-mode Love waves, with average phase velocities ranging from 4.00 km/s at 5s to 4.51 at 22s. Phase velocities are inverted for radially anisotropic shear velocity structure revealing a ~60 km thick fast lid for the region with velocities of 4.62 km/s, and small (2%) but significant amounts of radial anisotropy are required in the upper 200 km. Azimuthal anisotropy is similarly small –~2% at 18 seconds period (~25 km depth) and 1% at 91s period (in the upper 200 km).

Off-axis, the anisotropy is best interpreted in terms of deformation of peridotite due to fossil LPO and mantle flow, but is much smaller than previous numerical predictions and smaller than that observed near the East Pacific Rise (EPR). Furthermore, the anisotropy is oriented roughly parallel to the direction of plate motion and not the plate spreading direction. The magnitude of the anisotropy is largest near the ridge axis, and is best explained by ridge-parallel sub-vertical melt orientation against a steep marginal

LAB. Cumulatively, these differences between the EPR and MAR suggest very different styles of rifting between passive versus more active styles of oceanic spreading.

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