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A dynamic plate base at the slow spreading Mid-Atlantic Ridge from the PI-LAB Experiment

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The lithosphere-asthenosphere boundary is rheological transition from the rigid lithosphere that transfers coherently to the weaker underlying asthenosphere. A better understanding of this transition, the lithosphere-asthenosphere boundary (LAB), is essential as it may have implications for the driving forces of plate tectonics and mantle dynamics. Ocean lithosphere is the ideal place to study this plate transition. The Passive Imaging of the Lithosphere-Asthenosphere Boundary (PI-LAB) was designed to better characterize and understand the lithosphere-asthenosphere boundary of the oceanic plate at a range of resolutions. We deployed 39 broadband ocean bottom seismometers (OBS) and 39 ocean bottom magnetotellurics (OBMT) on 0 – 80 My seafloor at the equatorial mid-Atlantic Ridge near the Chain fracture zone from March 2016 – March 2017.

Here we present our first imaging results of the crust, mantle, and transition zone from, S-to-P (Sp) receiver functions, P-to-S (Ps) receiver functions, surface waves, body waves, SKS splitting, and magnetotellurics. S-to-P receiver functions image a velocity increase with depth at 4 – 8 km depth across the region associated with the oceanic Moho. Surface waves, body waves and magnetotellurics (MT) image a lithospheric lid characterised by fast seismic velocity and low conductivity. It is ~30 km thick beneath the ridge, increasing in thickness and seismic velocity with increasing age. The thickening occurs simply and gradually in at least one ridge segment, although the age variability is more complex and not necessarily monotonic in other locations. In the west its base is clearly delineated by a sharp velocity decrease in S-to-P receiver functions and a high conductivity channel in the MT model that increases in depth with age. The sharpness requires melt beneath the plate, likely transported to the ridge along a permeability boundary. This is consistent with greater degrees of upwelling in the west, as suggested by the thinned transition zone imaged by Ps. In the east, the base of the lid is weaker, patchier, and/or more complex in receiver functions and/or delineated by punctuated conductivity anomalies at 50 – 100 km depth. Several punctuated low velocity and high conductivity zones are imaged at 50 – 150 km depth, not necessarily centered beneath the ridge axis, and offset by 75 km and occurring up to 800 km from the ridge axis. These are likely associated with discrete upwellings. Anisotropy is weak and in the direction of absolute plate motion, likely impacted by broad scale motions and upwelling. The upwellings are likely associated with small scale convection, a potential influence on flattening of older aged seafloor. The variability in the character of the melt signatures from long and thin channels to broader and more punctuated zones suggests that the LAB is dynamic with depth and character that depend on mantle dynamics and melt generation and migration.