Three-dimensional seismic structure of the Rainbow area, Mid-Atlantic Ridge, at 36°14' N: Fault development, crust-mantle transition, core complex formation, and mantle alteration at slow spreading ridges

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Oceanic lithosphere formed along slow-spreading mid-ocean ridges is structurally and compositionally heterogeneous due to spatial and temporal variations in tectonic extension and magmatic accretion. While mid-ocean ridges with greater magma supply host a greater abundance of hydrothermal systems, the relative roles of magmatic input, heat advection and faulting in controlling ridge structures are still poorly understood. The MARINER (Mid-Atlantic Ridge INtegrated Experiments at Rainbow) seismic and geophysical mapping experiment was designed to examine the relationship between tectonic rifting, heat/melt supply, and oceanic core complex formation at a non-transform offset of the Mid-Atlantic Ridge, 36°14' N, the site of the Rainbow core complex and its associated hydrothermal vent field. Using the seismic refraction data from this experiment, we constructed three-dimensional tomographic images of the crust and upper mantle around the Rainbow area. The seismic velocity images reveal clear stripe-like structures with alternating high- and low-velocity patterns aligned in the ridge-parallel direction which correlate with the locations of large normal faults and the variation in lower crustal thickness. This structure suggests that the entire crust has been rotated by semi-vertical faulting during tectonic stretching. Throughout the experiment area, there is little evidence in the wide-angle data for persistent reflected arrivals from the Moho discontinuity (PmP). This implies that the crust-mantle transition occurs gradationally in the vertical direction rather than forming a sharp seismic boundary. At the Rainbow massif, where mantle rocks have been recovered by direct sampling, seismic velocities near the seafloor (the upper 2 km of the lithosphere) are lower than expected for mantle rocks and have a sharp contact with higher-velocities below. The velocity boundaries are consistent with reflectors within the Rainbow massif revealed by MCS reflection data [Canales et al., Geology, in press] and probably represent alteration and cracking fronts of the mantle lithosphere. These results suggest that fluid circulation channeled by dense faults alter the whole massif efficiently and enhances the active hydrothermal system.

Keywords: Mid-Atlantic Ridge, Seismic refraction, Normal faults, Hydrothermal vents, Mantle alteration

