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Seismic imaging and physical properties of the Endeavour segment: Evidence that skew between mantle and crustal magmatic systems governs spreading center processes

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We present tomographic images of the intermediate-spreading Endeavour Segment of the Juan de Fuca Ridge that constrain the segment-scale structure of an axial magmatic system in its entirety, from the topmost mantle to the upper crust. We use seismic energy from ∼5500 air gun shots refracted through the crust (Pg), reflected off the Moho (PmP), and refracted below the Moho (Pn)—as recorded by 64 OBSs from the active-source, multi-scale Endeavour tomography experiment—to image the isotropic and anisotropic P-wave velocity structure of the topmost oceanic mantle and crust, as well as crustal thickness variations beneath the segment. The isotropic velocity structure is characterized by a semi-continuous, narrow (5-km-wide) crustal low-velocity volume (LVV) that tracks the sinuous ridge axis. Across the Moho, the LVV abruptly broadens to approximately 20 km in width and displays a N-S linear trend that connects the two overlapping spreading centers bounding the segment. From the seismic results, we estimate the thermal structure and melt distribution beneath the Endeavour segment. The thermal structure indicates that the observed skew, or lateral offset, between the crustal and mantle magmatic systems is a consequence of differences in mechanisms of heat transfer at crustal and mantle depths, with the crust dominated by advective heat removal and the mantle by conduction. Estimates of melt fraction indicate significant along-axis variations in melt volumes that coincide with the observed skew between the mantle and crustal magmatic systems, with sites of enhanced crustal melt volumes and vigorous hydrothermal activity corresponding to regions where the mantle and crustal magmatic systems are vertically aligned. These results contradict models of ridge segmentation that predict enhanced and reduced melt supply beneath the segment center and ends, respectively. Our results instead support a model in which segment-scale skew between the crustal and mantle magmatic systems governs magmatic and hydrothermal processes at mid-ocean ridges.