On the lateral and vertical scale of ridge-flank hydrothermal circulation

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Marine geologists have recently become aware of the importance of ridge-flank hydrothermal circulation to crustal evolution. While less spectacular than their ridge-crest counterparts, off-axis systems contribute to greater thermal and (for some solutes) geochemical fluxes. Observations on the eastern flank of the Juan de Fuca Ridge, and resulting models of heat and fluid flow, provide constraints on the geometry of off-axis hydrothermal circulation in this setting.

Drilling and downhole measurements during Ocean Drilling Leg 168 provide new and compelling indications that ridge-flank systems may be dominated by very high aspect-ratio convection, and by convection having a geometry controlled by the heterogeneous permeability distribution of the upper oceanic crust. Heat flow measurements in several deep boreholes, one of which is at least 20 kilometers from the nearest known basement outcrop, suggest that heat is efficiently removed from the upper crust by lateral fluid flow beneath thick sediment cover. A second set of observations, including thermal and geochemical data from a basement ridge buried by only about 40 m of sediment, suggests that there may be distinct shallower and deeper off-axis hydrothermal circulation systems that exchange heat and mass with the overlying ocean in this area. The deeper system seems to contain older, more reacted seawater, and appears to require fluid flow pathways dominated by the intrinsic distribution of permeability within the basaltic upper oceanic crust. Simple, cellular convection within a homogeneous layer is unlikely to explain the observed heat flow and geochemical patterns. These new observations, in combination with numerical simulations of coupled heat and fluid flow, suggest that hydrogeologic models of the upper crust must incorporate extremely heterogeneous permeability distributions. Additional constraints will soon be provided by long-term observations of pressures and temperatures within two distinct components of these ridge-flank hydrothermal systems.