Anatomy of a deep sub-surface ridge flank aquifer: The “Red Brick” Horizon in ODP Hole 1256D

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Abstract

Long-lived conductive heat flow deficits, near isothermal basement temperatures, and sedimentary pore water profiles from mid-ocean ridge flanks provide compelling arguments for the substantial lateral movement of seawater-derived fluids within the upper oceanic crust. However, there are few descriptions of zones within the oceanic basement for which there is strong evidence for sustained low temperature hydrothermal fluid flow and alteration. This paper describes a distinctive horizon of intense low temperature alteration encountered in ODP Hole 1256D. Hole 1256D, located on 15 million-year-old East Pacific Rise crust formed at a superfast spreading rate (>200 mm/yr) provides a reference section for fast spreading ocean crust and is the only well to sample a complete section of lavas, sheeted dikes, and into the upper most gabbros. The volcanic sequences at Hole 1256D are >800 m thick. The Red Brick horizon occurs at ~400 m sub-basement (msb) in massive and sheet flows that overly a ~30 m-thick zone of massive flows. These flows probably crystallized at the base of the ridge axial slope within a few 1000 meters of the ridge axis (Tominaga and Umino, 2010). The Red Brick horizon comprises a 50 cm-thick zone of massive, sparsely olivinephyric microcrystalline basalt that is very strongly (80 to 90%) hydrothermally altered. Olivine, clinopyroxene, and plagioclase are replaced by beidellite, celadonite, K feldspar and iron oxyhydroxide, imparting blue-green and brick red colors to the rock. These secondary minerals plus quartz and carbonate also fill vugs and pore space. Compared to surrounding basalts that exhibit only background levels of low temperature alteration, the rocks of the Red Brick zone are strongly oxidized (Fe3 /FeTot >0.7), hydrated (>4 wt.%), and have highly elevated concentrations of alkali metals (K, Rb, Cs) and Mg. There are strong reductions in Si, Ca, Mn, Zn and Cu. Bulk rock oxygen isotope (δ18O ~8.5 to 9 per mil) indicate hydrothermal alteration at about 70 °C for a seawater-like fluid. 87Sr/86Sr is significantly elevated (0.7033 to 0.7045) compared to primary igneous values but still rock-dominated. The near complete mineral recrystallization should mean that Sr isotope ratios record the signature of the parent hydrothermal fluid. Intriguingly this range is much less radiogenic than our estimate for Site 1256 paleo-black smoker fluids (0.7051 to 0.7053) indicating that the altering fluids are not seawater-diluted black smoker fluids. The core pieces of the Red Brick zone can be confidently identified in the wireline geophysical measurements by integrating formation micro-scanner and gamma ray logs. The occurrence of intense alteration at the Red Brick horizon appears to result from the occurrence of an impermeable unit of massive basalt with few fractures directly below, that may have acted as a long term channel for the lateral flow of ridge flank hydrothermal fluids.

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