Dissecting an active hydrothermal deposit

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Strontium- and oxygen-isotopic measurements of samples recovered from the Trans-Atlantic Geotraverse (TAG) Hydrothermal Mound during Leg 158 of the Ocean Drilling Program provide important constraints on the nature of fluid-rock interactions during basalt alteration and mineralization within an active hydrothermal deposit.

The development of a silicified, sulfide-mineralized stockwork within the basaltic basement follows a simple paragenetic sequence of chloritization followed by mineralization and growth of a quartz + pyrite + paragonite stockwork cut by quartz-pyrite veins. Initial alteration involved the development of chloritic alteration halos around basalt clasts by reaction with a Mg-bearing mixture of upwelling, high-temperature (>300°C), black smoker-type fluid with a minor (<10%) proportion of seawater. Continued high-temperature (>300°C) interaction between the wallrock and these Mg-bearing fluids results in the complete recrystallization of the wallrock to chlorite + quartz + pyrite. A quartz + pyrite + paragonite assemblage replaces the chloritized basalts, and developed by reaction at 250°C-360°C with end-member hydrothermal fluids having 87Sr/86Sr ≈ 0.7038, similar to present-day vent fluids. The uniformity of the 87Sr/86Sr ratios of hydrothermal assemblages throughout the mound and stockwork requires that the 87Sr/86Sr ratio of end-member hydrothermal fluids has remained relatively constant for a time period longer than that required to change the interior thermal structure and plumbing network of the mound and underlying stockwork.

Precipitation of anhydrite in breccias and as late-stage veins throughout most of the mound and stockwork, down to at least 125 mbsf, records extensive entrainment of seawater into the hydrothermal deposit. 87Sr/86Sr ratios indicate that most of the anhydrite formed from ≈2:1 mixture of seawater and black smoker fluids (65% ± 15% seawater). Oxygen-isotopic compositions imply that anhydrite precipitated at temperatures between 147°C and 270°C and require that seawater was conductively heated to between 100°C and 180°C before mixing and precipitation occurred.

δ18O Seawater
Sulfate ≈ 9.34‰

δ18O (‰)

87Sr/86Sr vs. δ18O for anhydrite from the TAG hydrothermal mound. Trajectories are calculated for the Sr- and oxygen-isotopic composition of anhydrite precipitated from mixtures of hydrothermal fluid with seawater that has been conductively heated to the labeled temperatures before mixing.