Tracing fluid evolution during hydrothermal circulation

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Hole 504B located in 5.9-Ma-old crust on the southern flanks of the Costa Rica Rift is the deepest penetration (>1800 m) into oceanic basement and the only drillhole to sample the entire section of extrusive volcanics, though a lithologic transition zone and down to the base of the sheeted dike complex. Strontium isotope analyses ($^{87}Sr/^{86}Sr$) of whole rock samples and mineral separates constrain the changing composition of seawater-derived basement fluids due to reaction with the ocean crust. In particular, because of the high concentration of sulfate in seawater and the decreasing solubility of anhydrite ($CaSO_4$) with increasing temperature, $^{87}Sr/^{86}Sr$ measurements of anhydrite recovered from Hole 504B provide a unique record of the chemical evolution of seawater during recharge into oceanic crust and in the high-temperature subsurface reaction zone. Anhydrite is present as vein and cavity fillings in the lower volcanic section and the upper dikes, but replaces plagioclase and fills pore space in the lower dikes.

$^{87}Sr/^{86}Sr$ ratios of anhydrites are highly variable (0.7029-0.7084), spanning most of the range between MORB and seawater, indicating that significant basaltic strontium (and calcium) was present in the seawater-derived recharge fluids. There is a general trend of decreasing $^{87}Sr/^{86}Sr$ of anhydrite with depth in the volcanics with ratios indicating initially minor then increasing proportions of basaltic strontium towards the base of the pillow lavas. From below the transition zone between lavas and dikes, anhydrite $^{87}Sr/^{86}Sr$ ratios decrease rapidly with depth to values identical to host basalt (0.7029) for anhydrite pseudomorphs after plagioclase in the lowermost dikes. Anhydrite from the sulfide mineralized stockwork zone at ≈ 910 mbsf has a $^{87}Sr/^{86}Sr \approx 0.7037$ indicating sulfate precipitation due to mixing between seawater-like recharge fluids ($^{87}Sr/^{86}Sr \approx 0.7075$-0.7084) and upwelling black smoker-type hydrothermal fluids ($^{87}Sr/^{86}Sr \approx 0.7034$-0.7038) as recorded by epidote.