

Petrographic and geochemical controls on $\delta^{34}\text{S}$ of pyrite and the growth of the TAG hydrothermal mound, 26°N Mid Atlantic Ridge

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The Trans-Atlantic Geotraverse (TAG) hydrothermal field is one of the best-studied active seafloor hydrothermal systems in the world. The $\delta^{34}\text{S}$ signature of sulfide minerals at TAG is 3‰ heavier than at any other known sediment-starved mid-ocean ridge sulfide deposits. Thermochemical sulfate reduction coupled with oxidation of Fe^{2+} could yield heavy $\delta^{34}\text{S}$ in sulfides, but is expected only in limited portions of the mound and thus cannot account for the observed isotopic enrichment. Rather, we suggest that the elevated $\delta^{34}\text{S}$ results from incorporation of heavy sulfur originated from dissolving anhydrite. Here, we present textural evidence of this process, found in core samples recovered from the TAG hydrothermal field during ODP expedition 158. The samples were obtained at the TAG-1 area, at the transition between shallower pyrite-silica (\pm anhydrite) breccias and deeper pyrite-silica breccias. Our results suggest that at stockwork depth anhydrite is removed during interaction with hydrothermal fluids, leaving behind pores lined by quartz crystals. The pores are later filled by pyrite that partially incorporates isotopically heavy sulfur sourced from anhydrite dissolution. This mechanism involves gradual removal of anhydrite from the rock, leaving behind pyrite and quartz. Our petrographic observations are supported by geochemical modelling done at *in situ* temperatures, evaluated based on a study of fluid inclusions (FI) hosted in quartz. FI analysis reveals trapping temperatures that range between 348 ° to 367 °C.

Heavy $\delta^{34}\text{S}$ signatures in the disseminated pyrites of the stockwork zone, light signatures in vein-related mineralization, and the progressive enrichment of $\delta^{34}\text{S}$ with depth at TAG can all be explained based on the duration of the interaction between dissolving anhydrite and replacing pyrite. This research provides an explanation for the anomalous distribution of sulfur isotopes in TAG pyrites and sheds light on the mineral replacement processes occurring within the TAG mound over time. The textural evidence that represents these processes is characterized in details and aids the interpretation of the evolution of both modern and fossil hydrothermal deposits.