The control of anhydrite sulfidation on the stockwork mineralization in the TAG mound

Simone Pujatti[1], Yury Klyukin[2], Matthew Steele-MacInnis[2], Benjamin Tutolo[1]
[1] Department of Geoscience, University of Calgary, Reactive Transport Group
[2] Department of Earth and Atmospheric Sciences, University of Alberta

Summary

The Trans-Atlantic Geotraverse (TAG) hydrothermal field is one of the best-studied seafloor hydrothermal systems where a massive sulfide mound is actively forming. However, some of the geochemical and mineralogic processes that control the growth of the mound are still elusive. Specifically, the $\delta^{34}S$ ratio of sulfide minerals at TAG is ~3‰ heavier than at other known sediment-starved mid-ocean ridge sulfide deposits. This anomalous signature has been ascribed to sulfate reduction in a shallow hydrothermal circulation system. However, we lack an understanding of the residence time of the sulfate-bearing fluids and cannot justify this hypothesis. Alternatively, the $\delta^{34}S$ signature of sulfides at TAG can be explained by incorporation of isotopically heavy sulfur sourced from anhydrite dissolved within confined spaces, or by direct replacement of anhydrite by pyrite. We found textural evidence of these features 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-anhydrite breccias and deeper pyrite-silica breccias. The shallower breccias show porous domains associated with anhydrite, quartz and pyrite. Similar textures were also observed in the deeper samples, without anhydrite.

Our results suggest that - at stockwork depth - anhydrite is removed by the interaction with anhydrite-undersaturated hydrothermal fluids, leaving behind pores lined by quartz crystals. The pores are filled over time by pyrite that incorporates part of the sulfur sourced from anhydrite, inheriting its heavy isotopic signature. This mechanism gradually removes anhydrite from the rock, leaving behind pyrite and quartz. This is confirmed by the textures observed in samples recovered from the stockwork, where disseminated grain of pyrite are surrounded by indenting quartz crystals grown in open-space conditions. The inferences based on petrographic evidence are supported by geochemical modelling done at *in situ* temperatures based on fluid inclusion analysis in quartz, that show trapping temperatures ranging from 349° to 369°C.

Previously published $\delta^{34}S$ data from TAG are in agreement with our results. Both the heaviest signatures found in disseminated pyrite in the stockwork zone and the lightest ones in vein-related mineralization can be explained based on the duration of the interaction between replaced anhydrite and replacing pyrite.

This research sheds light on the mineral replacement processes that govern the evolution of the interior of the sulfide mound over time and aids the assessment of the distribution of target minerals for base metal exploitation both in modern and fossil hydrothermal deposits.