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Replacive sulfide formation in anhydrite chimneys from the Pacmanus hydrothermal field, Papua New Guinea

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Hydrothermal flow within the oceanic crust is an important process for the exchange of energy and mass between the lithosphere, hydrosphere and biosphere. Infiltrated seawater heats up and interacts with wall rock, causing mineral replacement reactions. These play a large role in the formation of ore deposits; at the discharge zone, a hot, acidic and metal-rich potential ore fluid exits the crust. It mixes with seawater and forms chimneys, built up of sulfate minerals such as anhydrite (CaSO4), which are subsequently replaced by sulfide minerals. Sulfide formation is related to fluid pathways, defined by cracks and pores in the sulfate chimney. Over time, these systems might develop into massive sulfide deposits. The big question is then: how is sulfate-sulfide replacement related to the evolution of rock porosity?

To address this question, sulfide-bearing anhydrite chimneys from the Pacmanus hydrothermal field (Manus Basin, Papua New Guinea) were studied using X-ray tomography, EMPA, FIB-SEM and –TEM. The apparently massive anhydrite turns out highly porous on the micro scale, with sulfide minerals in anhydrite cleavage planes and along grain boundaries. The size of the sulfide grains relates to the pores they grew into, suggesting a tight coupling between dissolution (porosity generation) and growth of replacive minerals. Some of the sulfide grains are hollow and apparently used the dissolving anhydrite as a substrate to start growth in a pore. Another mode of sulfide development is aggregates of euhedral pyrite cores surrounded by colloform chalcopyrite. This occurrence implies that fluid pathways have remained open for some time to allow several stages of precipitation during fluid evolution.

To start the replacement and to keep it going, porosity generation is crucial. Our samples show that dissolution of anhydrite occurred along pathways where fluid could enter, such as cleavage planes and grain boundaries. It appears that fluids ascending within the inner chimney conduit started anhydrite corrosion, perhaps because they were undergoing cooling and became anhydrite undersaturated. From these fluids, sulfides precipitated in the newly formed pores.

Compared to more evolved hydrothermal systems like TAG, the Pacmanus vent field shows only the beginning of sulfide formation. However, this early stage is the key to understand how replacement is going on, and how sulfidization can lead to a massive sulfide deposit.