Goldschmidt 2022 Abstract
https://doi.org/10.46427/gold2022.12562

Biohalogenation and gut mineralization of invertebrates specialized in deep-sea hydrothermal environments

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A central objective in geology is to understand how biological metabolisms contribute to the cycling of redox sensitive elements in extreme environments within the Earth's oceans and crust, and potentially how life may persist on water-rich exoplanets. In deep-sea hydrothermal vent systems, organisms cope with the presence of toxic chemical compounds (e.g., H_2S) and microbial communities facilitate survival in these extreme geochemical conditions by oxidizing H_2S for energy. However, it is essential to know how these animals interact with their microbiomes to immobilize, detoxify, and release elements back into the water, which enlightens how life can persist in extreme conditions and how biomass affects the availability of different chemical compounds. To investigate how large invertebrates cope with these extreme conditions and how this sequestration may affect biochemical cycling, we sampled several invertebrate species from the hydrothermal vents at 9°50'N East Pacific Rise. We used first used high resolution μCT-scanning to image the gut of several species of polychaete worms, crabs, and bivalves. Using diffusible iodine contrast-enhanced μCT-scanning, we could then visualize where minerals (if any) are distributed throughout the organism. Next, we used X-ray fluorescence microscopy to image the whole organism of each animal to characterize the elemental distribution throughout the tissue and also implemented pyrolysis gas-chromatography–mass spectrometry to further characterize the compounds. We discovered that sulfide mineralization in the guts of these animals is ubiquitous. Whether this is a byproduct of their surrounding geochemical environments or an adaptive strategy to assist in harnessing energy or trapping toxic metals remains to be determined. We also found that, in addition to widespread zinc and iron (which is highly correlated with sulfur), bromine tends to occur in high concentrations in some tissues as brominated phenolic compounds, particularly in specialized structures on polychaete worms, which may serve as a protective hardening and/or defensive agent. Because these animals process these toxic conditions in such unique ways, their role in the global cycling and bioavailability of elements such as copper, iron, zinc, and even halogens remain to be discovered.