

Microbial communities and geochemical energy in an arsenic-rich marine hydrothermal system

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Arsenic (As) is toxic to most biota, but it also can serve as an energy source to certain microorganisms. A number of bacteria are known that catalyze the reduction of arsenate (As^{V}) with various organic and inorganic electron donors, while others can mediate the oxidation of arsenite (As^{III}) with O_2 or NO_3^- as terminal electron acceptors. Far less is known about the role of archaea in As-redox reactions. Here, we present new findings on bacterial and archaeal community structures, determined by gene surveys, together with geochemical energy calculations for the shallow (5-15 m) marine hydrothermal system at Ambitle Island, Papua New Guinea. Vent fluids are As^{III} -rich (up to 1,000 $\mu\text{g/L}$), of low salinity, slightly acidic (pH~6), and discharge temperatures range from 90-100 °C. Adjacent to vent orifices, sediment and corals are heavily coated with As^{V} -rich hydrous ferric oxides and biofilm. With increasing distance from the hydrothermal activity, temperature and As-concentrations decrease, as measured in shallow porewaters, while pH and salinity increase, reaching seawater background values by ~300 m.

Phylogenetic analysis of DNA extracted from biofilm near the vents showed several groups of uncultured crenarchaeota and numerous bacterial groups, dominated by alpha- and gamma-Proteobacteria and Planctomycetes. These communities differed significantly from those found in the sediments, where the archaeal clones were dominated by different clades of uncultured crenarchaeota, and the bacterial clones featured predominantly Chloroflexis, Ralstonia, and Thermotogales, along with gamma-Proteobacteria. Attempts to extract and amplify DNA directly from the vent fluid has yielded only faint archaeal and bacterial signals. Glass slides incubated for ~1 week just above the orifice of a small vent were coated with a biofilm from which DNA was extracted, and bacterial but no archaeal DNA was then amplified.

Energy calculations based on physico-chemical parameters in porewaters along the sediment transects confirm that aerobic and anaerobic (with NO_3^-) arsenite-oxidation reactions, as well as lithotrophic arsenate-reduction reactions, are exergonic. In fact, the energy-yields for all investigated As-redox (and Fe-, S-, and N-redox) reactions are relatively constant as a function of distance away from the hydrothermal vent source.