Microbially mediated sulfur cycling in chemotrophic geothermal systems of Yellowstone National Park

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Sulfur exists in multiple electronic states and chemical forms, and plays a pivotal role in both catabolic and anabolic metabolism in prokaryotes. Elemental sulfur (solid phase) and reduced aqueous species (e.g. sulfide, polysulfides, polythionates, thiosulfate) may serve as both electron donors and acceptors for thermophilic microorganisms in geothermal systems of Yellowstone National Park (YNP). Prokaryotes have evolved to exploit the energetically favorable oxidation of dissolved sulfide (DS) to elemental S, thiosulfate, or sulfate, as well as the reduction of elemental S, polysulfides or thiosulfate to DS. Although numerous microbial electron transfer reactions involving sulfur have been suggested and identified, metagenomic analysis of geothermal microbial communities provides direct information regarding the metabolic potential of indigenous populations to carry out reactions central to sulfur cycling. This study combines metagenomic sequencing, geochemical and bioinformatic analyses, and microbiological techniques to identify processes controlling sulfur oxidation-reduction in geochemically diverse (>70° C, pH ~2-7), sulfur-dominated systems across YNP. Proteins involved in sulfur oxidation-reduction in known extremophiles were used to identify homologs in assembled, metagenome sequence using reciprocal BLAST. Identified amino acid sequences were then phylogenetically and structurally analyzed using bioinformatic techniques to identify specific organisms involved in sulfur cycling and characterize the potential function of these proteins across geochemical gradients. Amplification of genes and mRNA transcripts involved in sulfur oxidation-reduction in representative isolates from these communities and from field sites suggest possible mechanisms of microbial sulfur cycling. The oxidation and or reduction of sulfur is extremely dependent on the availability of dissolved oxygen (DO) as a terminal electron acceptor, while microbial populations in anoxic systems can potentially reduce elemental S or polysulfides back to DS. The convergence of phylogenetic and functional information from metagenome sequence of YNP environments provides a foundation for understanding the central role of sulfur in the metabolism of deeply-rooted thermophilic bacteria and archaea.

Helium isotope in the accreted ice of subglacial lake Vostok (Antarctica)

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Helium is a well-known tracer in earth sciences. It has two isotopes with contrasted proportions in Earth's reservoirs : ^{3}He is essentially primordial in origin whereas ^{4}He is produced by the radioactive decay of U and Th. When normalized to the atmospheric ratio ($R_a = 1.38\times10^{-6}$), typical ^{3}He/^{4}He ratios vary from <0.1 R_a in continental crust, to 8±1 R_a on average in the upper mantle, and up to ~ 40-50 R_a in products of plume-related ocean islands, such as Hawaii and Iceland. Here, we report new helium isotope measurements in the accreted ice of lake Vostok. Unlike most gases, helium can be incorporated into the crystal structure of ice during freezing, making helium isotopes in the accreted ice a valuable source of information. Previous measurements [1] have shown a pronounced difference in both the helium concentration and isotope ratio between glacier ice and the refrozen lake water, with atmospheric characteristics in the glacier ice and a factor of 3 enrichment and a clear radiogenic signature from underlying the continental bedrock in the accreted ice ([^{4}He] = 33.9±2.6 nmol/kg, R = 0.25 ± 0.04 R_a). Our new data, from a depth range 3650.40 - 3656.37 m display even higher helium concentrations ([^{4}He] = 161 ± 11 nmol/kg). The measured isotopic ^{3}He/^{4}He ratios (R = 0.127 ± 0.008 R_a) correspond to a mixture between atmospheric helium from the melted glacier ice and crustal helium added to lake waters with a radiogenic ratio R=0.007 R_a typical of the upper crust. The increase of helium concentrations with depth in the accreted ice implies the existence of sustained helium gradient in the lake, placing new constraints on water circulation and residence time.

[1] Jean-Baptiste *et al.* (2001) *Nature* **411**, 460–462.