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Correlations between Archaeal Diversity and Geochemical Parameters in an Arsenic-Rich Hydrothermal System

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Characterizing microbial communities within their geochemical environment is useful for understanding microbial distribution and microbial adaptations to extreme physical and chemical conditions. The hydrothermal waters at El Tatio geyser field (ETGF) demonstrate extreme geochemical conditions, with discharge water from springs and geysers at local boiling temperature (85^{o}C), arsenic concentrations of 0.5 mM, and inorganic carbon concentrations (DIC) as low as 0.2mM. Yet many of El Tatio's hundred plus hydrothermal features host extensive microbial mat communities. Recent work has shown correlations between the metabolic guilds of microorganisms present and variations in water chemistry.

ETGF is a high-altitude hydrothermal basin with over 100 mapped hydrothermal features, located within a 30km^2 area near the Chile-Bolivia border. The Na-Cl type waters have a circumneutral pH and contain abundant dissolved metals. Shallow runoff aprons extend tens of meters from some geyser features, where silica rapidly precipitates from cooling water. Thick mats, which appear microbial but consist primarily of silica, iron and arsenic mineral deposits, containing $<5\%$ organic carbon, extend the length of the run-off aprons and often are as thick as the water depth (2.5-8cm). In some areas, true microbial mats thrive, often covered with a thin (several mm) covering of silica.

Most probable number (MPN) statistical analysis was used to determine variations in culturable abundance of metabolic guilds between different hydrothermal features with different water chemistries. Metabolic functions such as the ability of the community to fix nitrogen, or use specific carbon substrates in the generation of methane were tested with this method and supporting genetic data was obtained. Many phylogenetic groups of microorganisms can fix nitrogen, but only specific groups of Euryarchaeota known as Methanogens are known to generate methane. MPN enumeration averaged 10^6 methanogenic cells per gram in sites containing dissolved methane. Sites lacking dissolved methane contain fewer than 1 cell per gram or less. An acetylene assay showed evidence for nitrogen fixation in a sample associated with methanogenesis, but microbial transformation of acetylene to ethylene did not occur in the non-methanogenic site tested.

Methanogenic archaea are dominated by microorganisms within the genus Methanospirillum and Methanobrevibacter. These microbes are associated with a number of unclassified archaea in the class Thermoplasmata Halobacteriales, and unclassified Crenarchaeota. In addition, preliminary results include an unclassified clone that is a member of the recently proposed third archaeal phylum Thaumarchaeota. Microbial mat sample from a non-methanogenic site included only Crenarchaeal clones within the Desulfurococcales order of Thermoprotei. Numerous bacteria phylum, including many known to reduce metals, are found at each site and do not appear to correlate to the Archaeal populations present.

The water temperatures and general water chemistry is similar between hydrothermal sites at ETGF, however, some variations occur. Methanogenic populations were found only at sites with relatively high DIC, and low Sb concentrations. No correlation between total arsenic concentrations and methanogenic populations has been observed; however, work is currently underway to determine if the oxidation state of the arsenic may affect methanogens. Previous work suggests that As(III) is toxic to methanogens at much lower concentrations than As(V).