Adventures in South African Gold Mines: A Model to Study Extraterrestrial Life

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South African (SA) gold mines provide an exceptional arena for investigating microbial processes in deep subsurface environments. Water, gas, biofilm, and rock samples were collected from South African deep mines at 0.8 to 3.3 km depths and temperatures up to 60^{o}C. These samples have been analyzed for microbial, geochemical, isotopic, and molecular attributes. Noble gas isotopic estimates of the subsurface residence times for some of the deepest, most saline water samples from the 2.7 Ga Ventersdorp Group volcanics range up to 400 Myr. H_2 and hydrocarbon concentrations are quite high in some samples and cellular concentrations quite low (~1000 cells/ml). Isotopic data indicate that the hydrocarbons formed by abiotic reduction of inorganic carbon. Sulfate concentrations can also be quite high and are isotopically enriched by microbial fractionation. The 16S rDNA sequences of environmental samples and the microbial enrichments are dominated by heterotrophic, sulfate- and metal-reducing bacteria with few autotrophs. When a weeping borehole was plugged to eliminate the influence of mine air, the microbial biomass in the fissure water increased over time. In addition, microbial community shifts over time were detected by changes seen in phospholipids and terminal-restriction fragment length polymorphism patterns. Stable isotope data revealed that sulfate (^{34}S) was converted to sulfide. Thus, the combined biogeochemical observations yielded important information on the microbial and geochemical processes that were occurring in that borehole. The South African mines have proven to be an excellent venue for investigating biosustainable energy and nutrient cycles of microorganisms on Earth as a prerequisite for looking for life on Mars.

Cross-disciplinary field- and lab-based education was a major goal of the seven week research experience for undergraduates (REU): Biogeochemical Educational Experiences – South Africa, as well as international and cultural exchanges between U.S. and SA students. The research projects included characterizing microbial communities with molecular and biochemical techniques, utilizing geochemical and isotopic parameters to constrain nutrient cycling in groundwater, investigating extreme enzymes, and examining functional genes. Research team consisted of three to five students with at least one student from each country and at least two of the disciplines represented. During the REU, students collected biofilms and hot saline waters emanating from gas-rich boreholes in the mines and performed research within their respective projects under joint mentorship of U.S. and SA scientists. As part of the REU, each team presented oral progress reports to the other teams to provide communication skill development and to serve as a forum for data exchange. During these progress sessions, discussion on interpretation of data from the perspectives of the various disciplines was encouraged. Thus, students learned how their research contributed to the big picture of microbial processes in the mines. Using the group research teams and the forums for discussion allowed the students to gain interdisciplinary knowledge and to expand thought processes and views of interdisciplinary research. http://geomicro.utk.edu