

Combining advanced microbiological cultivation, community metagenomics, nanogeoscience, and stable isotope analysis to understand the structure and function of deep subsurface microbial biospheres

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Description of proposed research:

The presence of microorganisms in ultradeep geologic environments has fundamental implications for our understanding of the origin and history of life on Earth as well as the potential for life on other planets (Nealson et al., 2001). The Deep Underground Science and Engineering Laboratory (DUSEL) facility will provide an unprecedented opportunity for investigation of the interactions of non-photosynthetic biota with minerals, liquids and gas in their in situ environment, e.g. through characterization of relationships between community composition and rock structure/mineralogy, quantification of biogeochemical processes, and experimental manipulations to examine community or process responses (McPherson et al., 2003). Phenomena that could be investigated include microbial community composition and function in relation to fracture transmissivity, groundwater-rock reactions driving ecosystem energy flux (e.g. production of hydrogen through mafic/ultramafic rock weathering or radiolysis), and other physical factors (e.g. temperature and pressure) and time of isolation; mineral precipitation and dissolution; biogeochemical evolution of groundwater properties; transport and migration of subsurface microbes; microbial adaptation and evolution in ancient sequestered groundwaters; ecological genomics and gene transfer; and microbial community responses to contamination (including the presence of DUSEL).

The proposed research will engage a broad interdisciplinary effort to examine extant microbial life and its (bio)geochemical signatures in selected long-term stable environments (such as fluid-producing fractures) within the DUSEL facility at the Homestake Mine in South Dakota (e.g. within the Ultradeep Life and Biogeochemistry Observatory proposed in McPherson et al., 2003). In addition, changes in microbial community structure and function could be assessed in conjunction with analysis of changes in the geochemical properties (e.g. the input of oxygen) of the mine during the initial de-watering phase. A combination of state-of-the-art microbiological cultivation and molecular biological techniques will be used to characterize the physiological and phylogenetic properties of specific microbial populations (e.g. lithoautotrophic organisms). Metagenomic techniques will be employed to assess the overall genetic potential of and record of genetic exchange with the same communities. In parallel, advanced mineralogical techniques (e.g. high resolution TEM, X-ray spectromicroscopy) will be used to assess the potential for generation of nanostructured mineral phases that may provide unique, permanent signatures of

microbial activities. One of the challenges in such studies will be the identification and isolation of experimental organisms within the natural setting. Stable isotope labels offer a powerful alternative, but they must be applied at a scale appropriate to the investigation. For complex microbial communities, this may require resolution of single organisms at the μm -scale. The new ion microprobe/ secondary ion mass-spectrometer (SIMS) facility at UW will be used to analyze stable isotope ratios at the μm -scale in rock materials that have been putatively influenced by microbial metabolism. Tracking of the partitioning of stable isotope-enriched substrates (e.g. of C, S, Fe) within biotic and abiotic components in situ communities (e.g. within the Deep Coupled Process Laboratory proposed in McPherson et al., 2003) and/or microcosms (e.g. crushed rock-filled cartridges analogous to those used in ultradeep gold mines in South Africa; Moser et al. (2003); Baker et al. (2003)) will provide a powerful means of linking microbial activity to the production of organic and/or inorganic isotopic biosignatures. For example, it is possible to stain and image microbes with DNA or RNA-specific Fluorescent In Situ Hybridization (FISH) and then to analyze the isotope ratio of single identified cells by ion microprobe (FISH-SIMS; Orphan et al. (2001)). A wide range of experiments is possible and the use of compounds enriched in a rare stable isotope (i.e., ^{13}C , ^{15}N , ^{18}O , ^{36}S , ^{81}Br , etc.) will provide isotope contrast much greater than 1000‰ and sub- μm spatial resolution.

Space requirements:

The research would require access to a simplified underground laboratory facility for basic wet-chemical analysis and other processing of fluid and solid samples.

Access timing:

The proposed investigations should be initiated during the de-watering phase of the mine, expand during the initial phase of studies at the 4850' level, and reach a peak during studies of the deeper regions of the mine.

Other requirements:

NA

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