Letter of Interest

Title: Impact of subsurface microbial activity on the physical and chemical properties of geological formations

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Collaborators:
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And others, including low level counting facility investigators

Science Goals:
Subsurface anaerobic microbial redox reactions product and consume aqueous species, many of which are ultimately derived from and produce mineral phases. In siliclastic formations microbial sulfate reduction typically leads to a reduction of porosity by precipitation of pyrite, whereas iron reducing reactions lead to an increase in porosity by reductive dissolution of iron oxide. Of particular importance is the source of H^+ in siliclastic geological units. The H^+ consumed by microbial reactions, such as iron reducing reactions, is derived from the conversion of clay to feldspar, the reverse weathering reaction. The coupling of microbial redox reactions to rock diagenesis supported by dissolved organic acids, such as those in petroleum reservoirs, has yet to be incorporated in basin evolution models. Observations on the distribution, types and activities of anaerobic microorganisms in the subsurface, however, clearly indicate that these processes are significant over geological time scales.
A critical next step to advancing basin evolution models is the validation of the coupling between subsurface microbial activities and rock diagenesis using two approaches. The first is to examine in a set of aseptically collected cores the chemical, physical and microbial properties of rock strata. Identify the principle electron accepting process(es) in the different rock strata and compare this to the rock's diagenetic history. The second is to install packers into the borehole resulting from the coring campaign and examine microbial biogeochemical processes and rates. In the second approach fine grained mineral separates from the rock strata are incubated within the boreholes along with the soluble electron donor and/or acceptor for the specific microbial redox reaction. The abundance of the substrates will be monitored over time to determine the in situ respiration rate. The mineral substrates will be periodically sampled to determine the extent of mineral transformation, dissolution and precipitation. The results of these experiments will provide the first basis for building basin evolution models that incorporate subsurface microbial ecosystems.

Research objectives:

- Obtain rock cores from several types of rock strata, if possible from different depths, in zones which possess fluid bearing porosity or fractures.
    - Characterize the physical and chemical rock properties.
    - Determine the abundance of "living" microorganisms.
    - Determine the rate of the principal electron accepting process.
- Installation of packers into fluid bearing the boreholes.
    - Performing televiewer logging of boreholes.
    - Design, construction and installation of metal free packer and sampling systems.

- Preparation of mineral substrates and initiation of incubation experiments.
- Monitoring of dissolved chemical substrates and examination of mineral substrates post incubation.

Methods:
The microbial properties would include measurement of in situ respiration rates, the abundance of "living" cells and their phylogenetic diversity by extracting and amplifying the RNA. The in situ respiration rate measurements utilize radiotracers and may involve analyses in the low level counting facility being proposed for DUSEL. The chemical properties would include geochemical analyses of the pore water, oxidized/reduced mineral species concentrations and the diagenetic history discerned from fluid inclusion, XRD and SEM analyses. The physical properties include the determination of pore throat distributions.

Integration with E&O:
Once the first set of high priority experiments have been performed, subsequent experiments can be designed in collaboration with local school groups.

Infrastructure Requirements and Impact on Other Users:
We anticipate that up to 21 boreholes ~50 meters long and 75 mm in diameter would be required for these experiments. The 7 locations of these boreholes will be based upon geological and hydrological database for Homestake. Multiple boreholes (~3) will be installed at each site for potential transport studies. Each drill site will need a side tunnel cubby of approximately 10 meters long, 5 meters deep and 4 meters high.

Readiness for Deployment of the Technology:
All the technology to be utilized in the proposed experiments has already been field tested in the South African NELSAM (Near Earthquake Laboratory in a South African Mine) site.

Readiness of Effort and Funding:
The drilling and installation of the first site can begin as soon as reentry into Homestake is initiated and the first site is identified. The drilling of the boreholes can take place sequentially, can be spread out over a period of several years, and can be extended to the 8,000 foot level as that level is dewatered and the lower campus developed. This sequential approach enables modification of the experimental and technical approaches.

Budget:
~$150,000 per year will be required for 5 years to support graduate students performing analyses of the core, mineral substrates and borehole fluids.
If the cost per core and borehole logging and installation is $20,000, then the total infrastructure cost would be~$420,000.

ES&H Issues:
The borehole packer and monitoring system will be designed to operate at high pressure (~2500 psi) and will be self-contained.