Letter of Interest

Title: Large scale versus small scale transport of microorganisms and multi-phase CHO fluids.

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Collaborators:

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And others, including low level counting facility investigators

Science Goals:
Numerous studies have been performed on the transport of bacteria, viruses, protists and reactive species in near subsurface porous media (e.g. Cape Cod and Oyster). The affect of pH, dissolved organics, grain size and oxidized mineral concentrations on these transport experiments have also been investigated. Few studies exist on the transport of bacteria in low porosity, fractured rock strata and none exist for the influence of multiphase transport although the theory has evolved rapidly in light of the recent focus on CO_2 sequestration. The difficulty in drilling to great depths with the precision required precludes this. DUSEL offers the first opportunity to establish a borehole array for such studies by starting at great depth and drilling short distances. The nature of the experiments will require significant alteration of the rock strata, so that a pristine site with fluid filled fractures, although ideal, is not essential. What is required is a zone of rock strata with significant interconnected porosity and fracture permeability so that an injection of bacteria or hydrocarbon bearing fluids can be tracked under a forced gradient over a period of months. The other requirement is that the fracture zone is extensive so that if one experiment doesn't make the borehole array unusable for other experiments. Selection of the site will require the performance of tracer tests either on existing boreholes or on 2 to 3 boreholes. In either case, each borehole would have to be logged and multi-level samplers capable of retaining moderate pressure would be required. The site which demonstrates the greatest interconnected porosity and permeability would be selected for the experiment and ~20-30 boreholes would be drilled at 0.5-5 meter spacing. The spacing would be based upon hydrological models of the fracture zone. The physical, chemical and microbial properties of the cores from this site will be studied. Cross borehole tomography will be performed in order to create a 3D picture of the permeability/porosity/mineralogy. The fractures will then be filled with ground water and an initial suite of tracer tests performed in forced gradient mode to test for preservation of mass balance across the borehole array, i.e. no fluid loss. By judicious selection of experiments and employing push-pull methods in some cases, this site could be used for experiments over decades.

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 from RNA analyses.
    - Enrich and isolate microorganisms to be used for the transport experiments.

- Installation of multilevel packers into the boreholes.
  - Perform televiewer logging of the boreholes and cross borehole seismic and radar tomography between the boreholes.
  - Design, construction and installation of metal free multi-level packer and sampling systems.
  - Install a research trailer for collection and sampling of fluids in an anaerobic glove bag.
- Initial Experimental program.
  - Performance of multiple tracer tests with conservative Br^- tracers to create a 3D hydrological map of the flow cell.
  - Inject and map the transport of two microorganisms with slightly different sizes and surface charges and hydrophobicities. Ideally one of these organisms should be a hydrocarbon degrading anaerobe that can be used in subsequent experiments.
  - Inject a hydrocarbon degrading anaerobe followed by a pulsed injection of hydrocarbon fluid over a limited portion of the flow cell, stop flow and then slowly reverse the flow (i.e. push pull) and monitor degradation of the hydrocarbon over a period of several months.
  - Use tomographic surveys across the plume over this time period to detect microbial gas production and hydrocarbon degradation.

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, XRD and SEM analyses. The physical properties include the determination of pore throat distributions. A set of cores will be archived frozen, to be used for bench top core experiments and available to investigators. Enrichments on anaerobic media will be carried out to provide an archive of potential candidate microorganisms that are already adapted to the environment. The microbes from this archive will be available to other investigators. The transport and growth properties of these organisms will be characterized. These organisms could act as hosts to genetic elements for specific experiments if permissible. If not, then exotic microorganisms can be brought in and tested in bench top core experiments.
The first set of experiments can be performed in low pressure mode with peristaltic pumps if the fracture zone doesn't contain high pressure fluids already. Otherwise more expensive HPLC pumps will be required.

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 20 boreholes ~50 meters long and 75 mm in diameter would be required for these experiments. The location of these boreholes will be based upon geological and hydrological database for Homestake. The site will require a dedicated side tunnel approximately 100 meters long, 10 meters wide and 4 meters high. A research trailer with an anaerobic glove bag will be required on site. Hi pressure tubing leaving each borehole head will be connected to this trailer.

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 site selection should take place after some drilling and characterization of various fracture zones has been performed. The site could be located at the 4850 level, although it may be prudent to await dewatering to the 8,000 foot level for final site selection. Once the site has been selected, drilling, logging, core analyses, model construction and installation of multilevel samplers and saturation of the fracture porosity will require ~ 1 year. The first tracer tests could be performed one year after breaking ground at the site.

Budget:
~$1,000,000 per year will be required for a consortia of investigators to characterize the site, geochemically, geophysically, hydrologically and microbially. Costs for the coring, borehole installation and the construction of the packer/sampler systems could be on the order of $400,000. An additional $100,000 will be required for the research trailer. Ideally this trailer should be portable so that it can be moved to other sites if not in use.

ES&H Issues:
The site needs to be located at a place where fracture fluids cannot escape into lower levels and thereby represent a water hazard. This implies that the site needs to be located in the deepest levels and/or at the perimeter of the current mined excavations. The borehole packer and monitoring system will be designed to operate at high pressure (~2500 psi) and will be self-contained.