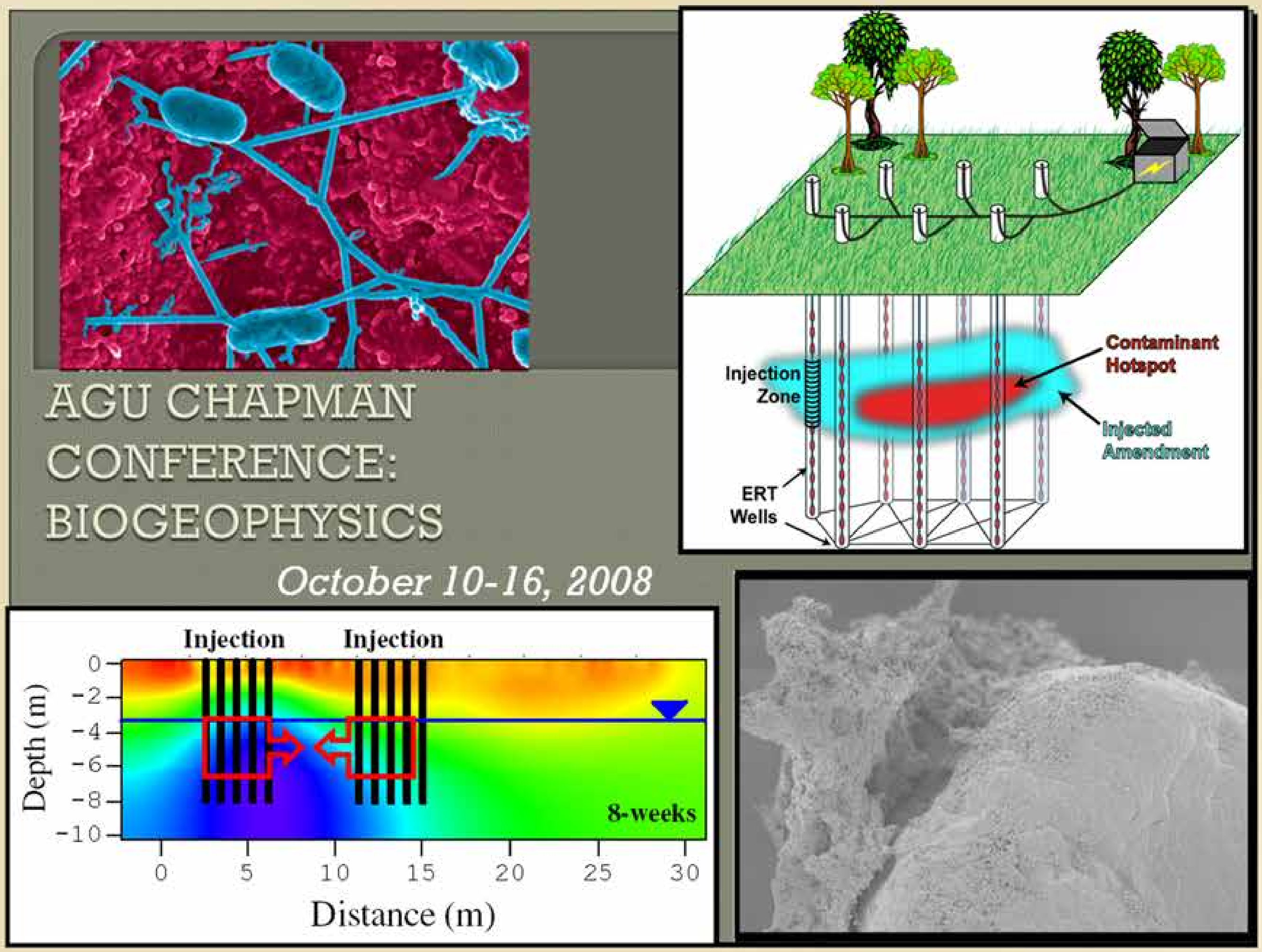
AGU Chapman Conference on Biogeophysics



Portland, Maine USA
13–16 October 2008

AGU Chapman Conference on Biogeophysics
Portland, Maine, USA
13–16 October 2008

Conveners

Lee Slater, Rutgers University, Newark, New Jersey, USA
Estella Atekwana, Oklahoma State University, Stillwater, Oklahoma, USA

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Sponsors

National Science Foundation (NSF)
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Meetings at a Glance

Sunday, 12 October 2008

5:00 p.m. – 7:00 p.m.	Welcome Reception

Monday, 13 October 2008

9:00 a.m. – 9:30 a.m.	Conveners Introduction
9:30 a.m. – 10:30 a.m.	Plenary Session I
10:30 a.m. – 11:00 a.m.	Coffee Break
11:00 a.m. – 1:00 p.m.	Oral Sessions
1:00 p.m. – 2:00 p.m.	Lunch (On your own)
2:00 p.m. – 4:00 p.m.	Oral Sessions
4:00 pm. – 4:30 p.m.	Coffee Break
4:30 p.m. – 5:30 p.m.	Open Discussion Session

Tuesday, 14 October 2008

8:30 a.m. – 9:30 a.m.	Plenary Session II
9:30 a.m. – 10:00 a.m.	Coffee Break
10:00 a.m. – 12:00 p.m.	Oral Sessions
12:00 p.m. – 1:00 p.m.	Lunch (On your own)
1:00 p.m. – 3:00 p.m.	Oral Sessions
3:00 p.m. – 3:30 p.m.	Coffee Break
3:30 p.m. – 6:00 p.m.	Oral Sessions
7:00 p.m. – 9:00 p.m.	Gala Dinner

Wednesday, 15 October 2008

8:30 a.m. – 9:30 a.m.	Plenary Session III
9:30 a.m. – 10:00 a.m.	Coffee Break
10:00 a.m. – 12:00 p.m.	Oral Sessions
12:00 pm – 1:00 p.m.	Lunch (On your own)
1:00 p.m. – 3:00 p.m.	Oral Sessions
3:00 p.m. – 3:30 p.m.	Coffee Break
3:30 p.m. – 5:30 p.m.	Oral Sessions
6:30 p.m. – 8:30 p.m.	Poster Session

Thursday, 16, October 2008

8:30 a.m. – 10:00 a.m.	Oral Sessions
10:00 a.m. – 10:30 a.m.	Coffee Break
10:30 a.m. – 12:30 p.m.	Wrap-up Session

Program Overview

Sessions and events will take place at The Eastland Park Hotel, Portland, ME. The Registration/Information Desk will be in the Eastland Ballroom foyer throughout the conference.

SUNDAY, 12 OCTOBER

5:00 p.m. – 7:00 p.m. **Welcome Reception** Gallery Room. All meeting attendees are invited to attend this kick-off event. Enjoy a relaxing evening with friends and colleagues Complimentary hors d'oeuvres will be provided and drinks will be available for purchase.

MONDAY, 13 OCTOBER

9:00 a.m. **Welcome and Opening Remarks** Eastland Ballroom
Co-Conveners: Lee Slater and Estella Atekwana

9:30 a.m. **Plenary Session I**

D Lovley *Exploiting Microbe-Electrode Interactions for Environmental Restoration*

10:30 a.m. **Coffee Break**

Session I: **Direct Signatures: Part I**
Chair: Rossbach/Gorby

11:00 a.m. **Y Gorby** *Bacterial Nanowires and Long Range Electron Transfer*

11:30 a.m. **D Bazylinski** *Construction and Significance of the Magnetosome Chain in Magnetotactic Bacteria*

12:00 p.m. **G Abdel Aal** *Electrical Properties of Bacteria in Sand Columns: Live vs. Dead Cells*

12:30 p.m. **C A Davis** *Investigating the Effect of Microbial Growth and Biofilm Formation on Seismic Wave Propagation in Sediment*

1:00 p.m. Lunch (On your own)

Session I: **Direct Signatures: Part II**

2:00 p.m. **C Prodan** *Cellular dielectric spectroscopy for biological applications*

2:30 p.m. **T Kendall** *Resolving Biological IP Mechanisms With Molecular-Scale, Surface Sensitive Force Microscopy Techniques*

3:00 p.m. **D Ntarlagiannis** *The low frequency response of artificial biofilms*

3:30 p.m. **Y Pan** *Magnetic Properties of Magnetic Minerals Produced by Magnetotactic Bacteria and Their Contribution to Sedimentary Magnetism*

4:00 p.m. Coffee Break

4:30 p.m. **Open Discussion Session**

TUESDAY, 14 OCTOBER

8:30 a.m. **Plenary Session II**

K Stetter *Hyperthermophilic Life*

SESSION II: Redox Signals: Part I

9:30 a.m. **Coffee Break**

10:00 a.m. **Introduction – Redox Signals**
Chair: Revil/Morgan

10:30 a.m**.** **G Druschel** *Voltammetric Electrodes and the Delineation of Detailed Microbial Redox Chemistry over Fine Spatial and Temporal Scales.*

11:00 a.m. **E Roden** *Quantitative Interpretation of Biogeochemical Processes Associated with In Situ Contaminant Remediation*

11:30 a.m. **A Revil** *A general theory of the relationship between redox potential and self-potential for abiotic and biotic systems. Forward modeling and inversion*

12:00 p.m. Lunch (On your own)

Session II: Redox Signals: Part II

1:00 p.m**.** **K Williams** *Biogeophysics and the Self-Potential Method: The Value of the Galvanic Response*

1:30 p.m. **F Freund** *Electric Currents Flowing Through Rocks Oxidizing Water to Hydrogen Peroxide*

2:00 p.m. **D Elias** *Does Extracellular Electron Transfer and Metal Reduction Occur via Proteinaceous Appendages in Desulfovibrio vulgaris?*

2:30 p.m. **C Zhang** *A Comparison of Electrodic Potential Signals and Self-potential Signals in Microbial Induced Sulfate Reducing Environments*

3:00 p.m. **Coffee Break**

Session III: Extreme Environments

3:30 p.m. **Introduction – Extreme Environments**
Chair: Knight/Nelson

4:00 p.m. **B Jørgensen** *The Mystery of Deep Subsurface, Slow-Growing Microorganisms*

4:30 p.m**.** **J Houghton** *Modeling Environmental Controls on Microbial Biogeography in Seafloor Hydrothermal Vent Systems*

5:00 p.m**.** **C Ruppel** *Methane Hydrates and Methane Seeps: The Potential of Biogeophysical Measurements for Identifying Microbial Hotspots*

6:30 p.m. Gala Dinner Longfellow Ballroom

WEDNESDAY, 15 OCTOBER

8:30 a.m. **Plenary Session III**

G Luther *Voltammetric solid state (micro)electrodes as in situ chemical sensors to understand microbial processes: from sediments and microbial mats to hydrothermal vents.*

9:30 a.m. **Coffee Break**

Session III: Microbe-Mineral Transformations: Part I

10:00 a.m. **Introduction – Microbe-Mineral Transformations**
Chair: Brantley/Yee

10:30 a.m. **K Singha** *Moving Toward Quantifying Kinetics in the Field: Where We Are and What We Need*

11:00 a.m. **J Ajo-Franklin** *Using Synchrotron Micro-CT To Monitor Microbially-Induced Calcite Precipitation on the Pore Scale*

11:30 a.m. **J DeJong** *Utility of Geophsyical Methods for Real-Time Monitoring Bio-Mediate Ground Improvement Processes*

12:00 p.m. Lunch (On your own)

Session III: Microbe-Mineral Transformations: Part II

1:00 p.m. **A Englert** *Field Scale Biostimulation: Understanding Induced Feedbacks Between Subsurface Biogeochemical Transformations and Physical Properties of the Subsurface*

1:30 p.m. **L Li** *Effects of Solid Phase Transformation and Biomass Accumulation on Physical Properties of Porous Media During Uranium Bioremediation at Rifle, Colorado*

2:00 p.m. **J Santamarina** *Bio-Mediated Processes in Soils - Implications and Geophysical Monitoring*

2:30 p.m. **Y Wu** *Geophysical signatures from calcite precipitation driven by urea hydrolysis*

3:00 p.m. **Coffee Break**

Session IV: Contaminated Land: Part I

3:30 p.m. **Introduction – Contaminated Land**
Chair: Hubbard/Kalin

4:00 p.m. **B Minsley** *Interpretation of self-potential data in contaminated environments*

4:30 p.m. **J Chen** *A state-space Bayesian framework for estimating biogeochemical transformations using time-lapse geophysical data*

5:00 p.m. **S Rossbach** *Geoelectric Signatures as a Guide for Microbiological Sampling During Bioremediation of Petroleum-Contaminated Sites*

6:30 p.m. **Poster Session** Nevelson/Greenhouse Room

B-01 - V Che-Alota *Using Geophysical Signatures to Investigate Temporal Changes* due to Source Reduction in the Subsurface Contaminated with Hydrocarbons

B-02 - J Deparis *Self potential measurement can be detect the microbial activities in contaminated site: a sandy box experiment*

B-03 - T McGee *Biogeophysics in the Context of Natural Gas Hydrates: Northern Gulf of Mexico*

B-04 - D R Glaser *A Summary of Recent Geophysical Investigations Performed at the Department of Energy Hanford Nuclear Facility*

B-05 - K Keating *Random walk simulations of the nuclear magnetic resonance response to changes in iron mineralogy*

B-06 - L Lazzari *Spatial variability of soil root zone properties using electrical imaging techniques in a tilled peach orchard system in Mediterranean semi-arid climate*

B-07 - C Marliere *Study of cyanobacteria films by local electric and electro-chemical investigations.*

B-08 - P C Schillig *Time-lapse GPR Monitoring of Enhanced Biological Activity in a Sandbox Reactor*

B-09 - A B Regberg *Interpreting Changes in Fluid Conductivity Due to the Reductive Dissolution of Iron Oxides*

B-10 - N Schwartz *The Influences of a Different Conductive Fluids Resulting From NAPL Biodegradation on the Bulk Electrical Conductivity of Porous Media – Laboratory Experiment and Numerical Simulation*

B-11 - K P Singh *SP and IP Monitoring of Biogeochemical Evolution and Activity of SRBs in a Simplified Winogradsky Column*

B-12 - R J Versteeg *Cyberinfrastructure for biogeophysical monitoring*

B-13 - K E Wright *Use of Electrical Methods to Predict Changes in Properties of Porous Media*

B-14 - S Hubbard *Geophysical Signatures of Remediation Amendments vs. Microbially-Mediated Transformations*

THURSDAY, 16 OCTOBER

Session IV: Contaminated Land: Part II

8:30 a.m. **Introduction – Contaminated Land**
Chair: Hubbard/Kalin

9:00 a.m. **V Naudet** *The Bio-Geobattery Model: a Contribution to Explain Self-Potential Signals on Contaminated Sites?*

9:30 a.m. **M Rijal** *Magnetic Properties of Hydrocarbon Contaminated Sediment and Their Linkage with Sedimentary and Geomicrobiological Parameters at the Former Military Air Base Hradcany (CZ)*

10:00 a.m. **L Slater** *Detection of Microbial-Driven Precipitation of Elemental Selenium Using Geoelectrical and Electrodic Potential Signatures*

10:30 a.m. Coffee Break

11:00 a.m. Wrap-up Session

Session Type: Oral

Electrical Properties of Bacteria in Sand Columns: Live vs. Dead Cells

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We investigated the electrical properties of live and dead microbial cells by making low frequency electrical measurements (0.1-1000 Hz) in sand columns. The sand columns were saturated with increasing concentrations of live and dead microbial (Pseudomonas aeruginosa) cells suspended in Bushnell Hass broth of 886 S/cm. The dead cells were prepared by breaking down the extracellular membrane of cells by autoclaving the cell suspensions at 135 oC for 30 minutes. Live and dead cell suspensions had the same cell counts and optical density (600 nm). Low frequency electrical measurements were also made in sand columns saturated with increasing concentrations of clay suspensions with fluid chemistry and optical densities similar to those used for the live and dead cells measurements. The live microbial cells and clay suspensions showed increase in the magnitude of the phase and the imaginary conductivity components. The live microbial cells and clay suspensions also showed relatively no change in the real conductivity. On the other hand, no changes were measured for phase, imaginary, or real conductivity for the dead cell suspensions. Our results suggest that both live and dead microbial cell concentrations should be considered when assessing the effects of microbes on the electrical properties of porous media.

Session Type: Oral

Using Synchrotron Micro-CT To Monitor Microbially-Induced Calcite Precipitation on the Pore Scale

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The quantitative interpretation of timelapse biogeophysical measurements requires an understanding of the processes responsible for rock alteration at multiple length scales. At laboratory dimensions (l < 1 m), mesoscale, column, and core experiments have provided a wealth of data in an environment where flow, chemistry, and microbiology can be closely monitored and controlled. Dynamic characterization of rock alteration on the scale of pores and grains (l < 1 mm) has been considerably more difficult; traditional measurement techniques capable of reliably imaging pore structure (e.g. thin section microscopy, TEM, SEM) are limited by their 2D nature and are generally incapable of monitoring realistic porous materials. With the recent development of micron-resolution 3D x-ray computed tomography (CT) systems, we have an unprecedented opportunity to build an understanding of how biological processes physically modify subsurface materials with precipitation processes being an attractive imaging target due to the density contrast between newly formed minerals and displaced pore fluids. The central advantage of CT-based analysis is access to geometric modifications in microstructural attributes which might be incorporated into effective medium models describing geophysical signatures on larger length scales.

In this investigation we exploit the high photon flux of a 3rd generation synchrotron x-ray source and use dynamic micro-CT to monitor microbially-induced calcite precipitation in sediment samples from Idaho National Laboratory's Vadose Zone Research Park (VZRP) site. The biological process in question is an enhanced urea hydrolysis treatment tailored for in situ stabilization of Sr-90 contamination through co-precipitation with $CaCO_3$. Calcite precipitation is expected to generate a variety of geophysical and hydrological signatures, most involving pore clogging, cementation of grain-to-grain contacts, or grain surface alteration. We have developed a polycarbonate/PEEK flow cell and stabilization platform designed for x-ray imaging of biological and general reactive transport processes. We present preliminary results showing 3D alterations of the porous frame occurring during the bio-precipitation process. We also discuss a first attempt at extracting relevant geometrical attributes of precipitated calcite zones for eventual inclusion in geophysical effective medium models. Key challenges which were encountered during the experiment included registering the baseline/repeat image volumes and correcting for fluctuations in source attributes.

Session Type: Oral

Construction and Significance of the Magnetosome Chain in Magnetotactic Bacteria

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A diverse group of prokaryotes, known as the magnetotactic bacteria, biomineralize intracellular, membrane-bounded, single-magnetic-domain crystals of the magnetic minerals magnetite and/or greigite called magnetosomes. The magnetosomes are synthesized de novo from soluble forms of iron and are generally arranged as a chain that is anchored within the cell by cellular structural components. The magnetosome chain causes the cell to passively align along the Earth's geomagnetic field lines while the cell swims, a property referred to as magnetotaxis. It is currently thought that the magnetosome chain functions to make chemotaxis more efficient in magnetotactic bacteria by aiding cells in locating and maintaining an optimal position in vertical chemical gradients in natural aquatic habitats.

Biomineralization of magnetosomes and construction of the magnetosome chain is under genetic control. The genes responsible for these processes are known as the mam, mms and mtz genes. Several of these proteins encoded for by these genes have been ascribed specific functions while those of others are unknown. For example, the proteins MamJ and MamK are known to be structural proteins involved specifically in the organization of the magnetosome chain. The biomineralization of magnetite by magnetotactic bacteria likely involves a number of redox reactions involving iron although specific reactions are not presently known despite the fact that both iron reductases and oxidases have been found in several species of magnetotactic bacteria.

The presence of magnetosome crystals (magnetofossils) and the organisms themselves in aquatic environments and sediments are indicative of relatively specific redox and chemical conditions. In general, they are most abundant at or just below the oxic-anoxic interface. Moreover, these organisms appear to mediate a number of important biogeochemical redox transformations and reactions at the oxic-anoxic interface and they themselves are likely an important factor in stabilizing specific chemical gradients in natural environments. The presence of magnetofossils in ancient sediments might provide important information about dominant chemical and redox conditions in the past.

Session Type: Poster

Using geophysical signatures to investigate temporal changes due to source reduction in the subsurface contaminated with hydrocarbons

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We investigated the geophysical response to subsurface hydrocarbon contamination source removal. Source removal by natural attenuation or by engineered bioremediation is expected to change the biological, chemical, and physical environment associated with the contaminated matrix. Our objective was to determine the effects of contaminant reduction on the contaminant plume as observed by anomalously high bulk electrical conductivity. We compared ground penetrating radar, self potential, and electrical resistivity surveys conducted between 1996 and 2007. In addition, we used groundwater chemistry as part of our evaluation of temporal changes in the chemical conditions in the groundwater. Removal of the contaminant source by soil vapor extraction (SVE) in 2001 caused a decrease in the total petroleum hydrocarbon in groundwater. Geophysical surveys across the contaminated plume showed that attenuated ground penetrating radar reflections became less attenuated, self potential signals became less positive, and electrical resistivity increased over time. We attribute the change in the geophysical properties mainly to removal of hydrocarbon in the free phase. We infer that as long as the free phase contamination does not contribute to microbial degradation, the bulk electrical properties of the subsurface will revert to background conditions. Therefore we conclude that the contaminant mass reduction in the subsurface by natural bioremediation or enhanced remediation can be effectively imaged by integrated geophysical techniques.

Session Type: Poster

A state-space Bayesian framework for estimating biogeochemical transformations using time-lapse geophysical data

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Quantitative estimation of biogeochemical transformations is important for monitoring and understanding bioremediation processes of contaminants. In this study, we develop a state-space Bayesian framework for combining time-lapse geophysical data with various other types of information to estimate biogeochemical transformations. Within this framework, we consider some measures of the end products of

biogeochemical transformations as a state vector that evolves under constraints of local environments and is governed by a defined evolution equation. We consider the time-lapse geophysical data as available observations that are linked to the state vector through petrophysical models or a defined observation equation. With the use of Markov chain Monte Carlo sampling methods, we can obtain the estimates of the state vector over time by conditioning to the time-lapse geophysical data and to its previous state vectors.

We apply the developed framework to synthetic, laboratory, and field data sets in order to demonstrate the utility of time-lapse seismic and spectral induced polarization (IP) data, collected during biostimulation experiments, to estimate transformations associated with the evolution. Particularly, we use the framework to estimate the effective volume fraction and mean-grain size of the evolved precipitates over the support scale of the geophysical measurements. We also compare the estimates obtained using IP data only with those obtained using both IP and seismic data. The results of those studies show that the developed state-space approach is effective in combining time-lapse geophysical data with other types of information to quantitatively estimate the end products associated with biogeochemical transformations and that IP and seismic data provide information about biogeochemical transformations at different scales.

Session Type: Oral

Investigating the Effect of Microbial Growth and Biofilm Formation on Seismic Wave Propagation in Sediment

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Previous laboratory investigations have demonstrated that the seismic methods are sensitive to microbially-induced changes in porous media through the generation of biogenic gases and biomineralization. The seismic signatures associated with microbial growth and biofilm formation in the absence of biomineralization, however, remains uncertain. Biofilm formation can result in significant changes to the hydraulic and mechanical properties of a porous medium. Here, we report on the results of a laboratory experiment aimed at assessing the spatial and temporal changes in acoustic wave propagation associated with microbial growth in porous media, while concurrently measuring the complex conductivity of the same system. Microbial growth was stimulated in silica sand-packed columns, and complex conductivity measurements and acoustic (compressional) wave data were collected over a two-dimensional region for 15 days. The imaginary component of the complex conductivity measured from the biostimulated column (nutrients and bacteria inocula) increased to peak values by Day 5, before decreasing to near background values by Day 15. The real component remained relatively steady through Day 7, decreased slightly to a minimum on Day 9, and then showed a gradual increasing trend through Day 15. In contrast, the complex conductivity results from the unstimulated column (nutrients, no bacteria) did not show any significant variations over time. The seismic signal from the biostimulated column shows a significant decrease in amplitude with time since biostimulation. The transmitted wave amplitude is relatively uniform over the scanned region for the standard sample with an average peak-to-peak amplitude of 0.56 ± 0.02 Volt. However, transmitted amplitudes from the biostimulated column vary spatially with an average amplitude of 0.47 ± 0.16 Volt. No significant change in velocity was observed. Visual examination of the biostimulated column showed biofilm growth. Planned microbiological and geochemical analyses upon destruction of the columns will help to constrain the measured geophysical results.

Session Type: Oral

Utility of Geophsyical Methods for Real-Time Monitoring Bio-Mediate Ground Improvement Processes

[*J T DeJong*] (Department of Civil and Environmental Engineering, University of California, Davis, CA 95616; ph. 530-754-8995; fax 530-752-7872; e-mail: jdejong@ucdavis.edu)

New, exciting opportunities for utilizing biological processes to modify the engineering properties of the subsurface – soil strength, permeability, compressibility, etc. – have recently emerged. Enabled by interdisciplinary research at the confluence of microbiology, geochemistry, and civil engineering, this new field has the potential to meet society's ever-expanding needs for natural treatment processes that improve soil supporting new and existing infrastructure. While the end objective is improving the mechanical properties of soil, non-destructive methods are required to monitor, in real time, the state of the chemical reaction network, the level of biological activity, and how these processes are actually altering the engineering properties of soil. This paper describes how resistivity, compression waves (P-wave), and shear waves (S-wave) as well as X-ray CT are being used to guide the bio-mediated treatment process and predict the extent to which various engineering soil properties have been improved. Bio-mediated calcite precipitation and gas generation processes, which increase the soil strength and stiffness and reduce the potential for liquefaction, respectively, are used to exemplify the application of each geophysical monitoring technique.

Session Type: Poster

Subsurface Imaging using Multilateral Wells

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When the natural permeability in a reservoir is not sufficient to produce hydrocarbons at an economic rate, the permeability can often be improved by hydraulically fracturing the reservoir around the well. The rock is fractured by pumping high pressure fluids into the well, opening existing fractures and creating new ones. This process generates microseismic events. To control the fracturing process and to efficiently sweep the reservoir afterwards it is of paramount importance to know the distribution and dimensions of these opened fractures. These fractures can be imaged by localizing the hydraulically-induced microseismic events. The most common used microseismic source localization method is to record the induced elastodynamic wavefield with a linear array of three-component receivers. The location of the source is characterized with polar coordinates, e.g., distance, elevation angle and backazimuth with respect to the upper receiver. The backazimuth is found using the polarization of the first P-wave arrival. The distance and elevation angle are found using the time delay between the first P- and S-waves from at least two receivers. This yields low uncertainty in source localization when the P and S velocity models are known. There are three major shortcomings of the traditional method. The P-wave signal is often undetectable because the source mechanism in fractures typically generates significantly more S than P. The P polarization often has large error, which is reflected in the localization error. Finally, systematic error in the P and S velocity models results in large localization error. Similarities with subsurface imaging for Biogeophysics purposes is obvious.

In this study, we investigate the magnitude of microseismic source localization given travel-time errors, polarization information uncertainty and systematic errors in the velocity models when considering using multilateral configurations of receivers instead of single-vertical-well receivers. With the increase of branched multilateral wells that are being drilled it becomes feasible to employ three-component downhole arrays of receivers. It is shown that microseismic source localization could be well constrained using solely S-wave time delays from non-planar multilateral wells. This brings three major advantages. First of all, it has broader applicability since no detection of a P-wave is needed. Secondly, the inversion can be done faster, since only S-wave time delays need to be forward modeled and extracted from the data. Finally, no polarization measurement is needed. Removing the requirement for polarization information is advantageous because this makes it possible to localize a source using only cheap omni-directional sensors instead of expensive three-component receivers. This yield the further advantage that less data would need to be sent uphole. Furthermore, the redundancy provided with additional P-wave travel time and polarization information is used for simultaneously invert for the source localization and velocity models.

Session Type: Oral

Voltammetric Electrodes and the Delineation of Detailed Microbial Redox Chemistry over Fine Spatial and Temporal Scales.

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Microorganisms play a major role in changes occurring in redox chemistry in every environment we have explored on this planet where liquid water is present. Changes in the activity of these organisms will largely occur in concert with changing redox chemistry (broadly described by the redox ladder where oxygen, nitrate, manganese, iron, sulfur and carbon dioxide are sequentially utilized as electron acceptors). The spatial scale of how microorganisms affect redox chemistry in an environment can vary widely, but in many subsurface environments and in critical zones where gradients are high and biofilms develop, the redox ladder can be compressed to micron scales with significant spatial heterogeneity. The timing of microbial response to changing conditions can occur in different ways over different temporal scales, as evidenced by purple sulfur bacteria response to light level changes over seconds to the more extended time it may take for the composition of microbial communities to shift with changing conditions based on competitive pressures. To gain better understanding of microbial systems in the environment, it is critical to work at scales where these changes can be investigated. Voltammetric electrodes have been used in a number of aquatic, marine, and subsurface environments to measure key redox species, in real time and in situ, over spatial scales down to microns with temporal resolution of a few seconds. I will review a large body of work from our lab and from others to discuss the utility and limitations of voltammetry to study fundamental biogeochemical processes.

Session Type: Oral

Does Extracellular Electron Transfer and Metal Reduction Occur via Proteinaceous Appendages in Desulfovibrio vulgaris?

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In recent years, one goal of biogeophysics has been to track microbial metabolism via both real and imaginary conductivity. This in essence means following the electrical signals given off during electron transfer steps of respiration. We have investigated the presence of extracellular appendages, i.e. nanowires, in the model sulfate-reducing bacterium Desulfovibrio vulgaris. These bacteria have repeatedly been shown to actively participate in metal and radionuclide bioremediation. Our evidence to date, together with support from the literature, suggests that such appendages are present in D. vulgaris and are electrically conductive. We have observed thick, flagellar-like appendages as well as very thin, pilus-like structures using TEM and SEM. Incubation of resting D. vulgaris cells on TEM grids with U(VI) as the sole electron-acceptor under acceptor limitation resulted in the reduction and precipitation of uraninite. The smaller, but not the larger appendages were coated with uraninite. The appendages were not present in acceptor excess. This was repeated with deletion mutants of two flagellar and two pilus genes and it was found that no such U(IV) coating appeared in any of the mutants. We are currently subjecting these strains and the wild type to AFM to determine electrical conductivity of the appendages. Separately, static sand sediment column incubations with growing D. vulgaris and each of the mutants are currently being conducted under sulfate- limitation versus excess. We suspect that sulfate-respiration and electrical conductivity may be diminished in the pilin mutant whereas sulfate excess columns may be similar to the wild type and flagellar mutants. SEM and TEM preparations will be examined from each column for the presence of appendages throughout the column length. When combined, these experiments should determine the presence and role of nanowires in D. vulgaris U(VI)-reduction and whether it is plausible to use biogeophysical signatures to follow metal-reduction in sulfate-reducing bacteria.

Session Type: Oral

Field Scale Biostimulation: Understanding Induced Feedbacks Between Subsurface Biogeochemical Transformations and Physical Properties of the Subsurface

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Biogeochemical transformation end products (i.e. gases, precipitates and biofilms) induced through biostimulation, have the potential to alter flowpaths in the subsurface. Although the impact of these end products on flow characteristics has been well documented at the laboratory scale, few studies have investigated the impact at the field scale. Ongoing work at the DOE Integrated Field Challenge Site (IFC) at Rifle, Colorado, aims at understanding the efficacy of immobilizing uranium through biostimulated reduction of U(VI) to U(IV) in a shallow alluvial aquifer. Several flowcells (sites instrumented with injection galleries and monitoring wells) have enabled experiments in which biostimulation is instigated through acetate injection, and the concentrations of pertinent chemical species, including acetate and U(VI), are monitored at downgradient wells. Based on conservative tracer test data collected before, during and after two biostimulation experiments done in the same flowcell but in subsequent years (2002 and 2003), we were able to infer the two-dimensional spatial patterns of amendment delivery, U(VI) removal, and the distribution of flow properties that controlled amendment distribution. We found that the initial heterogeneity controlled the delivery of the amendment and the removal of U(VI). We also found that the flow characteristics changed between the two experiments and that these changes in flow characteristics in turn changed the pattern of the amendment delivery and U(VI) removal. These findings suggest that biogeochemical transformations altered the flow properties. Such feedbacks may impact subsequent amendment delivery or remediation sustainability.

To better understand and predict these phenomena, it is necessary to characterize the three-dimensional subsurface heterogeneity and to understand how it changes in time. For this purpose, we acquired time-lapse geophysical measurements (i.e., crossborehole georadar; and neutron, electrical and gamma logs) and hydrogeological measurements (i.e., slug, flowmeter and tracer tests) at the most recent IFC flowcell. We use a sequential Bayesian inverse approach to integrate the various data at given times. Here, the crossborehole georadar data are fused with the slug and flowmeter test data to estimate a three-dimensional hydraulic conductivity field. This estimate of the hydraulic conductivity field is then used as prior information in an inverse modeling approach (using iTOUGH2) which refines the estimated hydraulic conductivity field by improving the match between simulated and measured tracer test data. The results of this study indicate that the approach is well suited for quantifying three-dimensional subsurface properties and temporal changes thereof, and for providing key input parameters for reactive transport modeling.

Session Type: Oral

Electric Currents Flowing Through Rocks Oxidizing Water to Hydrogen Peroxide

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All common igneous and high-grade metamorphic rocks contain dormant defects, which – upon application of deviatoric stress – release electronic charge carriers. These charge carriers are defect electrons, e.g. holes like in semiconductors, associated with O– in a matrix of O2–. Because these holes reside in the oxygen anion sublattice they are also known as “positive holes” or pholes for short. The pholes travel through rocks using energy levels in the valence band. They travel along stress gradients over distances on the order of meters in the lab and kilometers to tens of kilometers in the field. They can generate substantial electric currents in the ground. At the Earth’s surface these charge carriers turn into •O radicals, e.g. highly oxidizing reactive oxygen species, ROS. At rock-water interfaces they oxidize H2O into H2O2. Quantitatively, for every two phole charge carriers that arrive at the rock-water interface one H2O2 molecule is formed. The discovery of these elusive, yet ubiquitous electronic charge carriers, their activation by stress, and their effects on the Earth’s surface environment open a door to better under¬stand the early Earth and the evolution of Life.

Session Type: Poster

A Summary of Recent Geophysical Investigations Performed at the Department of Energy Hanford Nuclear Facility

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hydroGEOPHYSICS, Inc. (HGI) has conducted numerous geophysical investigations at the Department of Energy Hanford Nuclear Reservation since 2001. The projects range from small scale subsurface transport studies to large scale infrastructure mapping and resistivity characterization of near surface contaminant plumes. As a result, a number of advances were made including the development of (a) integrated rapid data acquisition techniques, (b) software and hardware for managing very large resistivity data sets, and (c) three-dimensional inverse modeling of large resistivity data volumes. In addition, HGI has monitored the integrity of multiple single-shell radioactive waste storage tanks during waste retrieval operations since 2004 using remote geophysical leak detection methods. In 2006, a leak injection study was successfully completed as a validation method for the leak detection and monitoring program. In 2007, the remote leak detection system was enhanced by the implementation of an automated data reporting, analysis, and early warning program. Select results from historic and ongoing investigations will be presented.

Session Type: Oral

Bacterial Nanowires and Long Range Electron Transfer

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Bacteria catalyze redox reactions that can significantly influence the fate and transport of heavy metals, radionuclides and organic contaminants in subsurface sediments and groundwater. Approaches for remotely detecting, monitoring, and controlling microbial redox reactions require an improved understanding of the components and mechanism that coordinate electron transfer reactions. Recent research demonstrates that organisms ranging from sulfate reducing bacteria to oxygenic phototrophic cyanobacteria produce electrically-conductive appendages called bacterial nanowires. Dissimilatory metal-reducing bacteria, such as Shewanella and Geobacter, produce nanowires that mediate the transfer of electron from cells to solid phase electron acceptors, such as iron and manganese oxides. This presentation provides a status report on our current understanding of bacterial nanowires and their role(s) in extracellular electron transfer.

Session Type: Oral

Modeling Environmental Controls on Microbial Biogeography in Seafloor Hydrothermal Vent Systems

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Using a combination of geochemical modeling and statistical evaluation of an integrated dataset of hydrothermal fluid chemistry, chimney mineralogy, and microbial species presence at vent sites along mid-ocean ridges in the eastern Pacific, this study is designed to explain geochemical and microbial observations compiled from the literature within a framework consistent with ecological principles. Analysis of the accumulating integrated dataset seeks to 1. create a standardized comparison of data across time and space, 2. define microbial communities within and around each vent structure at the time of sampling, and 3. constrain the geochemical environment at each vent through time. However, given that microorganisms populate the interior of chimney walls at temperatures favorable for life (<150 degrees C), geochemical reaction path modeling can provide a more reasonable estimate of the chemical conditions within chimney walls than simply the end-member fluids sampled at the chimney orifice (>300 degrees C) commonly reported in the literature.

One chimney-scale modeling study nearing completion attempts to constrain the geochemical environment within concentric sections of a white smoker near Bio9 vent corresponding to a carefully subsectioned microbial survey study (Kormas et al., 2006) for which mineralogy was reported and fluid chemistry exists in the literature (Von

Damm and Lilley, 2004). On a larger ridge scale, a second study is underway to statistically evaluate the currently compiled microbial survey data from 28 studies (using 1090 observed clones and/or strains) along the East Pacific Rise and Juan de Fuca Ridge to determine the taxonomic distinctness or functional diversity (based on genetic similarity within populations) at various locations through time. This analysis uses methods specifically designed for cases in which the data only consist of presence/absence information without abundance (i.e. cell counts or biomass), which is of particular importance in the seafloor environment where measuring abundance of cells attached to rock while simultaneously identifying those cells phylogenetically is extremely challenging. Results of taxonomic distinctness begin to indicate shifts in observed diversity over time and space as well as between different sampling methods (i.e. chimney samples vs. in situ devices placed over vent emissions). Geophysical techniques that can quantify subsurface microbial biomass would be an extremely powerful tool to further our understanding of biomass distribution, particularly if it could be coupled to techniques of microbial identification and geochemical function.

Session Type: Poster

Geophysical Signatures of Remediation Amendments vs. Microbially-Mediated Transformations

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Recent research has indicated that geophysical monitoring can elucidate microbially-mediated transformations associated with bioremediation processes, such as the distribution of injected remediation amendments and the evolution of microbially-mediated end-products (such as gasses, precipitates, and pore fluid geochemistry). This research has also identified challenges associated with such biogeophysical monitoring, one of which is the difficulty in distinguishing the impact of multiple and often competing processes that occur during in-situ treatments on the geophysical signatures.

Here, we discuss the results of column experiments designed to explore the sensitivity of seismic, radar, and complex electrical attributes to pore water replacement by three different amendments that are being widely used with biostimulation eexperiments: lactate, vegetable oil, and molasses. Co-collection of geophysical and biogeochemical measurements over time during column-scale biostimulation experiments permitted the investigation of the sensitivities of the different geophysical attributes to the pore fluid replacement. Of particular interest is the ability to remotely distinguish the injected amendment from subsequent biogeochemical transformations.

The laboratory experiments were designed to assist with the interpretation of time-lapse geophysical monitoring of field-scale biostimulation demonstrations conducted in contaminated aquifers at the Hanford Site in Washington. The biostimulation experiments are part of an integrated strategy for accelerating cleanup of groundwater chromium in an area located close to the Columbia River and upgradient from an in-situ redox manipulation barrier. The reduction in electron acceptor flux to the barrier associated with the biostimulation is expected to increase the barrier longevity, thereby increasing protection of the Columbia River. Key biostimulation design parameters associated with the bioremedion demonstrations include evaluation of: the different substrates, the radius of influence for each of the substrates, amount of substrate that can be injected, biomass yield for the substrate, bioreduction yield for chromate, nitrate, and oxygen for the substrate and biomass, and the rate of substrate and biomass depletion. An improved understanding of the geophysical signatures of porewater replacement by lactate, vegetable oil, and molasses (obtained through column experimentation) is expected to increase our ability to use field geophysical datasets to assess the efficacy of these demonstrations and to improve the design of subsequent in-situ bioremediation treatments.

Session Type: Oral

The Mystery of Deep Subsurface, Slow-Growing Microorganisms

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Most bacteria and archaea on Earth live in the sub-surface world of the continents and of the seabed. Microbial cells have been found in marine deposits, more than 1.5 km deep and 110 million years old, and in the basaltic ocean crust. The energy flux available to the deep microbial communities is extremely low. Modelling of the turnover of electron acceptors or donors provides calculated mean rates of cellular metabolism a million-fold below those of growing cultures. This corresponds to calculated mean generation times of years to thousands of years. Such a low electron flow is difficult to reconcile with current concepts of maintenance metabolism, cell repair costs, membrane permeability, and other basic cell properties. Although buried organic matter apparently provides most of the energy for the deep biosphere, more exotic energy sources, such as molecular hydrogen from the radiolysis of water by natural radioisotopes, make additional contributions. Most of the sub-surface bacteria and archaea are presently identified only by the genetic code of their DNA. The predominant phylogenetic lineages have no cultured or known relatives in the surface world and their functional role is therefore unknown.

Session Type: Poster

Random walk simulations of the nuclear magnetic resonance response to changes in iron mineralogy

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Proton nuclear magnetic resonance (NMR) measurements can be used toprobe the molecular-scale physical and chemical environment of water in the pore space of geological materials. In this study we explore the use of NMR relaxation time measurements as a method for monitoring iron mineralization processes. In a previous experimental study, we measured NMR relaxation times of a column packed with ferrihydrite-coated sand as it reacted with a solution of ferrous iron. The mineral concentrations formed during this reaction were simultaneously measured using x-ray diffraction (XRD) and extended x-ray adsorption fine structure (EXAFS) spectroscopy. By comparing the NMR measurements to spectroscopic measurements we were able to show, qualitatively, that changes in the NMR data corresponded to changes in the iron mineralogy. The XRD and EXAFS data showed that lepidocrocite and goethite formed first followed by magnetite; magnetite was the primary mineral in the final reaction products. The dominant feature in the NMR data was a consistent, and large, decrease in the relaxation time as the reaction progressed. We attributed this to the increase in the concentration of magnetite. At early times in the experiment we also observed a decrease in the average relaxation time but did not detect magnetite with XRD and EXAFS measurements. In order to quantitatively compare the NMR relaxation time measurements to the relative concentrations of the iron minerals present during the reaction, we developed random walk models that simulate NMR relaxation in 3D spherical grain packs with heterogeneous mineralogy. In this numerical study we used the models to simulate the average NMR relaxation times obtained during the reactions, parameterizing the models with the measured concentrations of the iron minerals. The numerical modeling produced the same observed decrease in average relaxation times for all the measurements in which magnetite was found to be present; yielding excellent agreement between the simulated and observed data. The NMR data from early times in the experiment could not be simulated without the addition of magnetite. We concluded that the NMR data were sensitive to the presence of magnetite that was below the detection limit of XRD and EXAFS. Additional NMR laboratory measurements on water saturated mixtures of lepidocrocite, goethite, ferrihydrite and magnetite confirmed this.

Session Type: Oral

Resolving Biological IP Mechanisms With Molecular-Scale, Surface Sensitive Force Microscopy Techniques

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Changes in geophysical signals in the presence of microbes may be rooted in surface processes that occur at the cell-mineral interface. Sorption of cells, cellular structures, and biofilms alter or occlude charge migration pathways within porous media. Chemical transformation of minerals, including redox driven dissolution or precipitation, lead to changes in the conductivity of pore fluids, but also to changes in mineral surface topography and roughness. When summed across macroscopic volumes these mechanisms may lead to the observed biological induced polarization (IP) response. Therefore, determining the nature and relative contribution of each mechanism is paramount for the interpretation of biological IP signals. Our approach employs a surface sensitive, nanoscale analog to bulk IP measurements called polarization and conductive force microscopy (PCFM). Localized, nanoscale equivalents to traditional IP measurables, such as complex conductivity and apparent chargeability are possible with PCFM. For example, the frequency-dependent dispersions in the maximum polarization forces we measure on a single bacterium parallel modeled electrical permittivity dispersions. Specifically, frequency cut-off values for maximum polarization forces increase with increasing ion mobility in a pattern that is consistent with the modeled values. Comparing PCFM observations of the mineral-microbe interface with column IP measurements should provide much needed molecular-level insight into the bio-IP phenomena.

Session Type: Poster

Spatial variability of soil root zone properties using electrical imaging techniques in a tilled peach orchard system in Mediterranean semi-arid climate

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Worldwide interest in reducing greenhouse gases has led to explore more accurate, less invasive imaging methods of geophysics for quantifying the root biomass and evaluating its critical role in space and time. This paper presents a combined application of

geoelectrical imaging techniques and conventional soil methods to study the spatial root distribution of a micro-irrigated peach orchard system in relation to physical soil properties in a tilled heterogeneous sandy-loam soil (Typic Xerofluvents, WRB). Resulting 2D and 3D resistivity ¦Ñ models, obtained by inversion procedure, can image root zones and hydro-pedological horizons and heterogeneities. Results reflect a complex spatial variability of the evaluated parameters. ¦Ñ parameter shows univariate significant statistical relationships with soil volumetric water content and white root density. Multi-regressive statistical analysis shows that the soil electrical resistivity is positively related to the stone content and woody root density, and is negatively related to the volumetric water content and fine root length. Multivariate statistical approach appears to be a good tool to study the relationship between resistivity measurements and other pedological parameters of the heterogeneous tree orchard soil system. An interesting prospect is of deriving the root biomass and subsequently the sequestered carbon into root systems by applying measurements of root characteristics on destructive soil sampling and geoelectrical approach.

Session Type: Oral

Effects of Solid Phase Transformation and Biomass Accumulation on Physical Properties of Porous Media During Uranium Bioremediation at Rifle, Colorado

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In situ uranium remediation involves the injection of organic carbon into the subsurface to stimulate indigenous bacteria that can transform soluble U(VI) to insoluble U(IV), therefore immobilizing U(VI). Such perturbation often leads to complex biogeochemical reactions, the products of which can result in biomass accumulation and changes in solid phase composition. In this work, we combine reactive transport modeling with field measurements to quantify the evolution of the microbial community structure and the solid phase composition during a field-scale uranium bioremediation experiment at Rifle, Colorado. The reactive transport model CrunchFlow couples the biogeochemical, transport, and microbial processes that occur during the experiment and explicitly keeps track of the microbial community structure. Constrained by aqueous geochemistry data, reactive transport modeling shows that biogeochemical reactions lead to an exponential growth of biomass, predominantly iron and sulfate reducers, and precipitation of secondary minerals, primarily calcite and iron sulfide. A maximum amount of biomass and precipitates accumulates close to the injection wells where the acetate concentration is highest. The physical and chemical heterogeneities of the aquifer, especially the spatial distribution of conductivity and iron oxide content, lead to localized larger amounts of precipitates and biomass accumulation, reaching as high as 7% of the pore space, which can potentially increase the possibility of pore clogging and change the flow path. Such feedback on the physical properties of the aquifer, can in turn result in flow rerouting and possibly increase the efficacy of uranium remediation due to the accessibility of iron oxide in the low permeability regions.

Session Type: Plenary

Exploiting Microbe-Electrode Interactions for Environmental Restoration

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Many microorganisms have the potential to interact electronically with electrode surfaces. However, previous studies have demonstrated that Geobacter species are the primarily colonizers of graphite electrodes that are introduced into aquatic sediments or the subsurface, either as an electron acceptor or an electron donor. This is attributed to the ability of Geobacter species to electronically interact directly with electrodes via outer-surface electron transfer proteins. Effective subsurface bioremediation often requires the addition of appropriate electron acceptors or electron donors to promote the desired microbial activity, but this can be technically difficult and expensive. Electrodes offer an alternative for more traditional electron donors and acceptors. They can readily be emplaced in the subsurface and have the added advantages that: 1) they are continually renewable; 2) they adsorb many contaminants, concentrating them at the point of oxidation/reduction; and 3) if necessary, the electrodes can be pre-colonized with microorganisms that can catalyze the bioremediation process of interest. Geobacter and closely related species have recently been shown to oxidize organic contaminants, such as aromatic hydrocarbons, with electrodes serving as the sole electron acceptor and can use electrodes as the electron donor to reductively precipitate uranium from contaminated groundwater or to reductively dechlorinate chlorinated solvents and aromatic compounds. Therefore, electrode-microbe interactions show great promise as a novel bioremediation tool.

Session Type: Plenary

Voltammetric solid state (micro)electrodes as in situ chemical sensors to understand microbial processes: from sediments and microbial mats to hydrothermal vents.

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We have used solid-state Au/Hg voltammetric electrodes to understand biogeochemical redox processes in hot spring and deep sea vent environments. These electrodes are non-specific and can measure simultaneously several of the principal redox species involved in early diagenesis (O2, Mn2+, Fe2+, H2S/HS-, and I-) as well as some Fe species (FeS and Fe3+) and sulfur species (Sx2- and S2O32-). Here we demonstrate how in situ data can be used to study specific iron/oxygen/sulfur reactions and processes at (sub)millimeter to centimeter resolution and over short time scales. Examples include the zero order oxidation of Fe2+ by O2 produced in cyanobacterial mats of Yellowstone National Park hot springs, the pseudo first order Fe2+ oxidation by iron oxidizing bacteria (FeOB) which reside at O2 concentrations < 50 M and the formation of S2O32- in diffuse flow waters from hydrothermal vents at Lau Basin. These dynamic environments show how kinetic data can be used to understand the interactions between biology and chemistry, and distinguish between different biotic processes. We know of no other analytical technique that can provide this information in both clear and turbid waters on the time scales (seconds) observed.

Session Type: Poster

Study of cyanobacteria films by local electric and electro-chemical investigations.

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Carbonate reservoirs are submitted to microbial metabolic processes promoting either the precipitation or the dissolution of calcium carbonate, especially in network of fractures and fault zones. Such phenomena may act as a seal during fault zone evolution and, later, reservoir production, modifying greatly the connectivity of fractures, permeability structure and drainage in the vicinity of otherwise major fluid conduits.

Several laboratory studies have demonstrated the utility of geophysical methods such as complex electrical conductivity ones for the investigation of microbial-induced changes in porous geologic media. The primary suggestion of these studies was that temporal variations in the geophysical signatures corresponded with microbial-induced changes in the geologic media. However these variations of electric signal could be due to the combined effects of surface and volume contributions in the studied geologic medium. Surface effects such as attachment of the bacteria on substrate surface or reactions of carbonate precipitation/dissolution are crucial for concerns about local seal or opening or, more generally, modification in connectivity of fracture or porosity network in reservoirs.

That is why we have launched a new study in order to clearly distinguish surface effects from volume one in electrical responses mediated by biogenic material. The surface processes of cell growth, attachment onto substrate surfaces and the reactions of carbonate precipitation/dissolution are studied by local (at sub-micrometric scales) methods such as atomic force microscopy (AFM) and scanning electrochemical potential microscopy (SECM) probing. These methods are carried out with living biological specimen under in situ conditions. Our first studies have been done by AFM in tunnelling mode on cyanobacteria (from $CaCO_3$ rich sediments from a hyper saline lake). The immobilized bacteria have been scanned in ambient gaseous atmosphere by the nanometric AFM tip. In these conditions the cyanobacteria are recovered by a micrometric film of water. Both the roughness signal and electric current flowing from the tip to the substrate through the sample have simultaneously been measured for different values of electrical voltage. The measured electrical signals are weak but well above the noise level. Our observations of the local variations of the electro-chemical signal at a high spatial resolution (at sub-micrometer level) and at short acquisition times will be presented and discussed in detail.

Session Type: Poster

Biogeophysics in the Context of Natural Gas Hydrates: Northern Gulf of Mexico

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Gas hydrates are solid solutions composed of gas molecules encased in cages of water molecules. Most interesting to the energy community are hydrates that contain hydrocarbon gases. In the northern Gulf of Mexico, hydrates of this type form on the sea floor of the continental slope and often occur in mounds located where faults intersect the sea floor. It has been observed that microbial activity is an order of magnitude greater in the vicinity of hydrate outcrops and hydrocarbon vents than elsewhere on the sea floor. The proliferation of microbes around gas hydrate sites is not coincidental; it is the result of a synergistic relationship between hydrocarbon gas hydrates and microbes, i.e. the carbon-rich gases within hydrates provide sustenance for the microbes and biosurfactants produced by the microbes enhance the formation of hydrates. Laboratory experiments show that small concentrations of biosurfactants in the water wetting porous mineral surfaces have the effect of increasing the formation rates and decreasing the induction times of hydrates substantially. Moreover, biosurfactants exhibit surface specificities for particular mineral surfaces; that is, biosurfactant adsorption on a specific mineral surface results in hydrates nucleating and emanating from that surface. Surfaces of smectite clay, common in the northern Gulf, act this way.

Session Type: Oral

Interpretation of self-potential data in contaminated environments

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Self-potential signals are sensitive to in-situ electrochemical processes in the earth, and therefore represent a complementary geophysical tool for characterizing contaminated sites. Interpretation of self-potentials in contaminated settings is often derived from similar mechanisms attributed to the 'geobattery' developed when a subsurface ore body spans a redox gradient in the earth. In both cases, remote sources of the self-potential signal can be attributed to the divergence of a source current density that is related to subsurface electrochemical processes. Concepts relevant to the generation of self-potential signals in contaminated environments, which are often biologically mediated, and the corresponding implications for the interpretation of these signals are discussed. Our interpretation approach involves the localization of self-potential current sources in the earth, which can subsequently be attributed to the locations and relative magnitudes of subsurface electrochemical processes. The self-potential source inversion method is briefly discussed, and an example is provided from a 3D field survey conducted over a DNAPL contaminated site.

Session Type: Oral

The Bio-Geobattery Model: a Contribution to Explain Self-Potential Signals on Contaminated Sites?

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Redox processes occurring in the ground with the presence of ore deposits can generate an electrical field in geological materials, which can be recorded at the ground surface using the Self-Potential method (SP). In this case, strong negative SP anomalies usually reaching a few hundred millivolts have been reported since more than 50 years. These anomalies are explained by a geobattery model. More recently, high SP anomalies have been observed and measured over contaminated sites, where contaminants are biodegraded through microbially mediated redox reactions. This natural electrical source has been termed as an electrochemical source or an "electro-redox" source. Field and lab experiments have shown a proportional relationship between the self-potential and redox potential gradient. Based on these results and on the SP theory developed for massive ore deposits, a bio-geobattery model has been proposed to explain this "electro-redox" source. In this model, bacteria and particularly bacteria that can produce structured extracellular appendages

called "microbial nanowires", play an important role. In this presentation, the biogeobattery model will be presented and discussed with a state-of-the-art of experimental and theoretical works performed to explain SP anomalies on contaminated sites.

Session Type: Oral

The low frequency response of artificial biofilms

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In recent years, research into the use of geophysical methods for monitoring microbial activity within the subsurface has advanced. One of the most promising methods, the induced polarization (IP), has indirectly shown sensitivity to changes in the presence of microbial cells and especially biofilms. The aim of this study is to conclusively show, and quantify if possible, the effect of biofilm accumulation on IP signals. To ensure biofilm accumulation, under controlled conditions, we created an "artificial" alginate gel biofilm which was introduced into an experimental column. We varied the amount of biofilm present in the column and we performed low frequency electrical measurements throughout. Our initial results showed that the IP method is sensitive to biofilm accumulation, after a certain point, and could potentially be used to monitor such microbial structures remotely. Further research with real biofilms under more natural conditions is needed to validate our results.

Session Type: Oral

Magnetic Properties of Magnetic Minerals Produced by Magnetotactic Bacteria and Their Contribution to Sedimentary Magnetism

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Magnetotactic bacteria synthesize single-domain, high chemical purity, and chain-arranged nano- magnetic minerals, magnetite (Fe_3O_4) or greigite (Fe_3S_4). Fossil magnetic minerals (magnetofissils) are ubiquitous in marine and lake sediments. Therefore, the magnetofossils may significantly contribute to magnetic signals of sediments and rocks. They can be important remanence carriers, proxies of palaeoenvironment, and even evidence of searching early life. However, knowledge of magnetic properties of these magnetic minerals is still very limited and identification of magnetofossils from bulk environmental samples is often challenging. The first step is to precisely characterize the magnetosomes and their differences from abiogenic magnetite. We have studied both cultivable and uncultured species through multiple approaches such as magnetism, molecular microbiology, transmission electron microscopy, and mineralogy. Magnetic properties of pure cell samples are also compared with lake sedimentary

samples and chemically-synthetic samples. These studies are useful not only for identifying magnetofossil in environmental samples but also interpretation of magnetic signals in views of palaeoenvionment. Moreover, we have experimentally found that magnetosome magnetite formation can be affected by growth condition of cells, which is contrast to previously thought -- purely biologically controlled.

Session Type: Oral

Cellular dielectric spectroscopy for biological applications

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Dielectric spectroscopy (DS) is a widely used technique to study the properties of cells, proteins and DNA in a fast, label free and noninvasive way. It measures the complex dielectric permitivities as a function of frequency for the given sample. Cellular membrane potential is on of the most important parameter of a living cell and represents the voltage difference between the inside and outside of a cell. Usual values of the membrane potential are in the range of 100 mV. Across a membrane of 2nm thick, this means electric fields of half million V/cm. Theoretical studies have shown that the membrane potential plays a dominant role on the dielectric permitivity of a cell suspension at low frequencies (0Hz-1kHz). Thus the membrane potential can be obtained from a simple measurement of the cell suspension dispersion curves. This talk presents the application of DS to measure and monitor the membrane potential from the low frequency dispersion curves of living cell suspensions.

Session Type: Poster

Interpreting Changes in Fluid Conductivity Due to the Reductive Dissolution of Iron Oxides

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In independent experiments, the iron oxide, goethite, (α-FeOOH) was reductively dissolved using ascorbic acid (abiotic), total membrane fractions from Shewanella oneidensis MR-1 (in vitro) and whole cells (in vivo). We varied the concentration of electron donor to vary rate and monitored pH, fluid conductivity, and ferrous iron concentrations over time; observing increases in fluid conductivity as well as the production of ferrous iron. Abiotic reduction of goethite with 0.01M ascorbic acid produced a 53 μS/cm increase in conductivity and 69 μM Fe(II) over five hours. In vitro experiments with TM and 0.01M sodium formate produced a 70 μS/cm increase in one hour and much larger

concentrations of Fe(II) (647 μM). However, much of this iron adsorbed onto the TM and goethite surfaces and did not contribute to changes in conductivity. Whole cell experiments conducted with 0.01M sodium formate exhibited similar increases in conductivity to abiotic experiments, but produced more ferrous iron (502 μM over five hours) The results of these experiments helped us to identify at least three diagnostic reactions that control fluid conductivity in dissimilatory iron reducing systems. Quantifying the stoichiometry of these reactions allows changes in electrical conductivity over time to be related to reaction rates. The three conductivity controlling reactions are: (1) the reductive dissolution of iron oxides, (2) the adsorption of ferrous iron onto cell and iron oxide surfaces and (3) acid-base reactions. Changes in the amount and charge of dissolved solids due to these reactions controlled the changes in fluid conductivity in our experiments. The method developed for interpreting conductivity changes in lab experiments should be scalable to field systems and similar reactions should control electrical conductivity at larger scales. Identifying these reactions in the lab allows us to target easily measureable conductive species in the field. Geochemical measurements of these species will quantify and support conclusions drawn from the geophysics. Further research in this area will facilitate the mapping and interpretation of changes in conductivity due to microbial activity.

Session Type: Oral

A general theory of the relationship between redox potential and self-potential for abiotic and biotic systems. Forward modeling and inversion

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The presentation is dedicated to the understanding of the self-potential signals that can be generated by biotic and abiotic systems and their application to contaminant plumes and the detection of the corrosion of metal at depth. We will present a general framework called SPOX that embodies the galvanic and geobattery model together and that accounts also for the component assocated with the gradient of the chemical potential of the ionic species in the subsurface. The theory will be compared to both laboratory experiments and field data and we we will demonstrate that we can invert optimally the distribution of the redox potential at depth for a variety of applications in hydrogeophysics and environmental sciences.

Session Type: Oral

Magnetic Properties of Hydrocarbon Contaminated Sediment and Their Linkage with Sedimentary and Geomicrobiological Parameters at the Former Military Air Base Hradcany (CZ)

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A former military air force base at Hradcany, Czech Republic, around 100 km northwest of Prague, is studied by environmental magnetic methods to find out possible changes of magnetic properties in sediments due to hydrocarbon contamination. It is assumed that geomicrobiological activity influences the (trans)formation of iron minerals. Most of contaminants from the unsaturated zone were already remediated during the past 15 years using in situ aerobic biodegradation with combination of venting and air sparging. However, the sediments at and below the groundwater table (GWT) are still severely contaminated with jet fuel as a main contaminant.

This study mainly focuses on hydrocarbon contaminated sediments around the GWT. Sediments were sampled at three different locations up to 4 m depth with a drilling device. Afterwards, the samples were measured for magnetic susceptibility (MS), frequency dependent of MS, isothermal remanent magnetization and hysteresis parameters as well as sedimentary properties (pH, bio-available and total iron; organic carbon). Some selected samples were analyzed for hydrocarbon content and microbiological cell count using maximum probable number (MPN) and microbial community analysis by denaturing gradient gel electrophoresis (DGGE)) technique.

The results obtained from magnetic measurement shows that there is an increase of MS below the GWT in all three profiles (between 2 and 2.5 m depth in different cores at the time of drilling) where the contaminants are mainly located whereas MS decreases significantly in clean sediments at larger depth of around 4 m. There is a good correlation between certain types of hydrocarbon content and MS below the GWT. Our study exhibits that environmental magnetic can be used to assess a hydrocarbon contaminated site and to localize hydrocarbon contamination in a contaminated site within the saturated zone. The results obtained from magnetic, geomicrobiological and soil parameters analyses will be compared and their linkage will be presented.

Session Type: Oral

Quantitative Interpretation of Biogeochemical Processes Associated with In Situ Contaminant Remediation

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Biogeochemical processes associated with in situ remediation of organic and inorganic contaminants have the potential to create or influence a variety of geophysical signatures in subsurface environments. Virtually all of these effects can be traced in some way to redox reactions involved in the oxidation of organic carbon compounds. Redox reactions govern the development (in space and time) of microbial communities, as well as the distribution of aqueous and solid-phase constituents vis-à-vis various mineral dissolution and precipitation reactions. Redox processes have classically been interpreted using equilibrium geochemical speciation approaches, which can provide a simple and tractable way to describe the effects of redox processes on the evolution of aqueous and solid-phase properties in the subsurface, e.g. within a contaminant plume. Recent advances in this approach link growth of microbial populations to geochemical reactions within the equilibrium speciation framework, a potentially powerful strategy that could aid in the interpretation of geophysical signatures of biogeochemical processes. Alternatively, a new generation of mixed kinetic/equilibrium, microbial population dynamics-based reaction models is emerging, which provide (at least in principle) a means for incorporating all relevant biogeochemical processes, including novel biogeophysical effects (e.g. long-range electron transfer through biological redox networks), into (predictive) reactive transport models of natural and remediation-driven subsurface redox phenomena.

Session Type: Oral

Geoelectric signatures as a guide for microbiological sampling during bioremediation of petroleum-contaminated sites.

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Aged, underground petroleum plumes at spill sites exhibit high electrical conductivities measurable with vertical resistivity probes (VRP). Since the presence of an electric resistive petroleum layer was expected, we started an interdisciplinary and multifaceted research project analyzing the microbiological, geochemical and geophysical parameters at a former refinery in Carson City, Michigan. Numerous microbiological techniques were applied to describe the microbial community structure at this site, including culture-based methods, such as the most probable number (MPN) determination of hydrocarbon-degrading

bacteria, and molecular methods, such as the construction of clone libraries based on the 16S rRNA gene. These analyses pointed to the presence of actively hydrocarbon-degrading, syntrophic and methanogenic populations at this site. Photographic images taken with a transmission electron microscope revealed the presence of numerous pili-like appendages on bacteria isolated from the contaminated, but not on bacteria from the non-contaminated background site. These "nanowires" could potentially transport electrons and contribute towards the geoelectrical signatures.

In addition, mesoscale columns were prepared in the laboratory to simulate field conditions. During the course of the 2-year experiment, increased conductivity values were measured in the petroleum containing laboratory columns, comparable to the findings in the field. Results from clone libraries showed that also in the laboratory columns an anaerobic, hydrocarbon-degrading microbial community had been established. Since the microbiological sampling and analyses are more cost and time consuming than geophysical methods, we suggest using geoelectrical signatures to guide the microbiological sampling for monitoring sites that are undergoing bioremediation or natural attenuation of underground petroleum spills.

Session Type: Oral

Methane Hydrates and Methane Seeps: The Potential of Biogeophysical Measurements for Identifying Microbial Hotspots

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Methane hydrate, an icelike combination of water and methane, occurs naturally, but usually at low concentrations, within sediment pore space in permafrost areas and marine continental margins characterized by low temperatures and moderate pressures. Most marine gas hydrates trap methane produced by microbial degradation of organic matter, and studies of sediments in and near gas hydrate zones and oft-associated seafloor seeps have revealed substantial microbial populations and revised our understanding of the extent, diversity, and population of the deep subsurface biosphere. Unfortunately, detection of microbial hotspots on and beneath the seafloor requires cumbersome direct sampling, painstaking analyses, and sheer luck. Biogeophysical sensors deployed on the seafloor or in boreholes could non-invasively map the vigor of microbial activity in and near seeps and above and within the hydrate stability zone, allowing rapid identification of target sample intervals and enhancing understanding of the environmental factors (e.g., sediment type, permeability, temperature) that promote the success of microbial populations at the scale of centimeters. In deep marine environments, biogeophysical techniques based on detecting subtle, microbially-induced variations in electrical conductivity probably face insurmountable challenges. Direct detection of microbes in this setting will likely exploit other physical principles and probably require the acquisition of time series data that can track changes in geophysical properties as microbial activity waxes and wanes.

Session Type: Oral

Bio-Mediated Processes in Soils - Implications and Geophysical Monitoring

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The understanding of soil behavior during the last three hundred years has centered on mechanical principles, geological processes, and later on, mineralogy and the relevance of colloidal chemistry. More recently, research in biology and earth science has enabled important advances in understanding the crucial involvement of microorganisms in the evolution of the earth, their ubiquitous presence in near surface soils and rocks, and their participation in mediating and facilitating most geochemical reactions. Yet, the effect of biological activity on soil mechanical behavior remains largely under-explored in the geotechnical field. Our work has explored four fundamental aspects of bio-geo interaction: (1) the role of geometrical constrains and soil-bacteria mechanical interactions, including restrictions on habitable pore space, traversable interconnected porosity, and sediment-cell interaction, (2) bio-gas generation and its effect on small and large strain properties of sediments, such as Skempton's B parameter, P-wave velocity and liquefaction resistance, (3) bio-cementation effects on stiffness, S-wave velocity and strength as a function of grain size, and (4) the non-linear consequences of biofilm growth on grain surfaces and the decrease in hydraulic conductivity in radial flow conditions, including monitoring methodology and inverse problem solution.

Session Type: Poster

Time-lapse GPR Monitoring of Enhanced Biological Activity in a Sandbox Reactor

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Research at the University of Kansas is evaluating the use of ground-penetrating radar (GPR) to remotely monitor bacterial growth and biodegradation processes in aquifers. A laboratory scale controlled experiment was conducted in a flow-through Plexiglas sandbox reactor using groundwater from a local aquifer as an inoculum. Measured parameters included two-way travel time and amplitude of 1.2 GHz GPR, pH, electrical conductivity, and temperature. Data were collected for 90 days, twice daily both upstream and downstream of nutrient injection ports. After 38 days of baseline conditions, bacterial growth was stimulated. Radar wave velocity and amplitude were shown to decrease down-gradient of the nutrient release wells relative to up-gradient locations. A sharp radar wave velocity gradient was noted in the location of the nutrient release wells. After 60 days, injected nutrient concentrations were doubled. At this time, gaseous bubbles were visually observed down-gradient of the nutrient release wells and radar wave velocity trends reversed, indicating an increase of velocity down-gradient of the nutrient release wells. After 90 days, core was extracted in two locations down-gradient and one location up-gradient of the nutrient release wells for total lipid biomass analysis. Consistencies in trends were observed between lipid concentrations and radar wave velocity changes suggesting that increasing biomass causes a decrease in radar wave velocity. Visual observation of active gas production correlated spatially and temporally with rapid radar wave velocity increase, offering evidence that GPR can monitor the generation of biogenic gasses. Research is ongoing to quantitatively relate GPR signal response to biomass and biogenic gasses.

Session Type: Poster

The Influences of a Different Conductive Fluids Resulting From NAPL Biodegradation on the Bulk Electrical Conductivity of Porous Media – Laboratory Experiment and Numerical Simulation

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NAPL biodegradation may significantly alter the geochemical and petrophysical properties of natural porous media. Therefore simplistic mixing models that consider only the electrical properties of pure NAPL are far from being sufficient. In this research a quantitative model to describe the electrical properties of multi-phase system (water-air-solid-NAPL) will be developed. Unlike "static" models, our new model will consider the biodegradation state at which the NAPL is.

Our research is composed of two stages. In the first we will quantify in the laboratory the electrical conductivity of artificially contaminated soils, first statically (i.e. instantaneous mixtures, including salts to represent biological and geochemical activities) and later dynamically (i.e. allowing biodegradation and resulting geochemical processes). An attempt will be made to relate the laboratory results in an empirical way. The second stage will include two kinds of models: A) a simplistic (capillary tube based) model that will conceptually account for changes in the electrical properties of the porous media considering the hierarchy between the different phases; B) a continuum based numerical flow model that will couple between the flow of the different phases (water-air-NAPL), their transport (including solubility and volatility), and most importantly their fate. The laboratory based data will be used to calibrate our mathematical models. The calibrated model will be used to generate significant dataset that will allow creation of model based petrophysical relations. We will present here our experimental design and preliminary results for both stages of our research.

Session Type: Poster

SP and IP Monitoring of Biogeochemical Evolution and Activity of SRBs in a Simplified Winogradsky Column

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Leading on from an initial experiment already conducted in a 1-D Winogradsky column, which has highlighted the potential for monitoring SP responses following microbial activities a second, 1-D column has been constructed. Self-potential (SP) and induced polarization (IP) geophysical measurements are being monitored in a simple Winogradsky column. The column should allow biofilm growth on homogeneous, non-toxic silica beads (3mm diameter) of a known surface roughness. The experiment column is filled with growth medium prepared by dissolving 0.025M sodium lactate, $FeSO_4$ (1 ppm) and KNO_3 (1 ppm) in Lagan river water. Geophysical observations at spacing of 5cm have been monitored for more than 30 days on the surface of the column to follow biogeochemical evolution and microbial activities in the column 'Real SP' electrodes that minimise chemical reactions on the electrode surface, are being utilised, and compared with Ag-AgCl, in order to record only the SP response of the microbial activity, referenced to an electrode fixed in pristine zone. The pristine zone and column have been connected electrolytically via a salt bridge. A second column, similar to experiment column, has been filled with the same matrix and fluid for biogeochemical analysis (pH, Eh, , Ions, metals and samples for microbes' analysis, SEM). Since H_2S has produced in the column, a change in geophysical responses and geochemical properties were observed. This potentially provides additional insight into the activities of sulphur-reducing bacteria (SRB's; as the anticipated dominant species) in a controlled well-defined environment. The geophysical SP and IP signatures of microbial activities both before and after SRB's dominate are to be recorded and compared to any biogeochemical responses. The results obtained from this experiment should contribute to further understanding of the biogeophysical responses associated with HS^- ion reaction with Ag-AgCl and non-reactive electrodes during the activity of SRBs in complex environments.

Session Type: Oral

Moving Toward Quantifying Kinetics In The Field: Where We Are And What We Need

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Electrical measurements have been shown to be sensitive to changes in hydrogeological properties resulting from microbial-induced alteration of sediment such as mineral precipitation (including biomineralization) and biofilm formation. These processes impact petrophysical properties of porous media and the common dependence of both electrical and fluid flow on interconnected porosity. Additionally, numerous researchers have evaluated the detection problem with respect to microbial changes in biogeochemistry with geophysical tools. Despite the progress that has been made in biogeophysics in recent years, many questions remain, including a few we aim to tackle here: (1) does the presence of the cells themselves change electrical conductivity, (2) how do we numerically model these coupled processes, and (3) how do we quantify kinetics?

We present work toward solving these complex issues. We consider abiotic, in vitro, and in vivo experiments to quantify kinetics during dissimilatory iron reduction. We report laboratory observations of changes in electrical conductivity that are attributed to specific (bio)geochemical reactions involving reductive dissolution of iron oxides. To determine the electrical conductivity changes without the added complexity of cells or biofilms, we introduce an innovative technique to measure metal reduction in vitro using membrane fractions from Shewanella oneidensis. These membrane fractions reduce iron and oxidize electron donors in the absence of cells.

Many conceptual models have been developed that link changes in geophysical signatures to biogeochemical changes. The next question is how to build more quantitative transferable, scaleable relations to enable geophysical monitoring of biogeochemical reactions applicable at the field scale. We present numerical modeling results using PHREEQC [Parkhurst, 1999], which allows users to add kinetics, to refine our conceptual models. PHREEQC allows us to model iron reduction as a dynamic process. We also present results where electrical geophysics is used to estimate parameters controlling first-order kinetic solute mass transfer.

Together, we use our data coupled with numerical modeling to take a first look at an interdisciplinary project considering the kinetics in laboratory and field settings, and discuss future needs for quantifying these changes.

Session Type: Oral

On the Detection of Microbial-Driven Precipitation of Elemental Selenium Using Geoelectrical and Electrodic Potential Signatures

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We measured electrical geophysical (resistivity, induced polarization) and electrodic potential (on Ag-AgCl electrode pairs) signatures during the microbial-mediated precipitation of elemental selenium (Se0), a semi-metallic element having an electrical conductivity of ~0.1 S/m. Electrical geophysical measurements appear insensitive to the onset of Se0 precipitation (visible from the characteristic red particles of monoclinic elemental selenium), with bulk resistivity changes likely dominated by pore fluid conductivity changes associated with the addition of selenite and resulting rate-limited mass transport between relatively hydraulically connected and hydraulically isolated parts of the pore volume. Positive electrodic potentials (relative to an electrode on the influent feed) developed concurrent with elemental selenium precipitation due to changes in redox chemistry local to the electrode surface as a result of the microbial activity. However, the exact mechanism for the electrodic potential is uncertain, the polarity suggesting a cathodic reaction (reduction of the electrode coating) within the column. Our findings indicate that, whereas microbial-induced precipitation of metallic, highly conductive iron mineral phases is readily detectable with electrical measurements (as per previous studies on iron sulfide biomineralization), the geophysical detection of microbial-mediated precipitation of semi-metallic (and presumably non-metallic) mineral phases presents a more challenging task.

Session Type: Plenary

Hyperthermophilic Life

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To-day, hyperthermophilic (“super-heat-loving”) bacteria and archaea are found within high temperature environments, representing the upper temperature border of life. They grow optimally at above 80°C and exhibit an upper temperature border of growth of up to 113°C. Members of the genera Pyrodictium and Pyrolobus even survive at least one hour of autoclaving. In their basically anaerobic environments, hyperthermophiles gain energy by inorganic redox reactions employing compounds like molecular hydrogen, carbon dioxide, sulphur and ferric and ferrous iron. Based on their growth requirements, hyperthermophiles could have existed already on the Early Earth, about 3.9 Gyr ago. In agreement, within the ss rRNA-based phylogenetic tree of life they occupy all the short deep branches closest to the root. The deepest archaeal phylogenetic lineages are represented by the Nanoarchaeota and the Korarchaeota. Cells of the Nanoarchaeota consist of minicocci, only 0.4 µm in diameter. Cultivation of Nanoarchaeum equitans requires the presence of a crenarchaeal host. The N. equitans genome is among the smallest known to date (490,885 bp). Recently, a complete genome sequence has been obtained from enrichment cultures of the Korarchaeota. It revealed an unprecedented heterogeneous

gene complement suggesting that they had diverged very early in the archaeal lineage.

Session Type: Poster

Cyberinfrastructure for biogeophysical monitoring

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Effective biogeophysical monitoring will require the integration of data and models from a range of different disciplines as well as effective tools for cross scientific collaboration. Such data includes, but is not limited to geophysical data , borehole characterization data, sample and sample analysis data, hydrological data, geochemical data and so on. This integration will require an application focused cyberinfrastructure – a research environment that support advanced data acquisition, data storage, data management, data integration, data mining, data visualization and other computing and information processing services over the Internet Part of the research at INL is focused on developing this cyberinfrastructure, which to the largest extent possible makes use of existing open source packages (such as Apache/Tomcat/Axis2, MySQL, PHP, IDV and so on), industry and academia developed data models and data exchange formats (such as NetCDF) as well as the latest Web 2.0 concepts (such as MVC design patterns and webservices). This cyberinfrastructure is used at the DOE sponsored 300 Area IFC and related projects.

This presentation will focus on the challenges and approaches associated with developing and implementing this cyber infrastructure, as well as a discussing open source tools available to all researchers for effective data management and distribution.

Session Type: Oral

Biogeophysics and the Self-Potential Method: The Value of the Galvanic Response

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The self-potential (SP) method is finding increased usage as a valuable tool for biogeophysical monitoring. Many of the anomalous SP signals associated with subsurface microbial activity have been attributed to current flow through endogenous conductive structures, such as mineralization and organic polymers. Under certain conditions, such SP source-generating mechanisms are valid. In contrast, SP anomalies resulting from galvanic mechanisms have been largely ignored or misinterpreted. Diagnostic of certain bacterial metabolic processes, specifically those resulting in the accumulation of electroactive end products, such as Fe(II) or dissolved sulfide, galvanically-mediated SP signals represent a viable and sensitive approach for delineating subsurface redox processes. This presentation focuses on a range of galvanic SP monitoring applications, with a focus on the transition from iron to sulfate reduction during stimulated subsurface bioremediation. Interpretation of anomalous SP signals measured using a variety of electrode materials is also presented, with an exploration of their electrochemical underpinnings.

Session Type: Poster

Use of Electrical Methods to Predict Changes in Properties of Porous Media

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In order for contaminant sequestration through precipitation to be successful, it must be possible to monitor the emplacement of nutrients or other amendments, and monitor resulting reactions in the subsurface.

Methods such as self-potential and complex resistivity are known to be sensitive to biogeochemical processes such as precipitation, oxidation and reduction, and changes at the electrical double layer at grain surfaces. However, there currently is not a quantitative way to predict the macroscopic geophysical signatures associated with property changes that result from biogeochemical processes that occur at the pore scale.

Our research is aimed at developing such a quantitative predictive capability, which will permit quantitative interpretation of electrical geophysical signatures, thereby facilitating accurate monitoring of subsurface contamination and remediation processes.

This presentation will focus on the challenges and approaches associated with this research problem including elucidating the first principles processes that link pore-scale biogeochemical processes with geophysical signatures, scaling of such processes and responses from pore-scale to laboratory-scale experiments, and the modeling necessary to link biogeochemical processes, measured response, and predictive capability.

Session Type: Oral

Geophysical signatures from calcite precipitation driven by urea hydrolysis

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Ureolytically driven calcite precipitation is a promising /in situ/ remediation tool for subsurface divalent radionuclide and trace metal contaminants through co-precipitation. Because subsurface urea-hydrolyzing microorganisms are ubiquitous and many arid western vadose zones and aquifers are saturated (or even oversaturated) with respect calcite, metal sequestration through calcite precipitation should be easily inducible through acceleration of naturally occurring process, and should be sustainable. Successful field applications of such remediation strategies require the capability to predict and, monitor the onset and distribution of the precipitates.

Geophysical methods have the potential to monitor /in situ /precipitation because electrical, dielectric and seismic properties are sensitive to calcite precipitation and the concurrent changes in pore fluid geochemistry. Precipitation of calcite is expected to: (a) reduce the chargeability of the porous media due to its non-polarizable nature, (b) alter the electrical conductivity of the media depending on the degree of pore plugging and direction and magnitude of changes of the TDS of pore fluid, (c) alter the dielectric constant of the porous media and (d) changes in seismic velocity and attenuation. Here we present the time-lapse geophysical signatures associated with a column-scale urea hydrolysis experiment, where the column was packed with material from the Idaho National Laboratory vadose zone research park site, which is analogous to the nearby ^90 Sr INTEC site. The column was saturated with site groundwater and amended with molasses and urea to stimulate ureolysis. Microbial, isotopic and analytical geochemical sampling was carried out to characterize the reaction processes and aid in interpretation of the observed geophysical datasets. Our results show that ureolysis-driven calcite precipitation produces detectable geophysical signatures and ongoing efforts are underway to establish the petrophysics of this precipitation process. Results obtained from this experiment will be used in conjunction with geophysical and biogeochemical monitoring data, collected during a field-scale urolysis experiment, as well as with reactive transport modeling results to assess the efficacy and sustainability of urea-driven calcite precipitation for sequestrating mobile subsurface contaminants.

Session Type: Oral

A Comparison of Electrodic Potential Signals and Self-potential Signals in Microbial Induced Sulfate Reducing Environments

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By employing a column experiment using dual sensor Ag-AgCl electrodes we compared self-potential signals resulting from possible ‘geobattery’ effect with electrodic voltages based on galvanic cell effect in the presence of dissolved sulfide. Two experimental columns were packed with fine-grained glass beads, and water from the Langan River (Belfast, UK), known to contain sulfate reducers, was obtained. Abiotic column was continuously circulated (close loop) with sterilized river water as a control, while the biotic column retained biologically active river water. Six Ag-AgCl electrodes equally spaced along one side of each column, and tree Ag-AgCl self-potential electrodes (where the metal is in electrolytic contact with the column via a sterilized 1M KCl agar gel), were placed on the other side of each column. Electrical potential were recorded continuously between both sensor electrode types, and complex resistivity and fluid geochemistry measurements (pH, Eh, temperature and conductivity) were taken once daily. Over the 10 day experiment duration, darkening of the circulating fluid, biofilm formation, and a characteristic sulfurous smell were observed in biotic column, whereas no such color or smell change was observed for the control column. Electrodic potential approached 570 mV in biotic column, whereas insignificant and stable readings (~8 mV) were detected in the control one. Daily fluctuation of electrodic potential was noticed in biotic column. Self-potential signals were consistently only 1-8 mV in both columns. The results suggest that although electrodic potentials respond to the microbial driven sulfate reduction at the electrode surface in the fluid chemistry, there is no measurable self-potential (geobattery) effect associated with this microbial proces.