Final Project Report

DE-FG02-08ER64632 "Funding to Support the Participation of Scientists Engaged in DOE Research in the 2008 AGU Chapman Conference on Biogeophysics"

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This project provided travel awards for scientists engaged in research relevant to the DOE mission to participate in the American Geophysical Union (AGU) Chapman Conference on Biogeophysics held October 13-16, 2008, in Portland, Maine (http://www.agu.org/meetings/chapman/2008/fcall/). The objective of this Chapman Conference was to bring together geophysicists, biophysicists, geochemists, geomicrobiologists, and environmental microbiologists that are leaders in their field and have a personal interest in exploring this new interdisciplinary field or are conducting multidisciplinary research with potential impact on biogeophysics in order to define the current state of the science, identify the critical questions facing the community and to generate a roadmap for establishing biogeophysics as a critical subdiscipline of earth science research.

About sixty participants engaged in five sessions designed to address the following five questions: (1) What are the direct geophysical signatures of microbial cells and biofilms? (2) How do microbe-mineral transformations generate geophysical signatures as a result of changes to the physicochemical properties of the grain-fluid interface? (3) What geophysical signatures are associated with the generation of microbial-driven redox chemistry? (4) How can Biogeophysics be used to improve understanding of biogeochemical processes in natural and anthropogenic environments? (5) Could Biogeophysics ultimately contribute to exploration of microbial activity in extreme environments such as the deep ocean?

Forty oral presentations were spread across these five sessions that took place over a 3.5 day period. Extensive time was allotted to facilitate discussions and RIMS Progress Information interactions between participants. Plenary speakers reviewed 'exploiting microbe-electrode interactions for environmental restoration (Derek Lovley, University of Massachusetts), 'voltammetric solid state (micro) electrodes as in situ chemical sensors to understand microbial processes' (George Luther, University of Delaware) and 'the mystery of deep subsurface microorganisms' (Bo Barker Jorgensen, University of Aarhus). An evening poster session (fourteen presentations) provided a forum for enthusiastic discussion around some of the more controversial biogeophysics research conducted in recent years.

The DOE funding that supported this Chapman Conference helped to catalyze a unique communication between geophysicists, biogeochemists and microbiologists to explore the opportunities for research presented by linking geophysical signals with microbial processes in the Earth. Although the existence of these geophysical signals was reinforced by many of the presentations, it was clear from the enthusiastic discussions around each talk that the mechanisms generating these signals remain uncertain. For example, some of the mechanisms invoked by geophysicists to explain natural sources of electrical current in the earth (measured with the self potential geophysical technique) are based on

microbiological research suggesting that microbes can facilitate electronic conduction over large spatial scales via connections of appendages. As the electronic conduction of such appendages is still a subject of intense research at the nanoscale, some participants felt that it was premature to be suggesting that electronic conduction via microbes could be invoked to explain field-scale geolectrical signatures. This issue led to more focused discussions around the source mechanisms of self potentials in general, with a lively debate developing over whether large self potential signals repeatedly observed over contaminated sites of active microbial degradation even necessitated the presence of an electron conductor.

Similar discussions also developed around presentations on electrical and seismic signals associated with microbial processes as observed in laboratory experiments performed by multiple research groups. Although geophysical signals resulting from microbial activity were again demonstrated, mostly conceptual models were invoked to explain these signals. The Chapman Conference thus highlighted the need for efforts to progress from observation/monitoring of biogeophysical signatures (the primary research of the last ten years) to the development of modeling approaches required to validate source mechanisms. Although advances in this arena have been made for cellular suspensions (e.g. dielectric spectroscopy in biophysics research for medical practices), discussion during this meeting highlighted that a porous medium represents a much harder modeling challenge. The complexity of the situation results from the fact that, in addition to the possible geophysical response associated with microbes/biofilms themselves (the target of experiments on cellular suspensions), biogeochemical alteration of the pore fluid chemistry and pore structure must be accounted for. These latter two effects are incompletely understood and very hard to constrain experimentally. There is a need for in-situ pore-scale imaging and quantitative analyses of these dynamic processes.

Other discussions developed around the techniques themselves, with questions raised about the sensitivity and resolution of geophysical measurements and whether some of the small signals faithfully recorded in the laboratory could be accurately recorded in field environments. However, presentations were given on recent research at field sites (where bioremediation monitoring strategies are being investigated) producing data consistent with laboratory findings. Also on instrumentation aspects, substantial discussion developed around the possible implementation of micro-electrodes (voltammetry), as used highly successfully to probe sulfur redox chemistry in the deep oceans, could be adopted in conjunction with geophysical surveys to better understand sulfide chemistry induced by microbial processes occurring in the near surface. Unlike geophysical techniques, these methods are sensitive to the geochemical conditions at the immediate vicinity of the electrode. In addition to exploring sulfur cycling in natural environments e.g. occurring in wetlands, the application of these voltammetric techniques for improving understanding of bioremediation processes associated with sulfate reducing bacteria was explored. In fact, presentations on a simpler electrodic method, relying on sensitivity of the electrode to aqueous chemistry at the point of measurement based on a galvanic cell effect, were presented for studies conducted at bioremediation sites. The linkage between small scale voltammetry (where speciation can be resolved) and these simpler galvanic cell electrodic techniques formed another focus of extensive discussion.

The sixty participants were an international group of academics, graduate students and scientists at government laboratories engaged in biogeophysics related research. Scientists from Europe, Israel and China traveled to engage North American colleagues in this highly focused 3.5 day meeting. The group included an approximately equal mix of microbiologists, biogeochemists and near surface geophysicists. The program committee consisted of Estella Atekwana (Oklahoma State University), Susan Brantley (Pennsylvania State University), Yuri Gorby (J. Craig Venter Institute), Susan Hubbard (Lawrence Berkeley National Laboratory), Robert Kalin (University of Strathclyde, UK), Rosemary Knight (Stanford University), Dale Morgan (Massachusetts Institute of Technology), Kenneth Nealson (University of Southern California), Andre Revil (Colorado School of Mines), Silvia Rossbach (Western Michigan University), Lee Slater (Rutgers University) and Nathan Yee (Rutgers University).

The recipients of the DOE travel awards were [1] Dennis Bazylinski (University of Nevada, Las Vegas), [2] Yuri Gorby (Craig Venter Institute), [3] Carlos Santamarina (Georgia Tech), [4] Susan Hubbard (Lawrence Berkeley Laboratory, [5] Roelof Versteeg (Idaho National Laboratory, [6] Eric Roden (University of Wisconsin), [7] George Luther (University of Delaware), and [8] Jinsong Chen (Lawrence Berkeley Laboratory)

The following two peer-reviewed articles were made possible in part as a result of the funding provided to support this Chapman Conference:

[1] Atekwana, A. and Slater, L., Biogeophysics: A New Frontier in Earth Science Research, *Reviews of Geophysics*, Submitted 03/01/09

[2] Slater, L. and Atekwana, A., 2009, Exploring the Geophysical Signatures Associated With Microbial Processes in the Earth: Biogeophysics Chapman Conference, Portland, Maine, 13-16 October, 2008, *EOS, Transactions of the American Geophysical Union*, 90 (10), p. 83

** About 50% of this report material is taken from an extended version of the Meeting Report that was submitted to the AGU news magazine EOS and is available as online supplemental content.