ELECTROCHEMICAL TECHNIQUES FOR LONG-TERM, REMOTE SENSING OF POTENTIAL MICROBIAL ACTIVITY IN THE MARTIAN SUBSURFACE A. Martin[1] C. E. Turick[2], C. E. Milliken[3], H. Colon-Mercado[4], S. Greenway[5] and J. M. Henson[6].
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Introduction: Evidence of life on Mars has accumulated over the last few years. In particular, speculation regarding the potential presence for methanogens [1] and dissimilatory iron reducing bacteria [2] has garnered considerable attention. If life sustaining conditions existed on Mars in the past, the Martian subsurface provides the best opportunity at present to harbor microbial life [3]. The subsurface would provide protection from adverse environmental factors like desiccation and UV radiation [3]. The demonstration that a Mars soil analog with supplemental water supports the activity and growth of methanogens [1] suggests that required micronutrients could be present as well.

While a number of potentially suitable conditions may exist on Mars that could support extant microbial life [3], metabolic activity may be low [1], hence methods for long-term monitoring need to address this likelihood otherwise extant life may go undetected. The detection of extant microbial life on other worlds such as Mars provides a number of logistic challenges, especially sample collection and analyses.

Approach: We have developed techniques to monitor biogeochemical changes and microbial activity in the subsurface without need for sample recovery or laboratory tests. Our in-situ approach uses electrochemical techniques to monitor progress of biogeochemical activities and/or as a sentinel technology for environmental changes that result from microbial activity.

Evidence of microbial activity and subsequent geochemical alterations include: increases in cell numbers; carbon source conversion; changes in mineralogy; and increased soluble metal content in the subsurface. A multi-phasic electrochemical approach incorporating voltammetric techniques [4] and electrochemical impedance spectroscopy [5] offers enormous potential to provide valuable information about changes to these subsurface parameters and microbial behavior, in-situ. Inexpensive patterned electrode arrays imbedded into subsurface probes provide electrochemical data pertaining to the subsurface without the need to remove samples. This allows for a greater monitoring frequecy needed for increased precision. This approach will also be useful in directing sampling activities to specific sites of interest, based on electrochemical monitoring and is designed to be run in conjunction with conventional tests as needed for confirmation of results.

Results and Discussion: To date we have used cyclic voltammetry to demonstrate alterations in electron transfer properties during microbial activity in a methanogenic consortium. We also used this approach to confirm that electron transfer was occurring at the microbial surface and not associated with the bulk phase liquid [6]. In separate studies, cyclic voltammetry was also used to characterize extracellular electron transfer reactions during dissimilatory iron reduction [4]. Impedance studies [5] focused on the following: (1) phase shift (φ), indicative of geochemical change at low frequencies (0.01 -1.0 Hz) and bacterial density at mid-level frequencies (10-1000 Hz); (2) conductive energy storage/polarization via complex conductivity (σ”), related to cellular activity; (3) relative permittivity ($\varepsilon'/\varepsilon_0$), a measure of cell membrane charge and indicates cell viability; as well as (4) total impedance, which is useful in determining changes in fluid properties due to microbial growth.

This in-situ analytical approach could be incorporated into existing drilling techniques designed to penetrate up to 1 m into the subsurface of Mars [7] and incorporate electrode arrays for long term monitoring.

References:

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