SOLITARY PROBE FOR ELECTROCHEMICAL ANALYSIS AND REPORTING (SPEAR), A MULTIPLEX INSTRUMENT FOR ELECTROCHEMICAL ANALYSIS OF HABITABLE ENVIRONMENTS

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Life below a planet's surface relies on energy from chemical oxidants and reductants (i.e. redox reactions). If an environment is at temperature that is suitable for life and liquid water is present, then, the availability of redox energy indicates habitability. Subsurface redox interfaces and are therefore priority targets in the search for life [1]. On Earth, redox interfaces are common in sediments, wet sand deposits and soil [2] and the shape and evolution of the electrochemical profiles can be used to evaluate whether life is present and active [3]. On Mars, redox interfaces occur between the oxidized top dust and the underlying basalt or olivine sand. Liquid water (another key requirement for life as we know it) was not directly observed on Mars.

Curiosity/Chem-Cam observations have revealed another gradient of interest in the Mars regolith, in the form of Mn-enriched bands below the surface [4]. It is unclear whether a redox gradient is associated with this Mn-rich band as no electrochemical probes are available on Curiosity. Other energy-rich interfaces with liquid water present may yet exist on Mars near spring zones, brines, in slope linae and bellow ice packs. Mineral deposits mixed with liquid phases and ice may also be present on Europa, Enceladus and Titan.

In sediments, electrochemical gradients are commonly analyzed by moving the electrodes back and forth across redox layers as reading are made. This disruption impedes making repeated measurements that are reproducible and accurate. It also hinders the ability to study chemical evolution of gradients.

We have developed an instrument called Solitary Probe for Electrochemical Analysis and Reporting (SPEAR) and software that can analyze chemical gradients in penetrable environments without using manipulators. This instrument has no moving parts and consists of electronic hardware, custom software and probes with up to 64 working electrodes, 8 reference electrode and 8 counter electrode. The instrument cycles through combinations of electrodes and makes a full suite of electrochemical measurements (including redox potential, cyclic voltammetry, differential pulse voltammetry, electrical conductivity and impedance). The SPEAR instrument can analyze chemical gradients and their evolution in wet environments such as mud, sediment, soil and sand, 25cm deep 0.8 mm resolution.

We show results indicating the performance of the SPEAR instrument in artificial gradients (deep gels and quartz sand deposits flooded with salty solution and spiked with oxidants and reductants at various depths). Experimental designs vary: in some cases the base layer contains a ferrous iron-bearing mineral sand such as olivine, and the upper layer contains a ferric iron bearing mineral such as hematite. In other experiments, the solution or gel at the base of the gradient may contains reducing chemicals (such as ferrous chloride or hydrogen sulfide) and the upper surface of the quartz sand is exposed to air or capped with gel containing oxidizing chemicals.

Chemicals of interests for Mars analogues in redox interface experiments are: oxidants such as nitrate, sulfate, perchlorate, Fe^{3+} and Mn^{4+} and reductants such as ammonium, hydrogen sulfide, amorphous iron sulfide, Fe^{2+} and Mn^{2+}

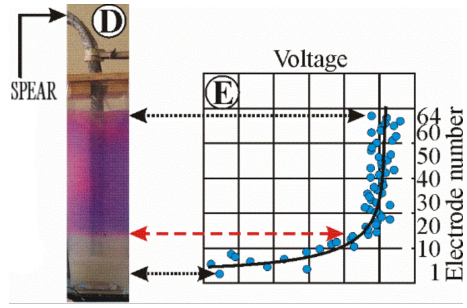

Fig. 1. SPEAR instrument probe (64 working electrodes, one reference electrode and one counter electrode) analyzing a redox potential profile in a gel with artificial H_2S/O_2 gradient. The redox interface was made visible with 0.1% resazurin. For each point the instrument also performs cyclic voltammetry analyses.

References:

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