

**APPLICABILITY OF ELECTRICAL AND ELECTROANALYTICAL TECHNIQUES TO DETECT WATER AND CHARACTERIZE THE GEOCHEMISTRY OF UNDISTURBED PLANETARY SOILS.** S. Seshadri<sup>1</sup>, M.G. Buehler<sup>1</sup>, R.C. Anderson<sup>1</sup>, G.M. Kuhlman,<sup>1</sup> D. Keymeulen,<sup>1</sup> I.W. Cheung<sup>1</sup> and M.G. Schaap<sup>2</sup>, <sup>1</sup>Jet Propulsion Laboratory, California Institute of Technology, MS 300-315, 4800 Oak Grove, Drive, Pasadena, CA 91109-8099; [Suresh.seshadri@jpl.nasa.gov](mailto:Suresh.seshadri@jpl.nasa.gov), <sup>2</sup>Univ. of California at Riverside, USDA/ARS GEBJ Salinity Laboratory, 450 Big Springs Road, Riverside, CA 92507.

**Introduction:** The search for life is a primary goal of NASA's planetary exploration program. The search is, of necessity, tiered in both the detection approach (looking for evidence of microbial fossils or the presence of water in the geological history of a planetary body and/or looking for evidence of water, energy sources, precursors to life, signatures of life and/or life itself in the present day planetary environment) and in the survey method (scale, range, specificity) employed. Terrestrial investigations suggests that life as we know it requires water. Thus, the search for extant microbial life and habitats requires identifying water-bearing soils. Determining Reduction-Oxidation (REDOX) couples present in water, once it is found, provides information on soil geochemistry and identifies potential chemical energy sources for life.

Mars offers a near-term target for conducting this search. The identification of gully formation [1], layered deposits [2] and elemental ratios of bromine and chlorine [3] present indirect evidence that water was abundant locally in the Martian past. Additionally, Viking images of polar ice and frost formation on the surface of Mars demonstrate that water can exist in at least some near-surface regions of present-day Mars. Atmospheric pressure data further suggest that liquid water may be stable for short periods of time in the mid-latitudes of the Martian surface. [4] Measurements of the global distribution of hydrogen in the Martian regolith offer tantalizing indirect evidence that water may at least exist in near-surface soils. [5] Evidently, any water to be found is likely to exist as soil mixtures at levels ranging between ~0.5% and ~5 %.

These observations raise the question of how one can easily perform in-situ surveys to uniquely identify soils containing water/ice, determine the relative abundance of water and characterize soil geochemistry. Such surveys would optimize the use of other instruments capable of performing more detailed in-situ measurements to identify suitable habitats for life and/or detect life itself. These maps would also help identify the most promising samples to return back to earth for more complete laboratory analysis than possible on a future rover or subsurface explorer. Instruments suitable for this purpose must be capable of directly investigating native arid soils.

**Current practice:** In-situ instruments on existing rovers provide indirect evidence of the role of water in the geologic history of Mars. However, they do not distinguish between ancient or recent geologic events. Nor do they uniquely identify water currently present in soils.

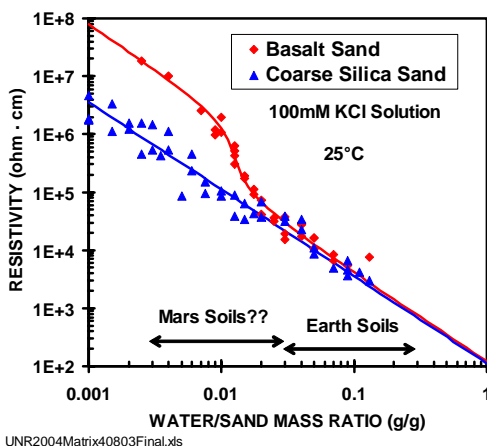
Calorimeters and evolved gas analyzers combined with mass spectrometers can provide unambiguous detection of water with good sensitivity. However, these instruments also require extensive sample handling and/or consumables, limiting their use in large-scale robotic surveys. In-situ neutron and IR spectrometer instruments have a survey capability to detect low concentrations of soil water. However, IR spectroscopy only samples the very top of the soil surface and cannot look deeper into the soil. Because of the interaction with the Martian atmosphere, the surface may have a much lower water content than somewhat deeper soil layers, as often occurs in terrestrial desert soils. Neutron spectroscopy measurements probe near-surface soils, but are sensitive to hydrogen, not water per se. Even if correlations between hydrogen and water are established for Mars soils, neutron scattering measurements will still not distinguish between liquid water, ice and water present in hydrated minerals.

Electrical soil surveying techniques also exist. DC electrical resistivity measurements are presently used in near-surface terrestrial surveys of permafrost regions and in agriculture. Ground Penetrating Radar (GPR) is useful to qualitatively identify stratigraphy and soil layering, but is a poor detector of water in soils or ice because it operates at frequencies where the dielectric response of provides no discrimination from the background soil/mineral matrix. This limitation can be overcome by lower frequency impedometric measurements since the dielectric constant of water and ice (80) at the operating frequencies is sufficiently higher than that of most minerals (~3-20), providing increased instrument sensitivity to the water/ice signal. However, the ubiquity of water on earth means that these techniques are rarely used to measure soils with the expected aridity of Mars. Laboratory electroanalytical instruments such as wet chemistry labs, while not useful to identify water in native soils because the measurement protocols typically require the addition of water, are valuable to investigate the aqueous geochemis-

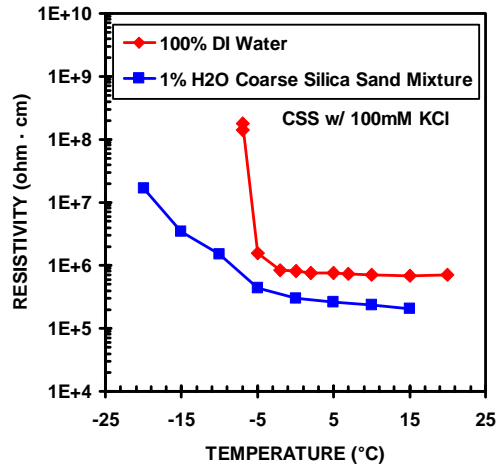
try of soils for existing REDOX couples once water is found. Such techniques are presently used to monitor the environment and bioremediation of ionic contamination of terrestrial groundwater and are being developed in instruments for use on Mars. However, these measurements also usually involve extensive sample handling and/or consumables, limiting their use in large-scale robotic surveys. The experimental results we present test the feasibility of performing both electrical and electroanalytical measurements directly in soils with moisture levels expected on Mars.

**Results:** The data in Figure 1 show that resistivity measurements are sensitive to the presence of <0.5% water mixed with soil. Figure 2 shows that the increased resistivity of soils at temperatures below the freezing point of water remains within measurable limits due to the presence of dissolved ions in the water/soil mixture. Impedance spectroscopy data in figure 3 shows that this technique, while also sensitive to <1% water mixed with soil, can also be used to identify water present as hydrated minerals. Figure 4 demonstrates that “wet” chemical analysis of soils is feasible in soils containing moisture levels less than 1%. These data indicate the feasibility of using electrical and electroanalytical methods for in-situ planetary surveys.

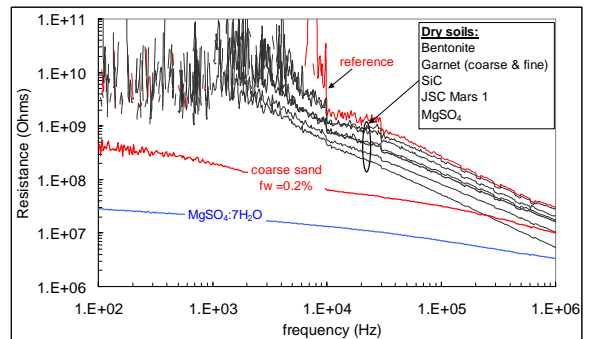
**References:** [1] Malin, M.C., and Edgett, K.S., (2000), *Science*, vol. 288, no. 5475, pp. 2330-2335. [2] Grotzinger, J. P. (2004) *AGU Fall Meeting*, abst. #P24A-01. [3] Zipfel, J. (2004) *AGU Fall Meeting*, abst. #P13B-03. [4] Mischna, M. A., and Richardson, M.I. (2004) *AGU Fall Meeting*, abst. #P13A-0977. [5] Boynton, W., et al., (2004), *35th LPSC*, abstract no.1950.



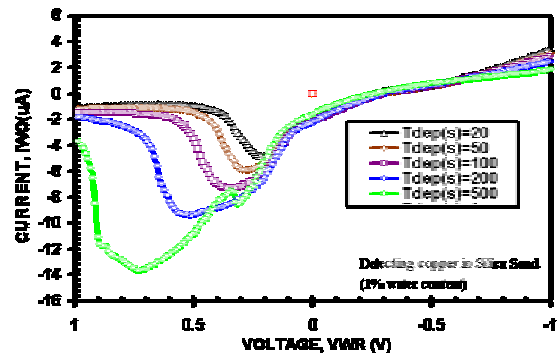
**Figure 1:** Resistivity of two sands indicates that instrument sensitivity is sufficient for the likely range of moisture levels in Mars soils.



**Figure 2:** Temperature dependence of coarse silica sand showing a slower increase in resistivity for a soil mixture than for pure water with decreasing temperature below the freezing point of water due to dissolved ions.



**Figure 3:** Measured frequency response of the complex impedance of soils indicates that the method is sensitive to water contained in hydrated minerals.



**Figure 4:** Wet chemical analysis techniques are used to determine the ionic speciation of solvents in aqueous media. Measured Anodic Stripping Voltammetry (ASV) data of copper acetate solution in coarse silica sand indicates that these measurements can also be made directly in soils with moisture levels as little as 0.5%.