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Sounding of Groundwater Through Conductive Media in Mars Analog Environments Using Transient Electromagnetics and Low Frequency GPR.

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INTRODUCTION: This study compares the use of (diffusive) Transient Electromagnetics (TEM) for sounding of subsurface water in conductive Mars analog environments to the use of (propagative) Ground-Penetrating Radar (GPR) for the same purpose. We show data from three field studies: 1) Radar sounding data (GPR) from the Nubian aquifer, Bahria Oasis, Egypt; 2) Diffusive sounding data (TEM) from Pima County, Arizona; and 3) Shallower sounding data using the Fast-Turnoff TEM method from Pe¤a de Hierro in the Rio Tinto area, Spain. The latter is data from work conducted under the auspices of the Mars Analog Research and Technology Experiment (MARTE). POTENTIAL OF TEM: A TEM survey was carried out in Pima County, Arizona, in January 2003. Data was collected using 100 m Tx loops, a ferrite-cored magnetic coil Rx antenna, and a sounding frequency of 16 Hz. The dataset has ~500 m depth of investigation, shows a ~120 m depth to the water table (confirmed by several USGS test wells in the area), and a conductive (~20-40 Ωm) clay-rich soil above the water table. The Rio Tinto Fast-Turnoff TEM data was collected using 40 m Tx loops, 10 m Rx loops, and a 32 Hz sounding frequency. Note ~200 m depth of investigation and a conductive high at ~80 m depth (interpreted as water table). Data was also collected using 20 m Tx loops (10 m Rx loops) in other parts of the area. Note ~50 m depth of investigation and a conductive high at ~15 m depth (interpreted as subsurface water flow under mine tailings matching surface flows seen coming out from under the tailings, and shown on maps). Both of these interpretations were roughly confirmed by preliminary results from the MARTE ground truth drilling campaign carried out in September and October 2003. POTENTIAL OF GPR: A GPR experiment was carried out in February 2003 in the Bahria Oasis in the western Egyptian desert, using a 2 MHz monostatic GPR, mapping the Nubian Aquifer at depths of 100-900 m, beneath a thick layer of homogenous marine sedimentary quaternary and tertiary structures constituted mainly of highly resistive dry porous dolomite, illinite, limestone and sandstone, given a reasonable knowledge of the local geoelectrical properties of the crust. The GPR was able to map the first interface between the dolomitic limestone and the gravel, while the detection of the deep subsurface water table remains uncertain due to the uncertainties arising from some instrumentational and geoelectrical problems. In locations were the water table was at shallower depths (less then 200 m), but with the presence of very thin layers (less than 0.5 m) of reddish dry clays, the technique failed to probe the moist interface and to map any significant stratigraphy. CONCLUSIONS: GPR excels in resolution, productivity (logistical efficiency) and is well suited for the shallower applications, but is more sensitive to highly conductive layers (result of wave propagation and higher frequencies), and achieves considerably smaller depths of investigation than TEM. The (diffusive) TEM method uses roughly two orders of magnitude lower sounding

frequencies than GPR, is less sensitive to highly conductive layers, achieves considerably deeper depths of investigation, and is more suitable for sounding very deep subsurface water. Compared with GPR, TEM suffers for very shallow applications in terms of resolution and logistical efficiency. Fast-Turnoff TEM, with its very early measured time windows, achieves higher resolution than conventional TEM in shallow applications, and somewhat bridges the gap between GPR and TEM in terms of depths of investigation and suitable applications.

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