MARS ANALOG INVESTIGATIONS OF THE WEST EGYPTIAN DESERT UTILIZING MULTI-FREQUENCY GPR AND OTHER ELECTROMAGNETIC SOUNDING TECHNIQUES.

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Introduction: During November 2005, research teams from the Lunar and Planetary Institute (LPI), Southwest Research Institute (SwRI®), and Centre d'étude des Environnements Terrestre et Planétaires (CETP), in cooperation with Cairo University and the Egyptian Geological Survey and Mining Authority (EGSMA), conducted geophysical sounding investigations at two locations in the West Egyptian Desert as potential geologic and hydrologic analogs of Mars. These investigations included ground-penetrating radar (GPR) studies, using multiple instruments and techniques, at central frequencies ranging from 2 – 500 MHz. Schlumberger DC resistivity vertical electrical sounding (VES) and transient electromagnetic (TEM) sounding data, and cliff exposure field samples for later laboratory characterization of the principal stratigraphic units, were also acquired at these locations. Although our analysis is still ongoing, initial findings indicate that considerable ambiguity exists in the geologic and hydrologic interpretation of data acquired from single-instrument investigations—ambiguity that is substantially reduced by the application of multiple techniques and multiple frequencies. These results suggest that obtaining an accurate understanding of the geology and distribution of water in the Martian subsurface will require a comprehensive program of geophysical investigations, employing multiple instruments, techniques and platforms.

Locations: Our field investigations were conducted in the western desert of Egypt, near the Bahariya and Farafra Oases, which are located approximately 360 and 600 km southwest of Cairo (Fig. 1). The first area, located ~14-km southwest of Bahariya, is where the erosional remnants of Quarternary-age basalts, interbedded with sandstones, creates a region of several hundred meter high hills and plateaus. Our field site was located on top of one of these plateaus (elevation ~220 m above the local water table) which was capped by a ~10-30 cm-thick highly weathered basalt, mantled by eolian sand. The second area was located on the El-Quss Abu Sa'id plateau (~240 m above the local water table), which is capped by lower Eocene-age, fluvial-marine limestone (Fig. 2A) and lies ~18 km northwest of Farafra.

Figure 1. Location of the two field sites, near the Bahariya and Farafra Oases (CNES SPOT 5 image).

Instruments and Procedure: The SwRI team investigated the resistivity of the subsurface as a function of depth using VES and TEM data [1]. The shallow measurements (to depths of ~60 m) were obtained with a DC resistivity meter manufactured by Advanced Geosciences, Inc. The TEM system is manufactured by Geonics, Ltd., and includes both TEM47 and TEM57 transmitters, and a PROTEM receiver, with both high-frequency and low-frequency coils. The system probes the subsurface to depths in the range of 40 to 300 m. Data were acquired at each site using both 40-m and 300-m transmitter loops.

The LPI team used two commercial GPRs (a SIR 3000 and SIR 10A) with three antenna systems (an unshielded Model 3200 Multiple Low-Frequency (MLF) 16 – 80 MHz central frequency bistatic antenna, a Model 3207 100 MHz shielded bistatic antenna, and a Model 3102 500-MHz antenna)—all manufactured by Geophysical Survey Systems, Inc. (GSSI). Data at 20-, 100- and 500-MHz were generally acquired along ~300 m profiles in continuous mode, stacking 32 to 64 times, with a time range of 500 to 4000 ns. (On the El-Quss Abu Sa'id plateau, data were also acquired at 20 MHz in continuous mode over a 3 km-long transect using a truck-mounted antenna system, Fig. 2C). At 16- and 20-MHz, stationary soundings were also conducted at the beginning, midpoint, and end of each profile, where the signal

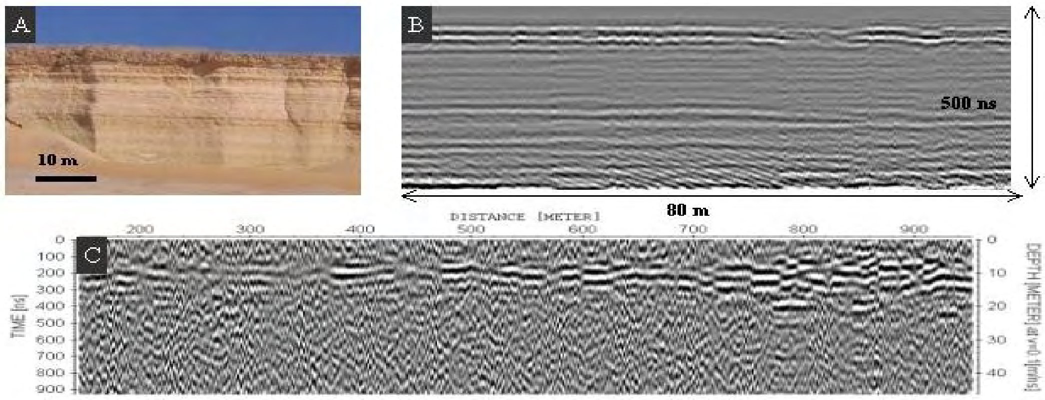

Figure 2. (A) Exposure of local carbonate stratigraphy with interbedded marls. Corresponding (B) 80-m 100-MHz and (C) 1-km 20-MHz continuous profiles of this same stratigraphy.

was stacked from 2048 to 16384 times with a time range of 4000 to 8000 ns.

The GPR used by the CETP team is a refinement of the prototype for the 2007 NetLander mission. The TAPIR (Terrestrial And Planetary Investigation by Radar) instrument is a stationary imaging low-frequency GPR that operates from 2 to 6 MHz with a 500 ns pulse duration, stacks up to 2^{31}, and can determine both the depth and inclination of a subsurface reflector by measuring the two horizontal electrical components and the three magnetic components of the reflected wave [2]. To calculate the propagation vectors of the measured electric and magnetic components of the echoes requires knowledge of the electrical characteristics of the shallow subsurface. These parameters can be determined from the characteristics of the transmitting electrical antennas (i.e., current and driving-point impedance) which depend on the nature of the ground on which they are positioned—a relationship discussed in greater detail in [2].

Finally, in addition to the data acquired by the various field instruments, samples of the principal stratigraphic units were also obtained from various exposures for compositional, physical, and electromagnetic characterization at LPI.

Initial Results: Due to a combination of factors, which include equipment loss, malfunctions in the field, and lingering data transcription difficulties, our most comprehensive suite of geophysical data was obtained on the El-Quss Abu Sa'id plateau, located ~18 km northwest of the Farafra Oasis. Therefore, our initial data analysis has focused on this region. More detailed discussions of each of the principal data sets are contained in [1, 2]. Here we present only a brief synopsis, noting that this analysis is preliminary, still ongoing, and subject to revision as the various data sets and lab results are examined in greater detail during the coming months.

Simultaneous inversion of the resistivity and TEM data at three sites on the El-Quss Abu Sa'id plateau, spaced ~100 m apart along a 200-m-long transect, revealed a 3-layer structure exhibiting a 60-m-thick 9 ohm-m near surface unit, overlying a 180-m-thick 3 ohm-m unit, overlying a third unit with a resistivity consistent with freshwater [1]. Based on the resistivity of this third unit, independent well observations, and the ~240 m depth of this unit below the local surface, it is interpreted to be part of the Nubian aquifer.

Initial analysis of the GSSI 20-, 100- and 500-MHz continuous-mode radar data reveal some layering in the top 20 m, but also rapid signal attenuation with depth, consistent with VES and TEM results [1, 2]. However, the 16- and 20-MHz stationary stacked data have yet to be examined.

The TAPIR data [2] show several regions of apparent pulse returns from 1500 to 6000 ns and greater. Assuming a dielectric constant of 9, the longer time delays translate to depths of up to 300 m. However, penetration to these depths appears inconsistent with the low resistivities indicated by the TEM/VES survey and with the attenuation experienced by the GSSI GPRs at higher frequency. Additional insights as to whether these echos are multiples from shallower interfaces, or are due to other causes, are expected as our data analysis continues.

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References: [1] Dinwiddie et al. (2006) these abstracts. [2] Ciarletti et al. (2006) these abstracts.