ON THE DIELECTRIC PROPERTIES OF THE MARTIAN-LIKE SURFACE SEDIMENTS. E. Heggy[1], S. M. Clifford[1], R. V. Morris[2], P.Paillou[3] and G. Ruffie[4], [1]Lunar and Planetary Institute, 3600 bay Area Blvd., 77058-1113, Houston, TX (heggy@lpi.usra.edu & clifford@lpi.usra.edu), [2]NASA Johnson Space Center, Houston, TX 77058, (richard.v.morris@nasa.gov), [3]Observatoire de Bordeaux, Floirac, France (paillou@obs.u-bordeaux1.fr), [3]Ecole National de Chimie et Physique de Bordeaux, Pessac, France (g.ruffie@enscpb.fr).

Abstract: We have undertaken laboratory electromagnetic characterization of the total set of minerals identified by TES [1] on the Martian surface in order to investigate experimentally the dielectric properties of the sediments covering it in the frequency range from 1 to 30 MHz. Volcanic Rocks with a well defined mineralogy and petrology from potential terrestrial analogues sites have also been included in the study. Our primary objective is to evaluate the range of electrical and magnetic losses that may be encountered by the various Radar sounding and imaging experiments dedicated to map the Martian subsurface searching for underground water. The electromagnetic properties of these Mars-like materials will be presented as a function of various geophysical parameters, such as porosity, bulk density and temperature. The secondary objective, is to locate regions were surface dielectric conditions are suitable for subsurface sounding.

Scientific context: The Mars Exploration Program has identified the search for subsurface water on Mars as a key investigation towards understanding the hydro-geologic history of the planet and for identifying potential environments for the survival of primitive life forms [2,3]. During the coming decade three different types of sounding Radars will be used to address this task and to reduce the ambiguities concerning the state, distribution and total abundance of water within the Martian crust [4]. The first one is the 2 MHz MARSIS experiment onboard the Mars Express orbiter. It will be followed by the 20 MHz SHARAD shallow sounder in 2005 and finally possible Ground Penetrating Radars that may be flown as part of future rover and geophysical network missions. The ability of these radars experiments to detect and identify the presence of liquid water will strongly depend on the physical properties, mineralogy and thermal structure of the Martian subsurface as they define the electrical and magnetic characteristics of the crutal propagation matrix [5,6]. The laboratory characterization of Mars-like volcanic and sedimentary materials in the low frequency range 1-30 MHz (the range covering the three types of radar experiments) is hence a key study in evaluating optimal locations for deep subsurface sounding sites and future data interpretation [7].

Experimental setup: To perform permittivity measurements we have used two capacitive cells specially designed in order to avoid the resonance that occurs in classical capacitive cells. The first one we used machined and compacted pellet. The second is an open coaxial cell used to measure the dielectric constant of powder-reduced material. Both of the two dielectric cells were connected to the HP4192A frequency analyser to perform the measurements in the frequency band 1 to 30 MHz. The analyser was connected to a central command unit to extract data and calculate in real-time the real and imaginary part of the complex dielectric constant ($\varepsilon^{/}$ and $\varepsilon^{//}$) and magnetic permeability ($\mu^{/}$ and $\mu^{//}$). For the low temperature measurements, we connected a liquid nitrogen circuit to the cells to keep the samples dry and cold during the measure, and avoid water vapour condensation.

Samples magnetic permeability was evaluated using the magnetic cell HP16454A, connected to the same analyser described above. Unlike the electrical cells we were only able to use reduced powder material, due to difficulties to perform rock machined and powder compacted samples having toric form to fit the cell cavity.

Porosity measurement on compacted samples were done using a mercury porosimeter, with two pressure cycles in order to evaluate small and large pores. This step enabled us to verify the Gaussian distribution of the grain sizes inside the compacted samples and detect the presence of fine fractures inside the samples that could produce resonance during the electromagnetic characterization process.

Results: We present in this paper only a brief selection of our measurement data set. More complete results will be exposed in the conference. Figure 1 show the permittivity measurements for a non-compacted powder (porosity of 50% corresponding to a bulk density ρ = 2.7 g/cm^3) of hematite, maghemite, basalt and silica. Measurements were performed using the open cell in the frequency range 1-10 MHz and for a temperature of 230 K. We obtain a relatively low value for the real part of the dielectric constant, mainly due to the high porosity, while the imaginary part is relatively high, except for silica. For basalt and silica, the real part of the dielectric constant does not show a significant frequency dependency on this narrow frequency range, due to their low concentration in iron oxide. For hematite and maghemite, we noted an important (quite exponential) frequency dependency of the two curves around 1 MHz. This behaviour concerns also the imaginary part of the dielectric constant (specially for maghemite), which mainly characterise the conductive properties of the material.

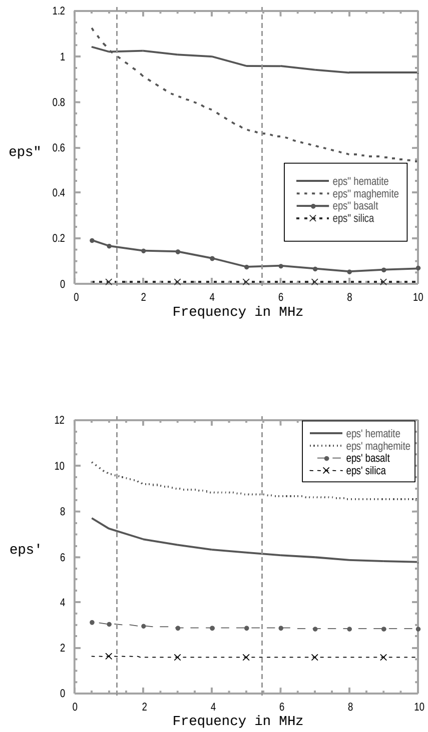

Figure 1: bottom; the real part of the dielectric constant for a selection of Martian-like materials (50 µm powder) in the frequency range from 1 to 10 MHz. Top; the corresponding imaginary part of the dielectric constant for each sample.

Measurements have been also performed on additional 36 samples, in the form of powder and compacted pellets that simulate the surface density of the materials. Materials densities for measurements on pellets have been driven from the TES thermal inertia data collected over the global Martian surface. We have related each measured mineral to its correspondent surface density observed at the location where it was identified. Results have shown that volcanic materials, once compacted (porosity between 20% and 30%), present higher dielectric constant.

$$\delta_p = \frac{\dfrac{\ln(J)\lambda_o}{4\pi}}{\sqrt{\dfrac{\mu_r^{/}\varepsilon_r^{/} + \mu_r^{//}\varepsilon_r^{//}}{2}\left[\sqrt{1+\left(\dfrac{\mu_r^{/}\varepsilon_r^{//} + \mu_r^{//}\varepsilon_r^{/}}{\mu_r^{/}\varepsilon_r^{/} + \mu_r^{//}\varepsilon_r^{//}}\right)^2} - 1\right]}} \quad (1)$$

We integrated those results in a simple electromagnetic propagation model [8] (cf. equation 1) allowing the calculation of the radar penetration depth δ_p as a function of the wavelength λ and the instrumental parameter J [5]. Results (for materials in figure 1) are shown in figure 2 for the frequency range 1 to 10 MHz and for the instrumental characteristic (J=100) of the orbital sounder MARSIS.

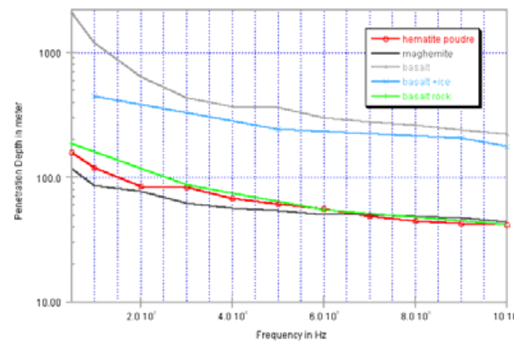

Figure 2: the penetration depth for a set of Martian-like materials as a function of the frequency (1 to 10 MHz)

The ongoing integration of this laboratory data combined with surface roughness model provided by MOLA [9] data gives a surface dielectric map of Mars and the distribution of the average penetration depth over the total area of Mars for the 1 to 30 MHz Frequency band.

Implications for Radar exploration: measurements on Martian-like minerals and rocks have shown an important variation in the Martian surface geoelectrical and geomagnetic descriptions. This variation is clearly observed in the low frequency range from 1 to 30 MHz, differences tend to minimize as we get to higher frequency range. This explains the quite homogeneous dielectric distribution observed from earth based radar observations [10]. Orbital low frequency sounding instruments may encounter a different dielectric configuration; hence there is a need for similar work in order to optimize orbital sounding on areas where surface dielectric properties combined with surface roughness gives a minimum reflection of the signal which in term lead to a better penetration depth.

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