DIELECTRIC PROPERTIES OF VOLCANIC MATERIAL AND THEIR ROLE FOR ASSESSING ROCK HARDNESS IN THE MARTIAN SUBSURFACE.

A. ElShafie[1], E. Heggy[2]. [1]Arkansas Center for Space and Planetary Sciences, University of Arkansas, Fayetteville, AR, USA (aelshafi@uark.edu). [2] NASA Jet Propulsion Laboratory, 4800 Oak Grove Drive, MS 300-243, Pasadena, CA 91109, USA (Essam.Heggy@jpl.nasa.gov)

Introduction: The success of the WISDOM radar in supporting the ExoMars drill to targets of opportunities and for maintaining optimal drilling capabilities is based on the complementarily of the two experiments in assessing the shallow subsurface physical properties. The dielectric properties as inverted from WISDOM radar will be used to assess the ground mechanical properties such as rock hardness, density and porosity which are crucial inputs for optimizing drilling operations. The main purpose of this research is to perform dielectric permittivity and hardness measurements for Martian analog rocks in an attempt to correlate between the physical and mechanical properties (i.e. dielectric constant and rock hardness) of volcanic rocks and its implication for optimizing ExoMars drilling and sampling activities.

Experimental Methods and Equipment: In this research, eight different types of volcanic rocks have been used. Of the eight volcanic rock samples, six were basaltic rocks, one sample was of welded tuff and another for pumice. Core and thin sliced specimens are cut for each of the samples for hardness and dielectric measurements. Dielectric and hardness measurements were performed for untreated and oven heated samples for 24 h at 100 ºC.

Rebound technique was our method of choice for the hardness measurements. Its operation is based on measuring the rebound of a spring loaded mass impacting on the surface of a sample. The distance travelled by the spring load mass is expressed as a percentage of the initial extension of the spring on a scale range from 0 to 100 which is known as the rebound number (R). Hardness measurements of volcanic rocks were performed using Proceq Schmidt hammer type-L with hammer impact energy of 0.735 Nm.

Electrical measurements of the thin sliced samples < 3mm in thickness were carried out at room temperature using a dielectric material test fixture attached to an Impedance/Material Analyzer. The analyzer is connected to a central command unit to extract data and to calculate, in real-time, the real and imaginary part of the complex dielectric constant. Sweeping over the frequency range of observation (10 MHz to 1 GHz), the real and imaginary parts of the relative complex permittivity were calculated from the capacitance and admittance knowing the thickness of the sample.

Results: Dielectric and hardness measurements were conducted in as-is and oven dried at (100 ºC for 24 h). Schmidt hammer hardness number ranged from 14.16 to 68.65 in as-is condition and from 12.8 to 68 for oven dried samples (Table 1).

Table 1.Density and rebound hardness values for different types of volcanic rocks.

Rock types	ρ^a	R^a	ρ^b	R^b
Belleville basalt	2.730	51.4	2.716	66.43
Basalt	2.756	68.14	2.736	64.45
Flood basalt	3.014	68.96	2.990	68
MMS	2.901	64.87	2.882	61.2
Olivine basalt	3.018	69.65	3.012	67.9
Welded tuff	1.6	33.37	1.594	39.7
Pumice	0.850	14.16	0.839	12.83
Lava basalt	2.232	20.22	2.225	18.30

[a] density in gm cm^{-3} for untreated condition
[b] density in gm cm^{-3} oven heated samples to 100 ºC for 24 h

Dielectric constant was observed to increase with increasing rock hardness, the harder the rock, the higher the dielectric constant, (Fig. 1). It was observed that both the hardness and the dielectric constant are directly related to the density of the materials.

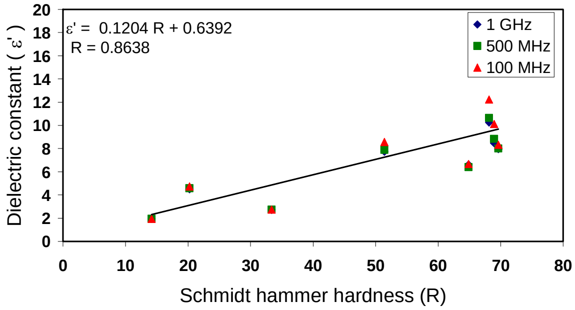

Figure 1. Dielectric constant versus Schmidt hammer hardness number (R) for untreated volcanic rocks at different frequency ranges.

[1] reported Schmidt hammer rebound hardness number (R), uniaxial compressive strength (σ_{UCS}) and dry density (ρ) for oven heated granitic rocks. We used these dry density measurements of granite to calculate its dielectric constant (έ) [2].

$$\varepsilon' = 1.919^{\rho} \tag{1}$$

Figure 2 shows the dielectric constant at three frequency ranges (100, 500 MHz and 1 GHz) and hardness values after heating the basaltic samples at 100 ºC for

24 h as well as the calculated dielectric constant based on dry density measurements done by [1].

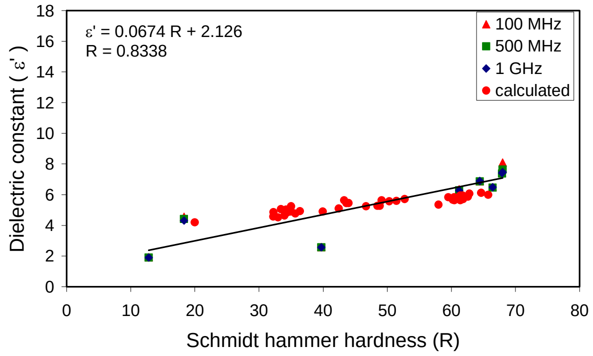

Figure 2. Dielectric constant versus Schmidt hammer hardness values of heated basaltic rocks and the calculated dielectric constant based on [1].

Moisture removal by heating caused a decrease in the dielectric constant. Dielectric constant was found to increase with increasing rock hardness since both of these physical and mechanical properties are function of the density of the samples. The predicted values of the dielectric constant fit very well the area in between our results and support the correlation between the dielectric constant and rock hardness. Equation 2 shows the calculated correlation between the dielectric constant and rock hardness.

$$\varepsilon' = (0.0674 \times R) + 2.126 \qquad (2)$$

Implication for the WISDOM radar and ExoMars driller: Rock strength is a primary factor affecting drilling activities. [3] conducted hardness and drill experiments on carbonates and some volcanic rocks using a rotary drill which is similar to ExoMars drill type. The drill operation power was 10 – 20 W and the weight on bit (WOB) was in the range from 140 – 170 N. We converted [3] hardness values from unconfined compressive strength (UCS) to Schmidt rebound hardness using equation 3 [4] to determine the relation between the drill penetration rate and Schmidt hammer hardness.

$$R = (0.2324 \times \sigma(MPa)) + 21.903 \qquad (3)$$

Figure 3 shows a decrease in the drill penetration rate as a function of the computed dielectric constant based Using our dielectric constant measurements of oven dried volcanic rocks; we calculated the drill penetration rate based on equation 4 (Figure 4).

$$DPR = (-2.3561 \times \varepsilon') + 18.615 \qquad (4)$$

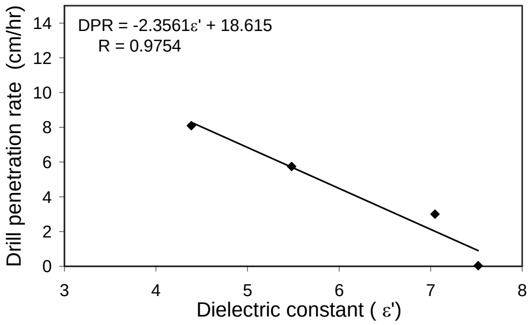

Figure 3. Drill penetration rate versus dielectric constant for carbonates and some volcanic rocks using rotary drill.

Pumice and welded tuff had low dielectric constant and low hardness, therefore, they had high drill penetration rate of 12 and 14 cm/hr. Basalt from Lava sources had intermediate hardness and dielectric constant values where its predicted drill penetration rate was about 8 cm/hr. The rest of the other types of basalts had high dielectric constant (6.4 – 7.5), higher hardness rebound number which corresponded to low drill penetration rate (1 – 3.8 cm/hr).

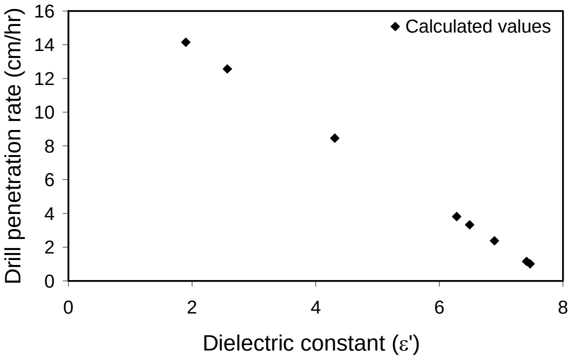

Figure 4. Calculated drill penetration rate for rotary drill versus dielectric constant of oven dried volcanic rocks.

Conclusions: Dielectric constant increases with increasing rock hardness. A decrease in the drill penetration rate was observed with the increase in both rock hardness and the dielectric constant. Therefore, WISDOM radar may communicate with ExoMars drill in order to avoid missing targets of opportunities, losing drilling performance, and in order to save power and energy for investigations.

References: [1] Aydin. A. and A. Basu (2005) *Eng. Geol., 81 (1):* 1-14. [2] Campbell, B. A. (2002) Cambridge Univ Pr. [3] Anttila, M. E. (2005) Ph.D. thesis. [4] Kılıç, A., and A. Teymen (2008) *Bulletin of Eng. Geol. and the Environment* 67 (2): 237-44.