**DIELECTRIC PROPERTIES OF MARTIAN REGOLITH ANALOGS AND SMECTITE CLAYS.** A. B. Cunje[1,2], R. R. Ghent[2,3], A. Boivin[2], C-A. Tsai[2], and D. Hickson[2,4]. [1]Department of Earth and Environmental Sciences, University of Illinois at Chicago, Chicago, IL, USA (acunje2@uic.edu), [2]Department of Earth Sciences, University of Toronto, Toronto, ON, Canada, [3]Planetary Science Institute, Tucson, AZ, USA, [4]Centre for Research in Earth and Space Science, York University, Toronto, ON, Canada.

**Introduction:** The Mars 2020 rover mission will provide an opportunity to further explore the surface of Mars at one of three landing sites shortlisted for final selection: Jezero Crater, NE Syrtis, or Columbia Hills [1]. In addition to surface exploration, the mission will allow for investigation into the shallow subsurface of the site through its ground penetrating radar (GPR) instrument, the Radar Imager for Mars' sub-surFAce eXperiment (RIMFAX), which will provide geologic context of the rover's traverse via subsurface profiling [2]. This additional perspective contributed by RIMFAX will significantly aid in the completion of the mission's primary goals of the investigation of a geologically diverse location where signatures of past habitability may have been preserved, and the procuring and caching of a diverse suite of key rock and regolith/soil samples. These sites all share a related key point of interest: the presence of phyllosilicate-rich outcrops and smectite clays [3-5] which are known as products of hydrous conditions and are desired features of insight into the history of water alteration, habitability, and past life [6, 7], as well as potential sites of organic matter preservation [8]. This work characterizes the dielectric properties of a variety of Martian analog materials, consisting of regolith analogs and smectite clays, to better understand the capability of GPR at the favoured landing sites under varying temperature and moisture conditions.

**Background:** Radar has long been used as a tool for remote sensing on Earth and other planetary bodies, and radar profiles from GPR experiments can be used to identify various subsurface geologic features, such as buried structures or geologic layer boundaries associated with changes in physical properties [2, 9]. The ability of electromagnetic waves to travel through a material is described in part by its complex dielectric permittivity, which governs how electric energy is stored and lost due to electric charges in materials, and is dependent on several key factors including the frequency of the waves and properties of the material such as mineral composition, temperature, moisture, and bulk density. Previous studies have examined various aspects of dielectric properties of planetary materials as they relate to GPR relevant frequencies with similar methods, demonstrating the importance of composition and temperature [10, 11]; however, no study has yet examined these properties for smectite clays. Smectites will be of key interest at each of the candidate sites, but they are typically poor targets under Earth-based conditions due to their commonly high moisture content, which greatly attenuates EM waves and reduces the depth penetration of GPR [9, 12]. By characterizing the real and imaginary parts of the complex dielectric permittivity ($\varepsilon = \varepsilon' + i\varepsilon''$) for various Martian material analogs at a range of relevant temperature and moisture conditions, the effectiveness of the GPR to operate at the target Martian environment can be determined.

**Objectives:** This work characterizes the dielectric properties of a variety of Martian analog materials with respect to GPR frequencies in the range of 10 MHz - 2 GHz (covering the RIMFAX operating range of 150 - 1440 MHz), under end-member temperature and moisture conditions. We investigated properties including dielectric permittivity/constant, loss tangent, and penetration depth as functions of frequency for seven total samples: two Martian regolith analogs varying in design from spectral to mechanical [13, 14], and five smectite clays sourced from The Clay Minerals Society. We measure the dielectric properties of these samples under four conditions, covering the range from a "warm and wet" environment as expected on Earth, to a "cold and dry" Martian environment:

| Conditions | Innate Moisture | Oven dried |
|---|---|---|
| Room Temp (298 K) | Warm/Wet | Warm/Dry |
| Mars Surf. Temp. (220 K) | Cold/Wet (frozen) | Cold/Dry |

**Method:** We powdered and sieved all samples to a maximum grain size of 212 μm. We measured the dielectric properties using an Agilent Technologies E5071C ENA series vector network analyzer (VNA), with samples individually loaded into a coaxial transmission line (14 mm diameter, 15 cm length), following the methodology used in related studies of planetary analog materials [10, 15]. We measured samples at room temperature with ambient moisture and after being dried in an oven at 115°C for a minimum of 48 hours, or until sample mass stabilized after complete loss of adsorbed water. To measure samples under cold conditions, we used a method similar to [11], but with some variation. We placed the filled transmission line and part of the connecting cables in a So-Low Ultra-Low freezer set to the target measurement temperature of -53°C/220 K until an independent resistance temperature detector (RTD) and temperature controller used to monitor the transmission line temperature displayed a consistent temperature reading at the target temperature. We then used the S-parameters measured by the VNA to calculate the various dielectric properties through the non-iterative method established by [16].

| Sample Code | Sample Type | $H_2O$ wt % loss | $H_2O$ wt % reabs. |
|---|---|---|---|
| JSC-M1A | Regolith spectral analog | 10.35 | 0.60 |
| MMS | Regolith mechanical analog | 1.42 | 0.38 |
| STx-1b | Ca-rich Montmorillonite | 11.07 | 0.77 |
| SWy-3 | Na-rich Montmorillonite | 9.17 | 0.41 |
| SCa-3 | Intermediate Montmorillonite | 15.32 | 0.56 |
| NAu-1 | Al-rich Nontronite | 9.72 | 0.60 |
| NAu-2 | Al-poor Nontronite | 12.65 | 0.42 |

Table 1: Sample codes, descriptions, and percentage of $H_2O$ lost during 48+ hours of drying/ gained after 1 hour of reabsorption after drying. Colours match Figure 1 plots.

**Data/Results:** To compare results between samples, we normalized the bulk densities to 1.60 g/cm$^3$. A consistent and considerable drop in both the real and imaginary parts of the dielectric permittivity, also translating to greater penetration depths (assuming dynamic range of 65 dB) due to the decreased losses, were determined in all samples with both the removal of moisture through sample drying and the freezing of samples at Martian temperature conditions. Samples measured at room temperature after drying typically demonstrated lower real and imaginary components of dielectric permittivity than those measured at 220 K but containing ambient (frozen) moisture. As expected, the greatest reductions are observed in dry and cold samples, demonstrating that the Martian environment is well suited to GPR experiments for all samples investigated. Maximum penetration depths range from 50 - 100 m for smectites at the lowest RIMFAX frequency, to approximately 150 m for the MMS mechanical regolith analog.

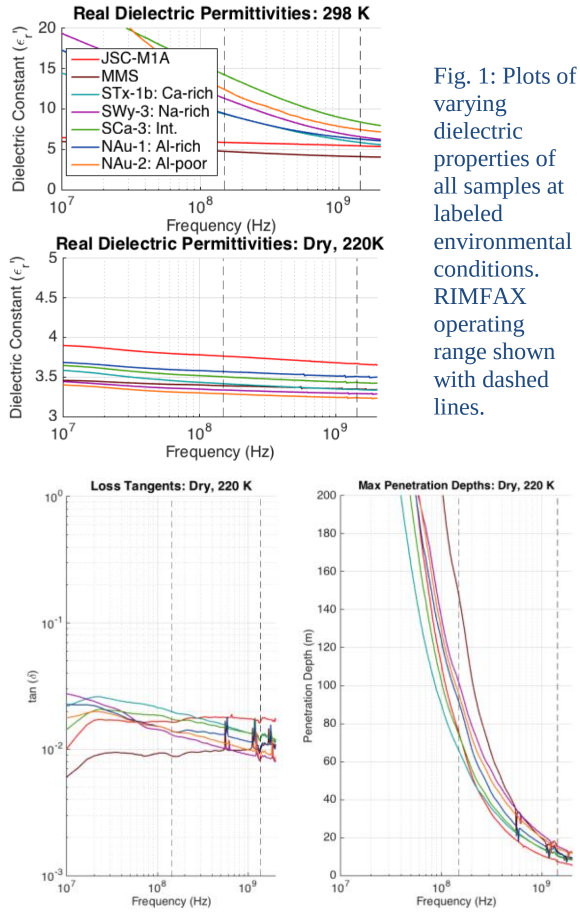


Fig. 1: Plots of varying dielectric properties of all samples at labeled environmental conditions. RIMFAX operating range shown with dashed lines.

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