ATTENUATION OF UV RADIATION IN ROCKS AND MINERALS: IMPLICATIONS FOR BIOSIGNATURE PRESERVATION AND DETECTION ON MARS. B. L. Carrier*, L. W. Beegle, R. Bhartia, W. J. Abbey, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA (*bcarrier@jpl.nasa,gov).

Introduction: Subsurface penetration of UV photons has implications for habitability and for preservation and detection of organic biosignatures. UV radiation is known to photodissociate amino acids, DNA and other common biological molecules [1 and references therein]. The CO_2 atmosphere on Mars absorbs most UV radiation below 204 nm, therefore wavelengths longer than this interact with the surface. It is therefore important to identify to what extent rocks and minerals can provide effective shielding against UV radiation as a necessary step towards constraining what constitutes suitable habitats for life as well as promising locations for organic molecule biosignature preservation. The variance in the depth of penetration of UV photons into different types of rocks and minerals results in a sizable variation in the probability of preserving biosignatures.

UV radiation, while damaging to organic biosignatures over time, can also be used to nondestructively detect organic molecules in the surface and near subsurface. The Scanning Habitable Environments with Raman and Luminescence for Organics and Chemicals (SHERLOC) instrument will be part of the Mars 2020 payload. SHERLOC will use a 248.6 nm laser to induce fluorescence emissions and Raman scattering from minerals, organics, and potential organic biosignatures in both natural and abraded surfaces on Mars [2]. Understanding how deep into a substrate both the incident laser photons and the sample specific Raman scattered and induced fluorescence photons can penetrate is key to understanding limits of detection for SHERLOC measurements.

The attenuation of UV radiation in natural mineral and rock samples has not been well characterized, partially due to the difficulty of obtaining mineral layers of sufficient thinness prepared with UV transparent materials. Here we have used a mechanical pellet press to form pellets of varying thickness from powdered samples of a natural gypsum, kaolinite, basalt and a welded tuff. The transmittance of these pellets to the full spectrum UV (200-400 nm) radiation, as well as to the UVC (200-280 nm), UVB (280-315 nm) and UVA (315-400 nm) wavelength ranges, has been determined. It is important to distinguish between these regions because the SHERLOC laser and Raman regions fall into the UVC range, while the fluorescence region extends over the UVA/UVB wavelength ranges. The UV transmittance for the SHERLOC laser wavelength of 248.6 nm has also been determined in order to better constrain interrogation volume and limits of detection of the instrument. These transmittance values have been used to construct correlation curves between UV transmittance and layer thickness for each wavelength or region of interest. Finally, we have used these transmittance values to determine the potential lifetimes of several organic molecules and biosignatures at different depths in the subsurface of these rocks and minerals.

Methods:

Sample Preparation: Samples used in these experiments were: the Mojave Mars Simulant (MMS) [3], kaolinite, gypsum and Bishop Tuff.

In order to remove potential organic contamination, which could contribute to UV absorbance, the rock or mineral dust was cleaned prior to being pelletized. Each sample of rock or mineral dust was leached at a 10:1 ratio using a solution of dichloromethane and methanol. Samples were also O_2 plasma cleaned using a Plasma Etch vacuum plasma cleaner. Following the sample treatment process, XRD analysis was performed to ensure that the substrates had not been altered.

Pellet Making & Characterization: Rock or mineral dust was massed and pressed into pellets of 13 mm diameter using a hardened carbon steel pellet die in a mechanical pellet press with a maximum force of 10 tons. The thickness of the resulting pellets was then measured using a Mitutoyo digital thickness indicator with an accuracy of ±3 μm. Thickness was determined at 25 different spots on each pellet and averaged.

UV source and detector: A UV-Enhanced Oriel-Newport 1000 W Xe-Arc lamp was used to generate UV photons. This lamp provides a close spectral match to the expected UV flux on Mars. UV transmittance through each pellet was determined by placing the pellet between the UV source and a NIST-calibrated spectroradiometer.

Results and Discussion: Transmittance data was collected as a function of layer thickness in each substrate for various UV wavelength ranges. Figure 1 shows a log-log plot of the transmittance data for the 200-400 nm wavelength range as a function of layer thickness for the four substrates analyzed. The linear trendlines indicate that the UV transmittance decreases exponentially with depth, as expected. Gypsum was found to allow the greatest UV transmittance, followed by the kaolinite, Bishop Tuff and MMS, indicating that basaltic type rocks provide the greatest UV shielding of the materials investigated.

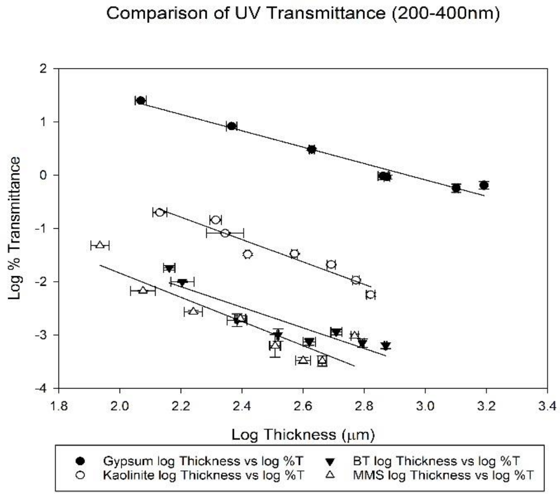

Figure 1. Plot of log % transmittance (200-400 nm) vs log layer thickness (μm) for each substrate analyzed.

Further analysis of the UVC/UVB/UVA wavelength ranges, as well as of the SHERLOC laser wavelength (248.6 nm) show that each substrate allowed significantly greater penetration of shorter wavelength UVC radiation than of the UVB and UVA photons. Figure 2 shows the % transmittance of MMS basalt to each wavelength range as a function of layer thickness. The other substrates investigated showed a similar pattern of increased UVC transmittance. This is significant because continuous exposure to UVC radiation is more damaging to potential organic biosignatures and microbial life than longer wavelength UVA/UVB radiation. This increased transmittance in the UVC wavelength region should also serve to increase the interrogation volume of the SHERLOC instrument, especially in the Raman region.

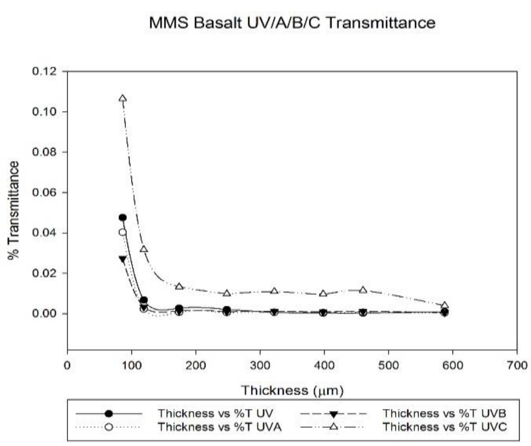

Figure 2. Comparison of transmittance curves for total UV (200-400 nm), UVA (315-400 nm), UVB (280-315 nm) and UVC (200-280 nm) wavelength ranges as a function of layer thickness (μm) for MMS.

Although transmittance falls off quickly with depth, all four substrates showed detectable UV penetration at depths greater than 500 μm. Thus over geological time scales it is unlikely that organic biosignatures would persist in the top mm of the martian subsurface. Table 1 shows extrapolated half-lives for glycine under 500 μm of the rocks and minerals investigated (extrapolated from surface $t_{1/2}$ of ~231-250 hrs presented in [4,5]). These lifetimes are based on continuous noontime peak illumination and neglect other factors contributing to surface organic degradation such as exposure to atmospheric oxidants and can thus be regarded as possible lower limits. This highlights the importance of abrading at least 1-2 mm below the surface in order to increase the likelihood of detecting preserved organics and biosignatures.

Extrapolated $t_{1/2}$ (Mars yrs) for Glycine in the Subsurface	
Gypsum 500 μm	~0.39 Mars years
Kaolinite 500 μm	~19 Mars years
MMS 500 μm	~154 Mars years
Bishop Tuff 500 μm	~473 Mars years

Table 1. Extrapolated half-lives for glycine in the subsurface.

Conclusions: The transmittance of UV radiation varies depending on rock and mineral type, with detectable levels of UV radiation penetrating >500 μm in all sample types investigated. These penetration depths suggest a larger sample interrogation volume for the SHERLOC instrument than the conservative estimates in the sensitity models. Depending on the mineraology being observed, SHERLOCs entire depth of field (±500 μm) can be used to detect trace organics that may be diffusely distributed in the mineral matrix.

The higher transmittance of UVC radiation highlights the importance of abrading below the surface to look for preserved organics. The current operational plan for Mars 2020 is to abrade surfaces by removing >2 mm of the outer layer of rock surfaces on Mars to get to regions where organics are protected from UV. In addition,

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References:

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