PHOBOS AND DEIMOS: CONSTRAINTS ON SURFACE COMPOSITION FROM ULTRAVIOLET-VISIBLE SPECTRA.

A. R. Hendrix[1], F. Vilas[1], C. Jaramillo[2], N. Pearson[1]. [1]Planetary Science Institute, Tucson, AZ. [2]Pennsylvania State University (arh@psi.edu).

Introduction. The surface compositions of Phobos and Deimos remain elusive, thus hindering understanding of their origins and surface processing histories. Origin hypotheses include the capture from the outer main belt, material left over from Mars' formation, and accreted ejecta from a large impact on Mars. CRISM measurements (0.4-3.9 microns) [1][2] have been used to compare Phobos and Deimos spectra with primitive objects such as D-type asteroids, and have shown the presence of two absorption features at 0.65 and 2.8 microns. These two Visible/IR features were interpreted either to highly desiccated endogenous Fe-phyllosilicate minerals indigenous to the bodies, or to a surface process involving Rayleigh scattering and absorption of small iron particles formed by exogenic space weathering processing. More recent IRTF spectra in the 0.7-4 micron range are consistent with D-type asteroids with a low albedo and featureless steep slope.

Ultraviolet spectra of Phobos and Deimos exhibit a unique feature that can help identify some of the surface components of these mysterious objects. We present results from the entire set of Mariner 9 Ultraviolet Spectrometer (UVS) observations and compare with other results to understand what can be gleaned regarding the surface compositions of these bodies by extending into the near-UV at different observational geometries. We compare with results from Mars Express (SPICAM) [3][4] and MAVEN IUVS (Chaffin REF). We compare with mineral and meteorite data in the near-UV (e.g. [5]), along with the UV spectra of other asteroids. Recent work on the UV characteristics of Ceres [6] and the UV characteristics of carbonaceous species [7] at various stages of processing will inform our understanding of Phobos and Deimos.

Observations. The Mariner 9 UVS operated in orbit at Mars, November 1971-November 1972 (e.g. [8]). It was an Ebert-Fastie scanning monochromator; the F-channel (IFOV 0.2° x 0.5°) used a CsTe photocathode and scanned the 170-340 nm range (spectral resolution of ~15 Å) every ~2.82 sec. While operations focused on the planet, several measurements were made of Phobos and Deimos, obtaining UV spectral reflectance measurements at varying observational geometries. The Phobos and Deimos data have reasonable signal-to-noise in the ~210-340 nm range.

Results. Our work expands on early studies of Mariner 9 UVS Phobos and Deimos spectra (e.g. [9]10]) by investigating the entire data sets of the moons. Our previous results have indicated [11] that Phobos and Deimos have near-ultraviolet reflectance spectra that are lower (darker) and flatter (less red) than S-class asteroids Gaspra and Ida (as measured by the Galileo UVS). We have showed (2016 meeting) that Phobos and Deimos are spectrally unique from other asteroids (Ceres, in the UV. In particular, two different UV-visible datasets [3][12] independently found that Phobos and Deimos have a convex spectral shape in the 210-340 nm region (also shown in MAVEN IUVS spectra [13], and, when considered along with the red slope of spectra in the visible, likely has an absorption feature centered near 350 nm. Thus, data from Mariner 9 UVS, SPICAM and MAVEN IUVS all point to an absorption longward of 310 nm, close to 350 nm. However, we note for completeness that the Rosetta OSIRIS WAC-NAC broad-band spectrum (~250-992 nm) [16] does not show an absorption near 350 nm.

Phobos and Deimos are spectrally unique, given their spectrally convex nature in the UV-visible and are not spectrally similar to other asteroids, including Trojans [14] and D-class asteroids [15]. No current UV-visible spectra of carbonaceous chondrites are similar to Phobos and Deimos. Phobos does not look like Tagish Lake in the UV; Tagish Lake is seen to have a concave spectral shape that is opposite that concave one of Phobos and Deimos.

We compare with a suite of laboratory reflectance spectra of mineral samples. We compare with carbon-based minerals including organics; some organics can reproduce the 350 nm absorption but may not have a red-enough spectrum in the visible. Other carbons such as graphites and some amorhous carbons exhibit broad reflectance (Fresnel) peaks in the UV, but primarily at shorter wavelengths (closer to 250 nm) than the broad peak in the Phobos and Deimos spectra, which is closer to 280 nm. Phyllosilicates do not produce reasonable spectral matches. Overall, the iron oxides goethite, ilmenite and hematite provide the best spectral matches to the overall UV-visible spectral shape of disk-integrated Phobos and Deimos.

Discussion. The surfaces of Phobos and Deimos sensed by optical wavelengths at broad scale (i.e. disk-integrated observations) are expected to be dominated by weathering processes rather than bulk processes.

The Phobos-Deimos surfaces are exposed to significant irradiation from solar wind and ions derived from the martian atmosphere (e.g. [20]) so it is likely that the surfaces are dominated by weathering components that are products of this irradiation. Furthermore, Phobos and Deimos orbit Mars in a significant dust torus environment (e.g. [18][19]); dust from Deimos dominates the torus and coats the surface of Phobos. It has also been proposed that the surfaces of Phobos and Deimos are dominated by IDP material [17].

Next Steps. The next steps we will take are to make further measurements of iron oxides (goethite, hemitate, ilmenite), and other minerals, that are prepared, by grinding to expose fresh grain surfaces, in a glove box; the reflectance will be measured in an inert environment so that the fresh, unexposed grain surfaces are pristine and unaltered by the terrestrial environment (Jaramillo et al, *this meeting*). We predict that these materials willl provide the best analogues for the broad-scale surfaces of Phobos and Deimos; results will be presented.

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Acknowledgements: This work has been supported by he National Aeronautics and Space Administration through the Toolbox for Research and Exploration (TREX) node of the Solar System Exploration Research Virtual Institute 2016 (SSERVI16) Cooperative agreement (NNH16ZDA001N).