CONSTRAINTS ON THE COMPOSITIONS OF PHOBOS AND DEIMOS FROM MINERAL ABSORPTIONS. A. A. Fraeman[1] S. L. Murchie[2], R.E. Arvidson[1], A. S. Rivkin[2], and R.V. Morris[3] [1]Washington University in St. Louis, afraeman@wustl.edu, [2]Johns Hopkins Applied Physics Laboratory, [3]Johnson Space Center

Introduction: The compositions of Phobos and Deimos have remained controversial despite multiple Earth- and space-based observations acquired during the last 40 years. Phobos is composed of at least two spectral units that are both dark yet distinct at visible to near infrared wavelenghts; a spectrally red-sloped "red" unit covers most of the moon and a less red-sloped "blue" unit is present in the ejecta of the ~9-km diameter impact crater Stickney [1,2]. Deimos is similar spectrally to Phobos' "red" unit [2]. Here we report results from mapping mineral absorptions on Phobos and Deimos using visible/near infrared observations from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM). We find evidence for an absorption feature at 0.65 µm in the Phobos red unit and Deimos that is reproducible in observations from other instruments. The phase responsible is uncertain but may be a Fe-bearing phyllosilicate and/or graphite, consistent with the notion that Phobos and Deimos have compositions similar to CM carbonaceous chondrites [3].

CRISM Observations: CRISM acquired disk-resolved hyperspectral images of Deimos and Phobos using the instrument's full spectral resolution of ~6.55 nm/channel and wavelength range of 0.4 µm to 3.9 µm [3, 4]. *Fraeman et al*. [3] derived single scattering albedo spectra from the CRISM independent of lighting and viewing geometeries. We searched the single scattering albedo spectra for absorptions due to mafic phases using mineral parameter maps that can detect broad olivine and pyroxene features around 1 µm and 2 µm [5], but found no discernible absorptions above the level of noise in the data. Additionally, there is no evidence for absorptions due to bound water or hydroxl around 1.4, 1.9, and 3 µm, although data at wavelengths longer than ~2.5 µm are confounded by a thermal contribution whose inaccurate removal could mask weak absorptions around 3 µm [3]. Initial investigation of CRISM I/F spectra revealed one potential mineral absorption, a broad, shallow feature centered near 0.65 µm on Phobos and Deimos [4]. We also detect the broad 0.65 µm absorption feature in the single scattering albedo data both in the Phobos red unit and on Deimos (Fig. 1, 2). We found that the presence and strength of this broad absorption feature are spatially correlated with visible to near infrared ratio. In general, spectra with a lower visible to near-infrared ratio have a deeper 0.65-µm band whereas spectra from bluer areas with higher visible to near- infrared ratio have a weakened band or lack the absorption all together (Fig. 1). The 0.65-µm absorption ranges in depth from about 1% to 5% in the Phobos red unit. On Deimos, band depth is independent of position and equivalent to the strongest band depths on Phobos.

Evidence for a 0.65 µm absorption in additional datasets: Ground based telescopic spectra of Phobos were obstained using the Mayall 4-m telescope on Kitt Peak with the RCSP spectrograph as part of a campaign of near-Earth object spectroscopy. 47 images from 4 September 2003 were combined into 10 final spectra with central longitudes varying from 52°-92°W. For reference, Stickney crater and its exposed blue unit is centered near 50° W longitude. The telescopic disk integrated spectra show a 0.65 µm feature having a similar shape to the feature observed in the CRISM single scattering albedo (Fig. 2, 3) whose depth increases as the central longitude of the observation increases from 52° to 92°, consistent with the notion that the disk-integrated reflectance becomes more dominated by the Phobos red unit material that carries this feature.

The same relationship of spectral shape within the 0.65-µm band and visible to near-infrared color ratio on Phobos was previously recognized in results from the Imaging Spectrometer for Mars (ISM) instrument on Phobos 2 [1]. Those workers showed that compared to the bluer unit, Phobos' redder unit exhibits a downward inflection at wavelengths shorter than 0.9-1.0 µm, similar to that observed in Fig. 3. The inflection is stronger in materials with lower visible to near-infrared color ratios. Calibration uncertainties and ISM's limitations to wavelengths >0.77 µm prevented recognition of the inflection as being the long-wavelength shoulder of an absorption at 0.65 µm. Instead it was mistakenly interpreted from ratio spectra as resulting from a weak 1-µm absorption in the bluer unit.

The 0.65-µm absorption was also recognized in disk-integrated spectra of the sub-Mars hemisphere of Phobos obtained from the ground on Mars by the Imager for Mars Pathfinder (IMP) [6]. Those data consist of 12-band spectra collected by averaging over the ~3-pixel disk of Phobos, which from the perspective of Mars is dominated by the red unit. Although these measurements were lower in spatial resolution than ISM measurements, they include wavelengths 0.44-1.0 µm covering the full absorption. The absorption's shape, depth, and center near 0.65 µm are consistent with results from CRISM. The multiband photometry approach used to retrieving those spectra yielded higher band-to-band uncertainties than in CRISM spectra, rendering any absorption in the spectrum of the <1-pixel disk of Deimos below the level of noise.

Possible Responsible Phases: A number of low-albedo asteroid spectra also show broad absorptions similar to the 0.65 µm feature observed in the red unit for Phobos and for Deimos (Fig. 3). The origin of these absorptions is commonly attributed to an Fe^{2+}-Fe^{3+} charge transfer in Fe-bearing phyllosilicates, such as saponites, serpentines, or a combination of the two [7, 8]. Fe-bearing phyllosilicates such as saponite and serpentine are both commonly found in CM carbonaceous chondrites, a spectral analog for Phobos and Deimos [3, 8]. However, Fe-containing phyllosilicates also have electronic transition absorptions due to Fe at ~0.92 to ~1.1 µm depending on the phase, and IR absorptions due to molecular H_2O at 1.4, 1.9, and 3 µm and metal-OH at 1.4 µm and at 2.2-2.3 µm depending on the cation [8]. These additional absorptions are not observed in the Phobos and Deimos spectra. The lack of OH- and H_2O-related IR absorptions could be due to desiccation of these minerals if they are present and masking by opaque phases [9,10], although it is difficult to explain why the large Fe-related feature near 1 µm would be obscured but the 0.65 µm feature would remain visible.

Another candidate for the 0.65 µm feature is graphite. Spectral reflectance properties of carbon-bearing species are varied, although several are red-sloped with broad absorptions near 0.65 µm [8, 11]. Graphite is an attractive candidate for the 0.65 µm feature observed on Phobos and Deimos because it has a similarly low absolute reflectance to Phobos and Deimos and its absorption is centered at the same approximate wavelength. Again, graphite is a common constituent of CM carbonaceous chondrite meteorites, and radiative transfer modeling has identified it as a candiate component on the surfaces of D-type Trojan asteroids [8, 12].

Our results help to contrain compositions for Phobos' red unit and the surface of Deimos. The absence of absorptions due to pyroxene and olivine does not support occurrence of Mars crustal material. Similarly, the lack of these absorptions fails to support a composition of higher-grade carbonaceous chondrites or darkened ordinary chondrites that retain olivine and pyroxene absorptions. Instead the presence of the 0.65-µm absorption is most consistent with a composition related but not identical to CM-type carbonaceous chondrites. Our inability to match the entire spectrum with a single mineral phase makes it most likely that the 0.65-µm absorptions is caused by a mixture of materials and/or may be affected by space weathering, so its assignment requires further investigation.

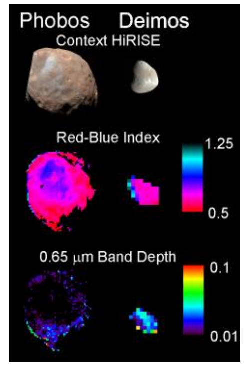

Fig. 1: VIS/NIR ratio and 0.65 µm band depth mapping from CRISM single scattering albedo observations of Phobos and Deimos. Areas with lower VIS/NIR ratio are redder and correlated with stronger 0.65 µm features.

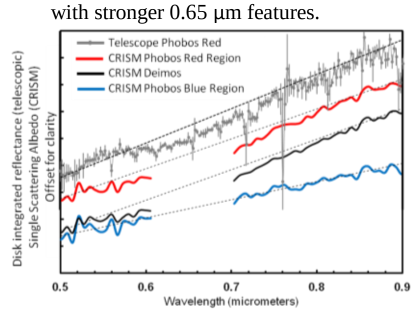

Fig. 2: Telescopic and CRISM short wavelength spectra plotted with 0.5 to 0.85 continuum. Spectra from the Phobos red unit and Deimos show the broad, 0.65 µm feature whereas the spectrum from the Phobos blue unit does not.

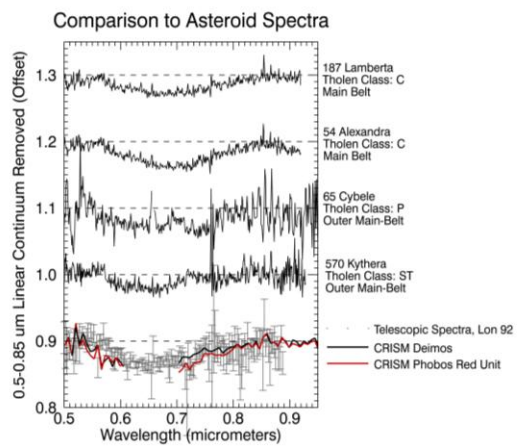

Fig. 3: Continuum removed CRISM and telescopic spectra compared with other continuum removed asteroid spectra showing a similar 0.65 µm feature.

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