SPECTRAL HETEROGENEITY ON PHOBOS AND DEIMOS: HiRISE OBSERVATIONS AND COMPARISONS TO MARS PATHFINDER RESULTS.

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Introduction: The High Resolution Imaging Science Experiment (HiRISE) onboard Mars Reconnaissance Orbiter (MRO) has been used to observe Phobos and Deimos at spatial scales of around 6 and 20 m/px, respectively. HiRISE [1] has provided, for the first time, high resolution colour images of the surfaces of the Martian moons. When processed, by the production of colour ratio images for example, the data show considerable small scale inhomogeneity which might be attributable, in some cases, to fresh impacts. The spectral gradients at optical wavelengths observed for both Phobos and Deimos are compatible with those found by unresolved photometric observations made by the Imager for Mars Pathfinder. The bluer material which is draped over the edge of the largest crater on Phobos, Stickney, has been perforated by an impact and must therefore be relatively thin.

MARS PATHFINDER: Mars Pathfinder landed in the Ares Vallis region of Mars on 4 July 1997. The lander carried a moderate resolution (1 mrad/px) stereo imaging system called the Imager for Mars Pathfinder (IMP) [2]. IMP contained a number of interference filters that could be used to make spectral maps of the surface and atmosphere of Mars. IMP was also used to make spectrophotometric observations of Phobos and Deimos repeatedly [3, 4].

MRO/HiRISE: Although not explicitly designed for pointings away from Mars [5], the capability exists and has been used to capture images of the Martian satellites. A stereo pair of Phobos was acquired on 23 March 2008, the first at 20:55:26 UTC (mid-point of exposure), the second some 10 minutes later at 21:05:26 UTC. Deimos images were taken on 21 February 2009, the first 13:54:53 UTC and the second approximately 5 hours and 35 minutes later at 19:29:53 UTC. The length of all image exposure times is approximately 8.5 seconds. The real strength of these observations come from the simultaneous colour data. HiRISE is a line-scan camera with three filters. The red filter (effective wavelength=694 nm, =RED), the infrared filter (effective wavelength=874 nm, =NIR), and the blue-green filter (effective wavelength=536 nm, =BG) allow for low-resolution spectroscopy and colour ratio images which show small-scale heterogeneity to be made

Data Reduction: The data were reduced using the recent update of the HiRISE pipeline within the ISIS (Integrated System for Imagers and Spectrometers) software available on-line from the web site of the U.S. Geological Survey (see http://isis.astrogeology.usgs.gov/). The software tool, hicalbeta, was used (see also [6]). (A comparison with a previous version of the HiRISE pipeline procedure, hiclean2, showed that hicalbeta was marginally superior.) The pipeline processing left some residual effects which have been corrected for.

Phobos: In Figure 1, we show a ratio of the infrared/blue-green colours of part of PSP_007769_0910. The ratio shows white as bright in the infrared and black as bright in the blue-green. North is roughly 30 deg clockwise from the vertical. The large crater to the left is Stickney and the moderately –sized crater within Stickney is Limtoc which is located at 11°S, 54°W. Figure 2 shows a false colour representation of Phobos. Particularly noteworthy are the green-coloured patches in the blue blanket of material to the east of Stickney. These patches are a result of (relatively) recent cratering and are evidence that the blue blanket east of Stickney is thin enough to be punctured by cratering.

Digital Terrain Models: This dataset is unique in that the two separate pointings allow for a digital elevation model to be constructed with vertical resolution of ~20-30 m/px, an 8- to 12-fold increase in vertical resolution over the latest DEMs [7]. Details on Phobos are very detailed around 0 longitude.

Deimos: In Figure 3 we show the calibrated Deimos data from ESP_012068_9000. North is roughly 30 deg clockwise from the vertical. The prominent unnamed crater underneath the bluish ridge lies at 17°N, 24°W. The crater is coincident with the reddest material of the satellite at this phase angle. The ridge is bluer than the surrounding regolith and has been identified previously as the material of the "blue streamers" [8].

COMPARISON: Observations by the IMP [2] of Phobos and Deimos were used to produce low resolution spectra of the satellites [4, 5]. Phobos and Deimos were observed on two occasions each. All observations were made during the night on Mars in order to minimize atmosphere straylight and reduce the effect of Marsshine on the photometry of the satellites. Phobos also observed exiting eclipse to derive the absorption scale height in the Martian atmosphere. No absorption bands were observed in the spectra of either Phobos or

Deimos at the IMP spectral resolution. The linear increase in reflectivity with wavelength allowed the use of least square fitting to produce reflectivity gradients which could be compared to other bodies. The reflectivity gradients found were 7.9(±0.5)% (100 nm)$^{-1}$ and 9.6(±0.6)% (100 nm)$^{-1}$ for Phobos and Deimos respectively. We have used the HiRISE colour data to derive spectral gradients for direct comparison with the IMP data. On Phobos, two areas were selected – one corresponding to the blue unit and one corresponding to the surrounding red unit. Regions were selected which were rather bland and relatively large areas were chosen to reduce pixel-to-pixel variations. The computed reflectivity gradients here are 3.6 %(100 nm)$^{-1}$ for the blue unit and 8.9% (nm)$^{-1}$ elsewhere. This is in good agreement with the IMP results. For Deimos, the spectral gradient is 10.8% (nm)-1 which is slightly above the IMP value. However, it agrees fully with the conclusion that Deimos is spectrally redder than Phobos even when one excludes the blue unit on Phobos.

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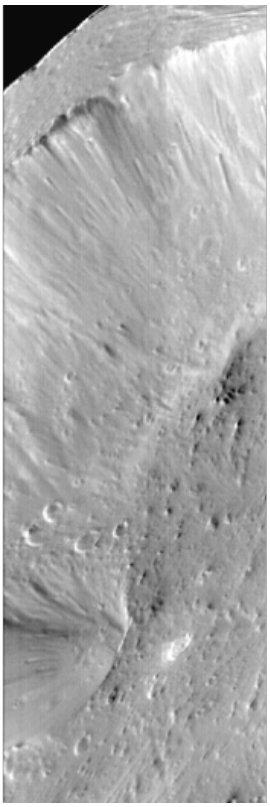

Figure 1 Phobos. Infrared/Blue-green colour ratio for part of image PSP_007769_0915. Limtoc crater is to the bottom-left. The northwestern rim of Stickney is to the top. The sides of both craters how evidence of impact followed by avalanche.

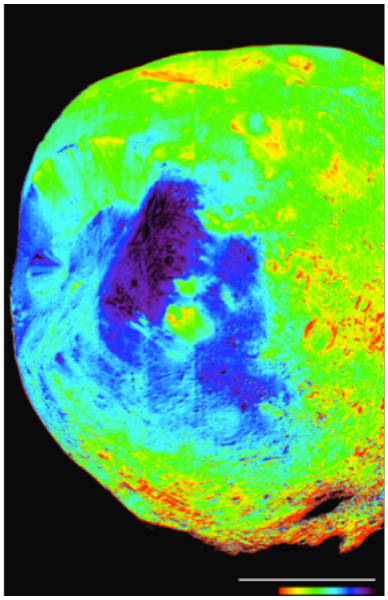

Figure 2 False-colour representation of the colour ratio for a section of PSP_007769_0910. Relatively blue regions are shown as blue or black. Yellow and red regions are more strongly reddened with respect to a solar spectrum. The scale bar is 5 km. A colour bar is shown.

Figure 3 The calibrated data in the three HiRISE colors has been brought together to produce this image. Note the striped nature of the brighter material near and on the ridge. The scale bar is 5 km.

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