EPSC Abstracts,
Vol. 4, EPSC2009-723, 2009
European Planetary Science Congress,

MRO/CRISM Observations of Phobos and Deimos

A. S. Rivkin (1), S. Murchie (1), T. Choo (1), D. Humm (1), J.-P. Bibring (2), Y. Langevin (2), B. Gondet (2), T. Roush (3), T. Duxbury (4), and the CRISM Team

(1) Applied Physics Laboratory, Laurel, MD (scott.murchie@jhuapl.edu), (2) Institute d'Astrophysique Spatial (IAS), Orsay, France, (3) NASA/Ames Research Center, Moffet Field, CA, (4) Jet Propulsion Laboratory, Pasadena, CA.

Summary: The Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) has acquired disk-resolved hyperspectral images of the sub-Mars hemispheres of both Phobos and Deimos in the instrument's high-resolution mode (362-3920 nm) [1]. Three Deimos images were acquired on 7 June 2007 at 1.2 km/pixel and a phase angle of 22°. Three Phobos images were acquired on 23 October 2007 at 350 m/pixel and a phase angle near 41°. These data confirm association of Phobos' "bluer unit" [2] with the interior and ejecta of Stickney crater. Phobos's redder unit and Deimos have a broad, shallow absorption at 0.65 µm resembling that in low-grade carbonaceous chondrites. There is no evidence for absorptions due to mafic minerals, bound water or organics.

Background: Early studies of Phobos and Deimos [3] yielded C asteroid-like spectra for both bodies, leading to speculation they are captured primitive asteroids. Later measurements of Phobos from *Phobos 2* showed it to be relatively red and lacking evidence for bound H_2O, suggesting a primitive, anhydrous composition (like D asteroids) or an evolved, space weathered, mafic composition (like the lunar mare) [2]. In addition, Phobos' surface is heterogeneous, with Stickney exposing material significantly less red than other parts of Phobos or Deimos [2]. Subsequent telescopic measurements confirm the red spectra of both moons and a lack of H_2O absorptions [4,5,6]. TES data confirm the distinctiveness of Stickney material [7].

The compositions of the two moons provide a window into the earliest part of Mars' history not preserved in Martian crustal rock [8]. If primitive bodies, they may be samples of impacting bodies that delivered volatiles to early Mars. A mafic-rich composition like Mars could imply an impact origin like that of Earth's Moon, or an ordinary chondrite-like composition would imply co-accretion with Mars or capture.

CRISM Results: Deimos (Fig. 1, 2) has a nearly featureless red spectrum lacking strong absorptions due to H_2O, organics, or mafic minerals, corroborating earlier results. A strong increase in emission at >2500 nm corroborates high surface temperatures [6].

On Phobos, large spatial variations in continuum slope are evident (Fig. 1). The mapped ejecta east of Stickney [9] exhibits a high 0.5/0.9-µm color ratio (Fig. 3), matching the "bluer unit" of [2] covering Stickney's interior and western flank. The bluer unit has shallower spectral slope at all wavelengths than the redder unit or Deimos, which are similar to one another (Fig. 4).

There is no evidence for mafic mineral absorptions [2,10], localized enhancements of an absorption due to bound water [10], or absorptions due to organics. The only definitive absorption is a broad feature up to several percent in depth, centered near 0.65 µm. This is present on both moons; on Phobos it is strongly correlated with the redder unit and with redder continuum slopes (Fig. 3). This absorption also occurs in low-albedo asteroids interpreted as primitive, and probably indicates ferric iron-containing phyllosilicates [11,12]. Previous "detections" of a 1-µm band in 0.8- to 3.2-µm ISM data [2,10] were based on spectral ratios that may have inverted the shoulder of the 0.65-µm band and created a spurious feature resembling a mafic mineral absorption.

Discussion: Implications of CRISM results for the Martian moons' composition and interrelationship are summarized in Table 1. The 0.65-µm band is the strongest spectral indicator to date of a primitive composition of Deimos and Phobos's redder unit. Its lack in the bluer unit means that unit cannot be a less space-weathered version of the same material. However, the bluer unit is clearly excavated by Stickney from depth, through a redder unit that is indistinguishable from Deimos and may be related genetically.

References: [1] Murchie, S. *et al.*, *JGR, 112*, doi:10.1029/2006JE002682, 2007. [2] Murchie, S. and S. Erard, *Icarus*, *123*, 63–86, 1996. [3] Pang, K. *et al.*, *Science*, *199*, 64-66, 1978. [4] Murchie, S. *et al*, *JGR*, *104*, 9069-9080, 1999. [5] Rivkin, A. *et al.*, *Icarus*, *156*, 64-75, 2002. [6] Lynch, D. *et al.*, *Astron. J.*, *134*, 1459-1463, 2007. [7] Roush, T. *et al.*, *LPS XXXII*, 1915, 2001. [8] Britt, D. and C. Pieters, *Astron. Vestn.*, *22*, 229–239, 1988. [9] Thomas, P., *Icarus*, *40*, 223–243, 1979. [10] Gendrin A. *et al.*, *JGR*, *110*, doi:10.1029/2004 JE002245,

EPSC Abstracts,
Vol. 4, EPSC2009-723, 2009
European Planetary Science Congress,

2005. [11] Gaffey, M. and T. McCord, in *Asteroids*, T. Gehrels, ed., pp. 688-723, Univ. Arizona, Tucson, 1979.

[12] Vilas, F. *et al.*, *Icarus*, *102*, 225-231, 1993.

Fig. 1. False color, brightness enhanced images of Deimos (left) and Phobos (right) constructed with 0.9-, 0.7-, and 0.5-μm values of I/F. Note the less red color of the interior and eastern ejecta of Stickney (the large crater to the upper left in the Phobos image).

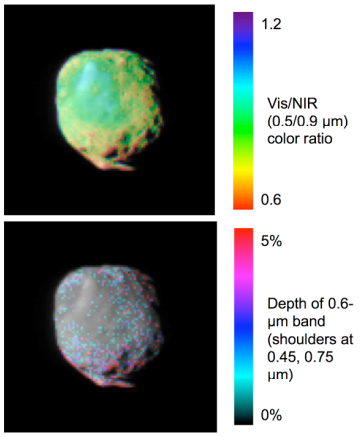

Fig. 3. Spatial variations in spectral continuum slope and strength of the 0.65-μm absorption on Phobos.

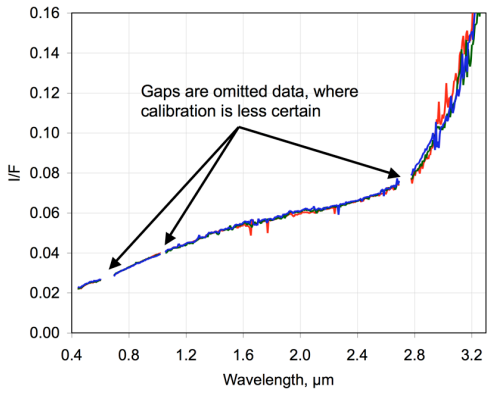

Fig. 2. 4x4 km average spectra from each of the three Deimos observations.

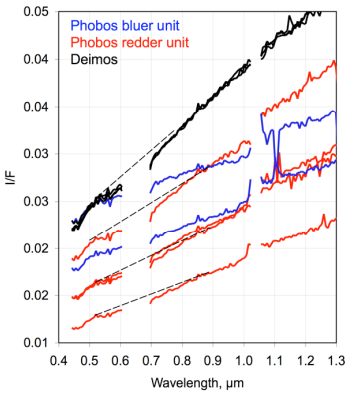

Fig. 4. Comparison of representative spectra of the bluer and redder units on Phobos with Deimos.

Hypothesis	Test	Result
What is the composition of Phobos's bluer unit?		
Mafic material (Mars ejecta or captured)	1-μm mafic mineral band	Not detected
Altered primitive material (e.g. C-type)	Bound water or OH	Not detected
Primitive material (e.g. D-type)	No bound water or OH	No bound water or OH; relatively gray material from depth
What is the composition of Phobos's redder unit?		
Space-weathered mafic material (Mars ejecta or captured)	1-μm mafic mineral band decreasing in strength in redder regions	No mafic band; lack of 0.65-μm band in bluer unit inconsistent with space weathering
Altered primitive material (e.g. C-type)	Bound water or OH	Not detected
Primitive material (e.g. D-type)	No bound water or OH	No bound water or OH, with Fe-mineral absorption like CM chondrite
What is the relationship of Phobos and Deimos?		
Distinct origins	Distinctive spectral features	True of Deimos and Phobos' bluer unit
Fragments of same body, or formed from common source	Nearly identical spectral features	True of Deimos and Phobos' redder unit
Phobos is distinct but covered with accreted Deimos material	Close spectral similarity of Phobos redder unit and Deimos	Most consistent with the data of any model for origin of Phobos' redder unit

Table 1. Truth-table summary of tests for compositions of Phobos and its relationship to Deimos. Gray indicates data inconsistent with hypothesis, and green indicates data consistent with hypothesis.