VISIBLE-NIR SPECTROSCOPIC EVIDENCE FOR THE COMPOSITION OF LOW-ALBEDO ALTERED SOILS ON MARS Scott Murchie, *Applied Physics Laboratory, Laurel, MD*; Erzsébet Merényi, Robert Singer, *Univ. of Arizona, Tucson, AZ*; Laurel Kirkland, *Lunar and Planetary Inst., Houston, TX*.

Spectroscopic studies of altered Martian soils at visible and at NIR wavelengths have generally supported the canonical model of the surface layer as consisting mostly of 2 components, bright red hematite-containing dust and dark gray pyroxene-containing sand. However several of the studies have also provided tantalizing evidence for distinct 1-μm Fe absorptions in discrete areas, particularly dark red soils which are hypothesized to consist of duricrust. These distinct absorptions have been proposed to originate from one or more non-hematitic ferric phases. We have tested this hypothesis by merging high spatial resolution visible- and NIR-wavelength data to synthesize composite 0.44-3.14 μm spectra for regions of western Arabia and Margaritifer Terra. The extended wavelength coverage allows more complete assessment of ferric, ferrous, and H_2O absorptions in both wavelength ranges. The composite data show that, compared to nearby bright red soil in Arabia, dark red soil in Oxia has a lower albedo, a more negative continuum slope, and a stronger 3-μm H_2O absorption . However Fe absorptions are closely similar in position and depth. These results suggest that at least some dark red soils may differ from "normal" dust and mafic sand more in texture than in Fe mineralogy, although there appears to be enrichment in a water-containing phase and/or a dark, spectrally neutral phase. In contrast, there is clear evidence for enrichment of a low-albedo ferric mineral in dark gray soils composing Sinus Meridiani. These have visible- and NIR-wavelength absorptions consistent with crystalline hematite with relatively little pyroxene, plus a very weak 3-μm H_2O absorption. These properties suggest a lithology richer in crystalline hematite and less hydrated than both dust and mafic-rich sand.

Background. Recent spectroscopic studies of altered soils on Mars have been conducted in two wavelength ranges, the extended visible (~0.4-1 μm) [e.g. 1-3] and the NIR (~0.8-3 μm) [e.g. 4-6]. These studies have suggested that altered soils form three major groupings based on positions and strengths of their Fe and H_2O absorptions. (*a*) "Normal" soils are bright red or dark gray at visible wavelengths, and have mineralogic absorptions consistent with intermixture of the two components believed to dominate Mars's surface: bright red, hematite-containing, hydrated dust, and dark, relatively gray, less hydrated, pyroxene-rich sand [7,8]. (*b*) "Dark red" soils in Oxia and Lunae Planum have 1-μm Fe absorptions that are weaker and at shorter wavelengths than those in normal soils of comparable albedo, plus stronger 3-μm H_2O absorptions. The difference in Fe absorptions has been hypothesized to originate from non-hematitic ferric minerals in the dark red soils [5,6]. (*c*) Some low-albedo patches have absorptions suggstive of enrichment in hematite rather than pyroxene [9]. However these studies are limited by their wavelength coverages. NIR data cover the 3-μm H_2O absorption and 1- and 2-μm pyroxene absorptions, but not visible-wavelength absorptions diagnostic of ferric phases. Extended visible data are limited in their ability to distinguish non-hematitic ferric minerals from pyroxene and are insensitive to variations in water content.

Procedure. We combined high spatial resolution observations of the same regions taken at different wavelengths but comparable times, to provide composite spectral coverage from 0.44-3.14 μm. For the extended visible wavelength range we used telescopic slit spectra acquired by Singer et al. [3]. Comparisons with independent measurements of the same regions has shown good calibration at wavelengths <0.9 μm [9]. For the NIR wavelength region we used data from the ISM instrument on Phobos 2. These also have been shown to be in good agreement with independent data sets where the spectral and spatial coverages overlap [10]. The two data sets overlap in western Arabia and Margaritifer Terra, which contain dark gray regions, bright red dust, and dark red soils. The data were merged by (a) identifying coverage of overlapping regions or of the same spectral units [9], (b) averaging spectra from each data set in the matching regions, (c) verifying congruence of spectral shape in the overlapping wavelengths, and (d) scaling the visible-wavelength data to the ISM data. To measure positions and relative depths of absorption bands we adapted the procedure of Mustard and Sunshine [11], by fitting a linear continuum in wavenumber space to regions outside major mineralogic absorptions and ratioing spectra to this derived continuum.

Composite spectra are shown in Fig. 1, and in Fig. 2 ratioed to bright red soil in Arabia. Figs. 3 and 4 show the spectra ratioed to the derived continuum, with the 1-μm and 2-μm regions enlarged for clarity.

Arabia (bright red soil). This spectrum is most representative of "dust." It is very red at visible wavelengths, has weak Fe absorptions near 0.63 and 0.86 μm, and exhibits a strong 3-μm H_2O absorption. These properties support the canonical model of dust as being a hydrated alteration product with ferric iron as hematite in both crystalline form (responsible for absorptions at 0.63 and 0.86 μm [1]) and nanophase form.

Margaritifer Terra (mafic dark gray soil). This region is typical of those dark gray soils interpreted as mafic sands, and consistent with this interpretation the spectrum exhibits absorptions at ~1 μm and ~2 μm indicative of pyroxene. The broad, shallow absorption centered near 2.2 μm is indicative of calcic pyroxene; however, the wavelength center of the ~1-μm absorption (~0.94 μm) is shorter than expected for pyroxene of this composition. There is also a stronger absorption near 0.63 μm. The 3-μm absorption is weaker than in Arabia, and the spectral continuum is highly negative as expected if there is an intermixed ferric component [8,12]. These results support a lesser water content than in bright red dust, and are consistent with Mustard and Sunshine's [11] conclusion from band fitting in the 1-μm region that crystalline hematite and pyroxene occur together in many dark gray soils.

Oxia (dark red soil). Oxia is intermediate in albedo to typical dark gray and bright red soils, but its continuum-removed spectrum exhibits an Fe absorption with a wavelength center and depth closely similar to those of the bright red soil of Arabia. The primary differences from Arabia are lower albedo, a more negative continuum, and a stronger 3-μm H_2O absorption. These differences do not support occurrence of an additional ferric phase with a significant absorption near 1-μm. In fact, the lower albedo and more negative continuum could both be explained simply by intermixture of bright dust with a small fraction of a dark phase [12], or perhaps by a textural difference [13]. The stronger 3-μm H_2O absorption may arise from a different history of environmental exposure if soil texture is different, or it may be associated with a cementing phase in the duricrust such as a hydrated sulfate.

Sinus Meridiani (ferric dark gray soil). Although the dark gray visible-wavelength color of this region superficially resembles that of Margaritifer, the mineralogic absorptions indicate a different composition. The 1-μm band is deeper than in Margaritifer but centered at a shorter wavelength, near 0.86 μm. Despite the depth of this band there is no evidence for a 2-μm pyroxene absorption, although there does appear to be a significant 0.63-μm band. These results suggest that, compared with Margaritifer Terra, Sinus Meridiani is much richer in crystalline hematite and poorer in pyroxene, supporting Bell's [2] and Merényi et al.'s [9] inferences that some dark gray regions may be dominantly ferric rather than ferrous in composition. The 3-μm absorption is weaker than for other soils examined, suggesting relatively low H_2O content and a comparatively anhydrous lithology.

References. [1] Bell, J. *et al.*, *J. Geophys. Res.*, *95*, 14,447, 1990. [2] Bell, J., *Icarus*, *100*, 575, 1992. [3] Singer, R. *et al.*, *Lunar Planet. Sci. XXI*, 1164, 1990. [4] Murchie, S. *et al.*, *Icarus*, *105*, 454-468, 1993. [5] Mustard, J., *Lunar Planet. Sci. XXVI*, 1021, 1995. [6] Murchie, S. *et al.*, *Lunar Planet. Sci. XXIV*, 1029-1030, 1993. [7] Christensen, P., and H. Moore, in *Mars*, ed. by H. Kieffer *et al.*, pp. 686, Univ. of Ariz., 1992. [8] Roush, T., in *Remote Geochemical Analysis: Elemental and Mineralogical Composition*, ed. by C. Pieters and P. Englert, Cambridge Univ., 1993. [9] Merényi, E. *et al.*, *Icarus*, in press, 1996. [10] Mustard, J., and J. Bell, *Geophys. Res. Lett.*, *21*, 353, 1994. [11] Mustard, J. and J. Sunshine, *Science*, *267*, 1623, 1995. [12] Morris, R. *et al.*, *Geophys. Res. Lett.*, *9*, 548, 1982. [13] Arvidson, R. *et al.*, *J. Geophys. Res.*, *94*, 1573, 1989.