SPECTRAL PROPERTIES OF ROCKS AT THE MARS PATHFINDER LANDING SITE. S. Murchie[1], J. Johnson[2], H. McSween[3], N. Bridges[4], R. Anderson[4], D. Britt[5], J.F. Bell, III[6], J. Crisp[4], [1]Applied Physics Laboratory, The Johns Hopkins University, Laurel, MD, [2]U.S. Geological Survey, Flagstaff, AZ, [2]University of Tennessee, Knoxville, TN, [5]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, [4]Jet Propulsion Laboratory, Pasadena, CA, [6]Cornell University, Ithaca, NY.

Four major classes of rock surfaces are recognized in Imager for Mars Pathfinder (IMP) spectral measurements. Three classes, dark gray, bright red, and bright pink rocks, form a "main spectral trend" in which higher reflectances are accompanied by higher red/blue ratios and a stronger 530-nm ferric absorption. These rocks have reflectance maxima at 750 nm and lack an infrared absorption with a resolved minimum. The highest albedo rocks approach properties of drift. In contrast, dark red rocks have high red/blue ratios and a strong 530-nm absorption like drift, but are darker, exhibit a ferric absorption at 900-930 nm, and have a reflectance maximum shifted longward to 800 nm. Spectral variations among the main trend rocks are highly consistent with expected effects of thin drift coatings. The infrared properties of dark red rocks suggest instead a coating with a ferric mineralogy different from that in drift.

Analytical Methods. Three main techniques were used to assess spectral variations in rocks. First, spectral parameter images were produced, mainly from the "gallery panorama" because of its continuous spatial coverage and favorable lighting. Second, using parameterized images as a guide, representative spectra were extracted from the superpanorama and multispectral spot measurements. Finally, based on the results of analysis of type spectra, unit classification maps were derived by thresholding of spectral parameter values. Superpanorama data were used for this purpose, because they are the only data covering substantial swaths of the landing site in all of the wavelengths necessary to discriminate rock and soil units. All data were calibrated using CCD corrections and measurements of the IMP calibration targets as described by Reid et al. [1].

Rock Spectral Classes. Four classes of rocks were recognized. Type spectra are shown in Figure 1; in Figure 2 they ratioed to typical drift to highlight spectral differences. "Dark gray" surfaces have a 750-nm reflectance of 10-25%, a low red/blue (670/440 nm) ratio of £2.9, and a 530-nm ferric band £7% in depth. Peak reflectance occurs at 750 nm; at longer wavelengths, no well-defined absorption band minimum is observed. "Bright red" rock surfaces have reflectances of 15-30% at 750 nm, a red/blue ratio (2.9-4.5) higher than on dark gray rocks but less than in drift, and an intermediate 530-nm band (7-18%). "Bright pink" surfaces occur on tabular rock-like masses and as crusts in soil and on pebbles. Reflectance at 750 nm is 35-45%, higher than in most drift, but red/blue ratio (4.5-5.5) and 530-nm band depth (18-28%) overlap the range in drift. The type location, "Scooby Doo," was found in APXS data to be soil-like in composition [2]. No abrasion of the rock's surface resulted from a rover soil mechanics experiment, consistent with a lithology at least as well-indurated as hardpan soil [3]. "Dark red" surfaces occur mostly on large, rounded boulders. Most spectral attributes are similar to those of drift, but at infrared wavelengths many dark red rocks are distinct: the reflectance peak is shifted longward to 800 nm, and there is a weak ferric absorption band at 900-930 nm.

Scatterplots of reflectance, red/blue ratio, and 900-nm band depth (Figures 3 and 4) show that the four rock classes form two larger groups. In the "main spectral trend" (dark gray, bright red, and bright pink rocks), with increasing reflectance rocks assume more of the ferric attributes of drift (higher red/blue ratio, greater 530-nm band depth). The reflectance peak is consistently at or near 750 nm, and no infrared band minimum is resolved. A greater nominal "900-nm band depth" in darker, less ferric rocks is attributable to greater curvature of the infrared spectra of less altered rocks. We believe this curvature results from an Fe^{2+} absorption in glass or high-Ca pyroxene, whose center is at or beyond the limit of IMP's wavelength range. In the "redder spectral trend," containing dark red rocks and some drifts, red/blue ratio and 530-mm band depth are nearly invariant but reflectance varies by a factor of >2 and an Fe^{3+} absorption is present at 900-930 nm. In rocks and soils with the strongest absorption, the reflectance peak is shifted longward to 800 nm.

Spatial Variations in Rock Properties. Spectral properties of rocks appear strongly related to wind direction. Rocks of all types exhibit predominantly dark gray properties on their northeast surfaces, facing the prevailing wind. Dowwind surfaces are typically bright red, and parts of bright red rocks most exposed to eolian abrasion are dark gray. On large boulders interpreted to be the oldest rocks at the site [4], a large portion of the downwind surfaces are dark red.

Evidence for Coatings. Both spatial and spectral variations in rock properties lead us to hypothesize that the dominant source of spectral heterogeneity on "main spectral trend" rocks is thin coatings of drift. The relationship of spectral properties with prevailing wind direction is consistent with preferential removal, or lack of deposition, of a thin ferric coating on upwind rock surfaces. In addition, as these rocks assume a more ferric character, their red/blue ratio and 530-nm band depth approach those of drift but reflectance exceeds that of drift. A similar relationship is seen in the laboratory between ferric materials occuring as a rock coating and as a powder [5]. The spectral variations among main trend rocks follows quite closely the variations resulting from different areal coverages of a dark, gray surface by an optically thick ferric coating. Coating effects are isolated in Figure 5 by ratioing IMP spectra and laboratory spectra of coatings to ferric materials (drift and ferric powder respectively) occuring as uncompacted powder. Variations among main trend rocks also mimic the effects of variations in thickness of an optically thin coating. Either type of coating is predicted to cause an increasingly drift-like composition of rocks having progressively redder, more ferric spectra, as confirmed by Bridges et al. [6].

Rocks in the redder spectral trend exhibit different spectral systematics, unlikely to be explained by the same physical processes. Their differing infrared spectral properties may indicate the presence of one or more additional ferric minerals, perhaps ferrihydrite, that is less abundant on the surfaces of main trend rocks.

References. [1] Reid, R. et al., this issue. [2] Rieder, R. et al., *Science*, *278*, 1771-1774, 1997. [3] The Rover Team, *Science*, *278*, 1765-1768, 1997. [4] Smith, P. et al., *Science*, *278*, 1758-1765, 1997. [5] Fischer, E. and C. Pieters, *Icarus*, *102*, 185-202, 1993. [6] Bridges, N. et al., this issue.

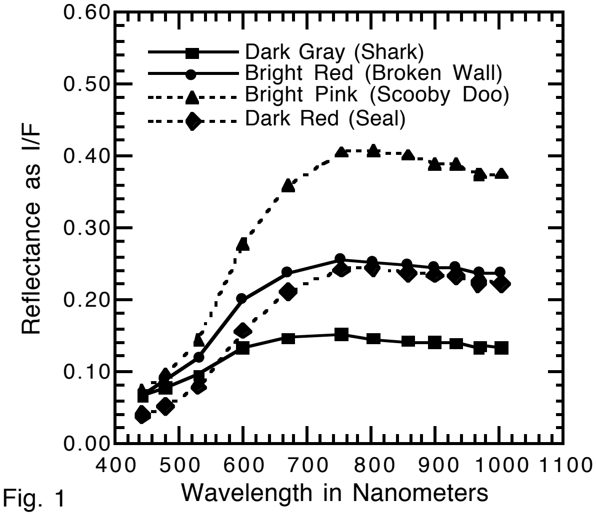

Fig. 1

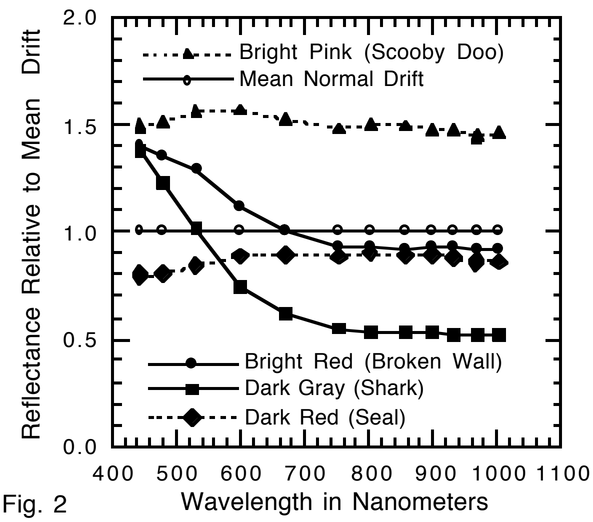

Fig. 2

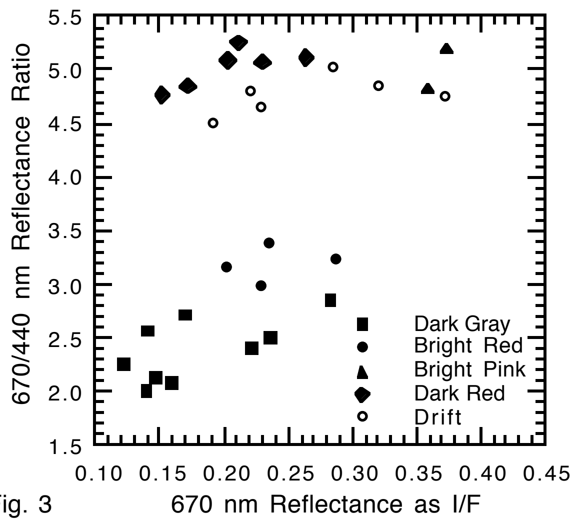

Fig. 3

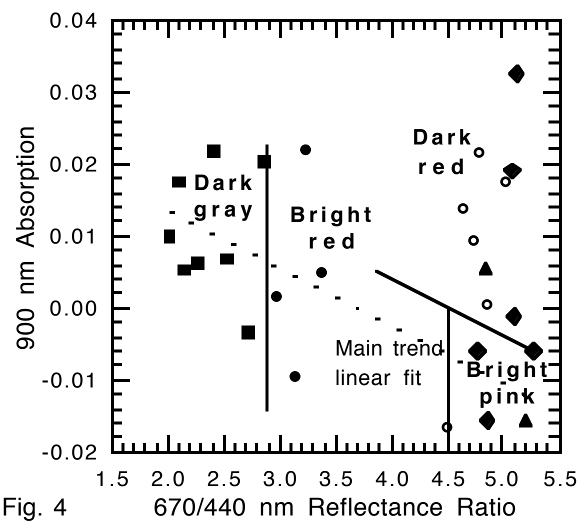

Fig. 4

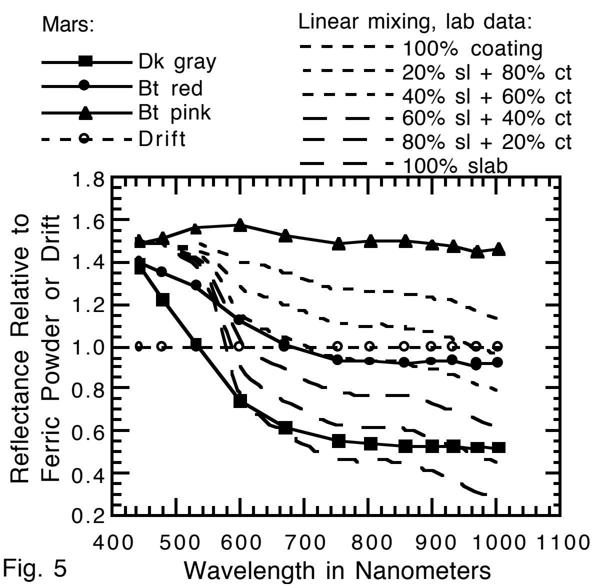

Fig. 5