

**Introduction:** The Imager for Mars Pathfinder (IMP) has provided images of the Mars Pathfinder (MPF) landing site in 15 geology filters, designed to reveal the composition and mineralogy of the landing site [1]. A first calibration of these images [2] has yielded a wealth of geologic results. Local rocks and soils have been classified based upon spectral signature [3, 4], spectra have been correlated with APXS data [4, 5], and many of the photometric properties of the surface materials have been determined [6]. The compositional connection between local rocks and soils has been examined [4, 7], and it has been suggested that the ferric soils are not solely products of weathering of the local rocks. Several issues remain unresolved, however, including the determination of ferric phases in rocks and/or soils [7] and the apparent lack of any pyroxene band in rock spectra [e.g. 3,4,8]. Recalibration of the IMP images has provided spectral details that clarify many of these early results [9, 10].

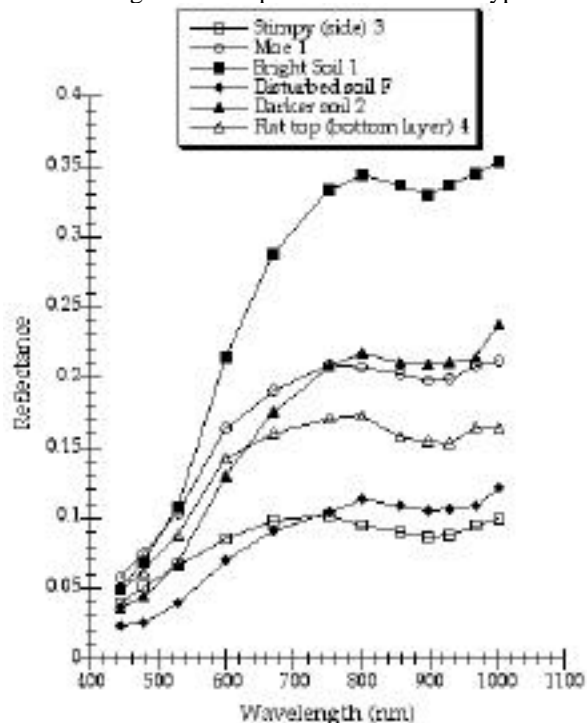
**Method:** We have analyzed images surrounding Mini-Matterhorn (MM), Space Ghost (SG) and within the Rock Garden (RG) as sample regions. Because these images represent a wide range of features and terrain, they demonstrate the geologic variation of the site. Images in each filter were calibrated [2, 10] and were registered to each other and stacked to create two hypercubes yielding information in the left (8 filters) and right (7 filters) camera eyes. Three filters were duplicated in both eyes to produce stereo images.

In order to highlight potential geologic variations, both individual filters and ratios were examined. For example, the ratio of the 752/900 nm filters distinguishes variations around the  $Fe^{3+}$  and  $Fe^{2+}$  (mafic) absorption band feature, while the 752/443 nm and 530/480 nm ratios highlight differences in slope attributable to the variations of ferric oxide and oxyhydroxide minerals [1]. Point spectra were taken to identify detailed spectral signatures of geologic features as well as any anomalous features. First-order classification of spectra was made based on variations revealed by these and previous results. The registration process is accurate in these scenes to  $\sim 1/4$  pixel; thus spectral information taken from each pixel is an accurate representation of the reflectance for that pixel. Error bars on these spectra are around 2-3% band-to-band reflectance [10].

**Geologic Setting:** Regions studied included those surrounding Mini-Matterhorn and Space Ghost, regions of angular rocks, a preponderance of cobbles and pebbles, and a great deal of soil disturbed by airbag retraction. Spectra were also taken from the Rock Garden, a region dominated by rounded, imbricated rocks likely deposited through fluvial action [e.g. 11, 12].

**Spectral Types:** Sampled rocks and soils may be

divided into two rock and three soil spectral types, shown in Figure 1. The parameters for these types are



**Figure 1.** Rock and soil types.

similar to those presented by [3, 4] in terms of albedo and shorter wavelength features, while longer wavelength features have been more clearly revealed by recalibration. The first group, typified by Stumpy, is characterized by a low overall reflectance, a relatively flat slope from 443 to 752 nm and a weak feature centered at 900-931 nm. This dark rock (DR) signature is associated with the angular, pitted rocks around Mini-Matterhorn and various rock faces in the Rock Garden, and is similar to that previously identified as typical of relatively unweathered, angular “dark” rocks [3] or “gray” rock faces [4]. We therefore interpret this spectral type to be analogous to gray rocks [4], representing the most dust-free, well-illuminated rock faces.

The second rock type, represented by Moe, has a higher overall reflectance, a steeper 443-752 nm slope and a more prominent local minimum centered at 900 nm. This bright rock type (BR) typically is associated with imbricated rocks in the Rock Garden, as well as Space Ghost and the surrounding cobbles, with 752/443 nm slopes of the larger rocks (e.g. Moe, Half Dome) appearing flatter than those of the smaller rocks (e.g. Ren, Lone Pine). Typical signatures may correspond to the “bright” rocks in [3] interpreted to be

more weathered or dust-contaminated rocks of similar composition to DR, and the “bright red” rocks [4] which are interpreted to be downwind, dust-contaminated regions of DR. We note that no rocks analogous to “pink” or farfield “maroon” types [4] were included in the scenes examined.

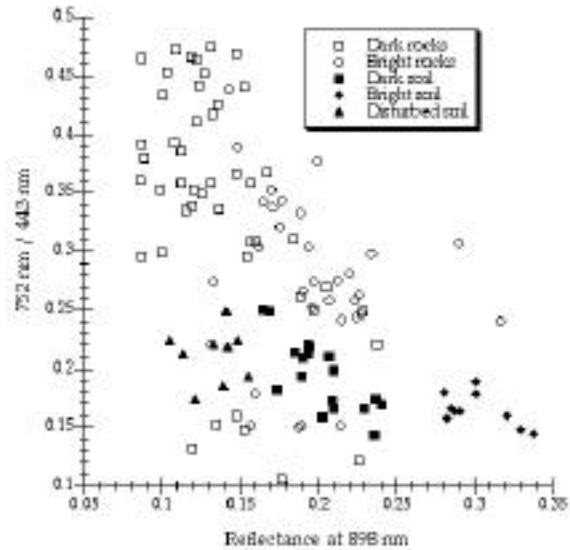
Three soil types were sampled: bright, dark and disturbed. Bright soils (BS) are characterized by a high reflectance, a steep slope from 443 nm to 752 nm and the presence of a local minimum at 900 nm. Dark soils (DS) have a lower reflectance and 443-752 nm slope, similar to the shape of BR spectra, although the local minimum at 900 nm is more prominent. These soils are comparable to the “bright drift” and “brown soil” classifications of [4] respectively. An additional soil type, disturbed soil (DisS), was also sampled. This soil type has a very low reflectance, comparable to that of DR. However, the 443-752 nm slope is significantly steeper, and the long wavelength local minimum is centered at 900 nm rather than around 900-931 nm.

**Comparison with Previous Results:** The vast majority of rocks sampled have a maximum reflectance at 752 nm. However, Moe, Frog, Wedge, Snoopy, Space Ghost and several cobbles, as well as all but the lightest soils around Space Ghost, have peak reflectances at ~802 nm. This maximum is comparable to that diagnostic of the secondary spectral trend introduced by [4], although all soils have this shifted maximum, while only “brown” soils and large “maroon” farfield boulders [4] typically show peak reflectances at 802 nm. Ferric phases displaying a 802 nm peak reflectance include maghemite and ferrihydrite [7].

None of the spectra examined in this study showed the puzzling negative slope from 752-802 nm to 1000 nm previously observed [e.g. 3,4,7]. Instead, there is a consistent local minimum visible at ~900 nm for nearly all spectra. This band deepens from DR to BR and DS to BS, and could thus represent a ferric component in the soil and in coatings of various thicknesses or consistencies on local rocks [e.g. 4]. We note that because there is no correlation between the position of peak reflectance (752 nm or 802 nm) and the classification of a rock as DR or BR, the relationship between soils and rock coatings is not a simple one. More than one ferric phase may be represented in the soils and any coatings. As mentioned above, the center of this feature shifts to ~931 nm for about 2/3 of DR, as demonstrated by the lower portion of Flat Top in Figure 1. One interpretation of this shift is the presence of pyroxene in a majority of the DR.

Soil and rock types may be separated through analysis of ratios and scatterplots, as shown in Figure 2. Subtle differences in various spectral features revealed by the recalibrated images suggest that DS and BR spectra are more similar than previously indicated. Thus, although local soils are not derived solely from local rock weathering [4, 7], there may be a stronger link between DS and BR. For example, it is possible

that DS has a higher component of local



**Figure 2.** Ratio of 752/443 nm compared with reflectance at 898 nm for rock and soil types.

rock. We continue to examine the recalibrated images to clarify any relation between local rocks and soils.

**Conclusions:** A recalibration of the IMP images has provided confirmation of earlier soil and rock classifications [3, 4], as well as clarification for the spectra of MPF landing site rocks and soils. Specifically, we note the following results and implications:

- A 900 nm local minimum exists in nearly all spectra, weak in rocks and stronger in soils, suggesting a ferric oxide absorption band. For those materials where this feature is also associated with a 802 nm peak reflectance, the ferric oxide in question may be maghemite or ferrihydrite.

- A shift in the position of this local minimum to 931 nm for many of the DR may be explained by the presence of pyroxene in these rocks.

- Although all soil and rock types are easily separated, more similarities in spectral shape and the position and depth of features exist between BR and DS than was previously suggested. These units may thus be more intimately related than previously assumed.

**References:** [1] Smith, P. H. et al. [1997] *JGR*, 102, 4003-4025. [2] Reid, R. J. et al., [1999] *JGR*, 104, 8907-8925. [3] Smith, P. H. et al. [1997] *Science*, 278, 1758-1765. [4] McSween, H. Y. et al. [1999] *JGR*, 104, 8679-8715. [5] Bell, J. F. and D. Bustani [1999] *LPSC*, 30<sup>th</sup>, 1388. [6] Johnson, J. R. et al. [1999] *JGR*, 104, 8809-8830. [7] Morris, R. V. et al. [1999] *JGR*, submitted. [8] Bell, J. F. et al. [1999] *JGR*, submitted. [9] Yingst, R. A. et al. [1999] *LPSC*, 30<sup>th</sup>, 1915. [10] Reid, R. J. et al. [1999] this volume. [11] Masursky, H. et al. [1977] *JGR*, 82, 4016-4038. [12] Komatsu, G. and V. Baker [1997] *JGR*, 102, 4151-4160.