Comparison Between APXS and IMP Multispectral Data at the Pathfinder Landing Site: Evidence for Dust Coatings on Rock Surfaces.

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Introduction

The *Mars Pathfinder* mission provided detailed chemical and mineralogical information on Martian surface materials. Elemental abundances for atomic numbers ≥ 11 (Na) were deduced by the x-ray backscattering characteristics of samples analyzed by the APXS [1,2]. The IMP camera imaged virtually the entire landing site in 15 geology filters ranging from 440 to 1000 nm [3,4]. It was recognized early in the development of the *Pathfinder* mission that correlating APXS and IMP data would provide important information on the chemical makeup of the Martian surface and insight into the processes that acted to form the rocks and soils [3,5]. Initial work on the correlation of those two data sets is reported here. We show that the redness of most rocks is proportional to sulfur content, indicating that the sulfur in APXS measurements of rocks is affected by superficial coatings of dust or soil.

Soils and rocks have distinct attributes in both the APXS and IMP data sets. The APXS detected high abundances of sulfur in the soil, consistent with the enrichment of this element in the soils at the two *Viking* landing sites [6]. On average, soils contain 2.3 times as much S and 1.2 times as much Fe as rocks, with the apparent sulfur content of rocks varying by about a factor of six. The apparent amount of sulfur in the rocks is much greater than that found in most terrestrial basalts, which generally have sulfur abundances of less than 2000 parts per million [7]. From IMP data, absorption bands characteristic of distinct mineral species are relatively absent [4]. However, soils and rocks exhibit characteristic spectral shapes that can be quantified using spectral ratios. As a class, Martian soils generally have reflectances that are brighter in the red and infrared than rocks, which translates into higher red/blue ratios. Considering both the APXS and IMP data sets, soils are sulfur-rich and "red" whereas rocks are sulfur-poor and "blue." Sulfur's high abundance in soil relative to fresh rocks potentially allows it to be used as a chemical tracer of soil or dust contamination on rock surfaces.

Procedure

At the time of this writing, x-ray data have been extracted from eleven APXS sites [2]. This includes five rocks and six "non-rocks." In the latter category, four units are unequivocally identified as soils, whereas Mermaid and Scooby Doo, although exhibiting many soil-like attributes, have properties that make them unique. The exact position of each APXS spot was determined through careful analyses of rover camera and IMP images. In cases where location was especially difficult to estimate, JPL rover engineering software was used to accurately measure rover and APXS positions. The number of pixels subtended by the APXS spot in IMP images was assumed to be a linear function of distance from the IMP. For each spot, spectra were generated using data calibrated to relative reflectance (R*) [8] from all IMP geology filters in the "superpan" and "multispectral spot" sequences. The R* values in each wavelength were adjusted slightly to account for small differences between the left and right eyes of the IMP caused by calibration errors. Redness of each spot was measured by taking the ratio of relative reflectances at 750 nm (infrared) and 440 nm (blue). In most cases, R* values from the IMP right eye were used. The Yogi right eye 440 nm image had missing packets in the area of the APXS spot, so left eye data for this wavelength were used in this one case (the left eye image contained a minor degree of pixel saturation due to over-exposure). For most APXS sites, two or more spectra, each taken at a different time of day and under varying lighting conditions, were available. Except in cases where spots were heavily shadowed, all spectra were used. Under optimal lighting conditions at slightly different times of day, ratios varied by no more than 12% for rocks, 3% for soils, 13% for Mermaid, and 2% for Scooby Doo. Because of these minor differences, these points were averaged together.

Results

The 750/440 nm ratio was plotted against SO_3 because Martian soils are very sulfur-rich and red relative to rocks [Figure 1a]. Ratios were also plotted against FeO and Cl because Martian soils are slightly enriched in iron and chlorine relative to rocks [Figures 1b and c]. As the plots illustrate, the soil APXS sites are generally redder than those for rocks, with only Yogi rock having a slightly higher 750/440 ratio than Mermaid, which may be armored with basaltic sand or granules [9] and therefore be bluer than pure soil. The materials with the highest and lowest iron and chlorine contents are soils and rocks, respectively, with both classes having intermediate iron and chlorine contents. The 750/440 nm ratio correlates well with SO_3, with a multiple correlation coefficient (R^2) of 0.806. The rocks on their own have an R^2 of 0.685 and, except for Half Dome, show a clear trend of increasing redness with increasing sulfur. The rock correlation with Cl is weaker ($R^2 = 0.266$), with Half Dome again breaking the trend, and there is no discernible relationship between redness and FeO. A moderate correlation between 750/440 ratio and Cl ($R^2 = 0.582$) and SO_3 ($R^2 = 0.427$) for soils is evident.

Interpretation

These observations imply that many rocks at the *Pathfinder* landing site are covered with significant amounts of dust or soil, even in apparently clean areas selected for APXS measurements. The only exception may be Half Dome, which has an intermediate amount of sulfur and a large amount of Cl for rocks, but is relatively blue. The proposed dust or soil coatings on the sampled rocks cannot be thick, because IMP images show the APXS sites to be free of large accumulations of bright red material. Therefore, it is proposed that the sulfur detected in the APXS rock measurements is strongly affected by superficial coatings of dust or soil and is not representative of primary rock chemistry. The poor trend of 750/440 nm ratio with FeO implies that the iron content of uncontaminated rock surfaces is similar to that of soil. This poor trend also suggests that the thickness and areal distribution of dust on rock surfaces, rather than the abundance of spectrally-active ferric components in the dust, exerts the strongest influence on rock spectral properties. Although sulfur-rich rocks cannot be completely ruled out, the strong correlation between redness and sulfur content implies that the rocks at the *Pathfinder* landing site have dust-free compositions similar to terrestrial igneous rocks.

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References:

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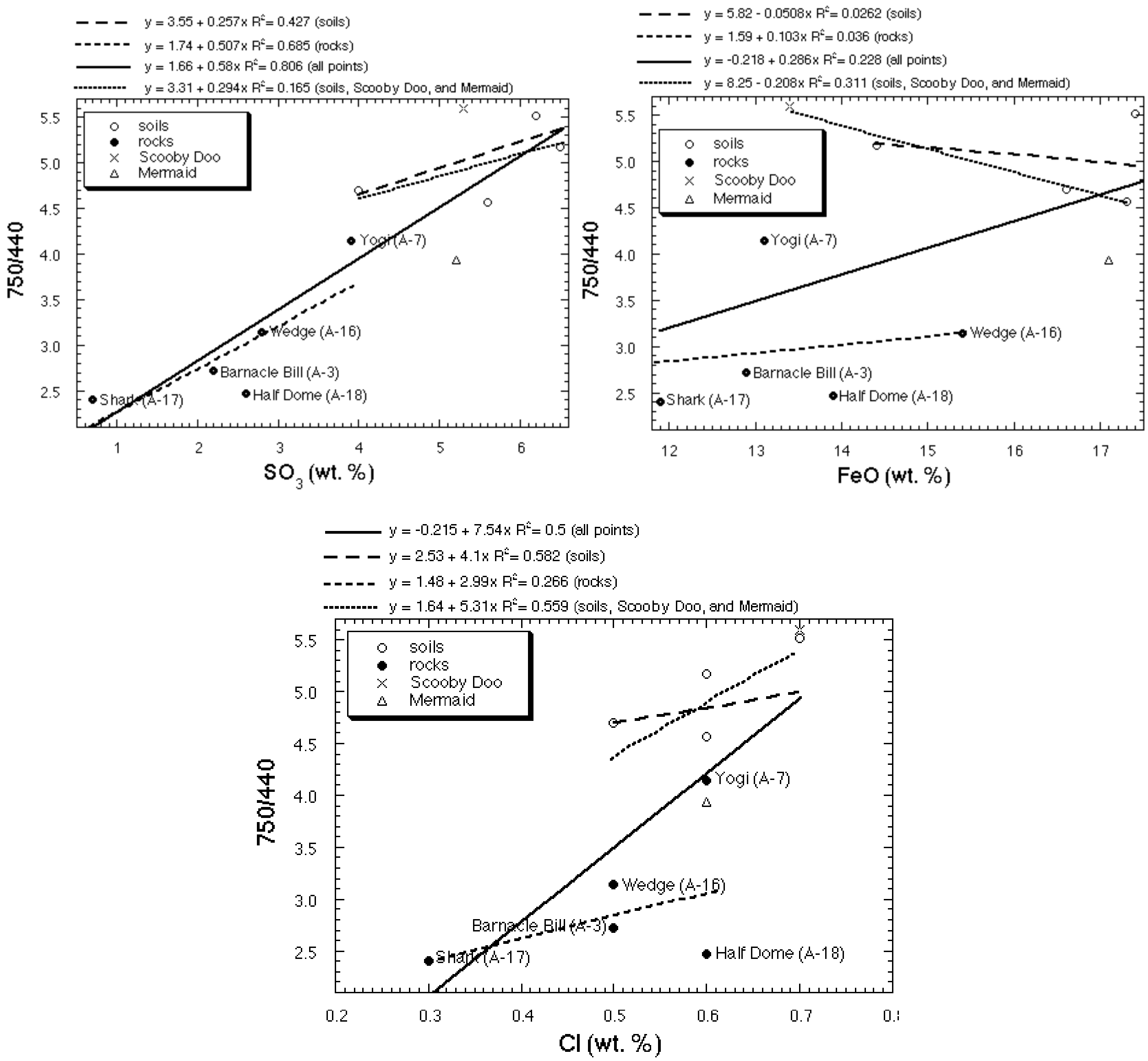

Fig. 1: 750/440 nm ratio plotted against SO_3 (a), FeO (b), and Cl (c). The redness of rocks is well correlated with sulfur, but is weaker for chlorine and absent for iron.