

THE MARS PATHFINDER APXS SITES: NEW INSIGHTS FROM IMPROVED IMP CALIBRATION AND IMAGE ANALYSIS N. T. Bridges and J.A. Crisp, Jet Propulsion Laboratory, California Institute of Technology (MS 183-501, 4800 Oak Grove Drive, Pasadena, CA 91109; nathan.bridges@jpl.nasa.gov); J.F. Bell III, Cornell University, Ithaca, NY 14853,

Introduction

The Alpha Proton X-ray Spectrometer (APXS) from the Mars Pathfinder mission measured elemental abundance data from 5 rocks and 6 soils [1-3]. Complementary to this dataset are visible/near IR multispectral image cubes acquired by the Imager for Mars Pathfinder (IMP). Together, these data address important topics such as the amount of dust on rock surfaces [2-5] and the role of soil components in determining soil chemistry [3,6].

Critical for a proper interpretation of the APXS results is thorough documentation and analysis of all relevant IMP data. Here, we report on preliminary results using the latest calibrated IMP images [7] and on detailed studies of the photometric geometry, location, and characteristics of each APXS spot. We show that: 1) Reflectances (R^{λ}) derived from the most recent IMP calibration routines are different enough from Version 1 to warrant their use. 2) Incidence angle, taking into account surface geometry, varies significantly among APXS spot sequences and has an important effect on red/blue ratio. When rock reflectances from similar incidence angles are compared, the relationship between 750/440 nm ratio and SO_3 content generally holds. 3) Soil spectral properties and morphology do not correlate with APXS-derived elemental chemistry. In at least some cases, this is attributable to heterogeneities within and among soils.

Methods

Of the seven IMP multispectral sequences [8], the Insurance Pan (stowed), Multispectral Spots, and Superpan were used. These are superior to other sequences because they have minimal (2:1) or lossless compression and, in the case of the MS spots and Superpan, were acquired in all twelve geology filters. Although having less spectral coverage, the Insurance Pan contains 440 and 750 nm images, ideal for making red/blue ratios. It also imaged the APXS soil sites before they were disturbed by rover activity.

All raw images of the APXS sites from these sequences were cataloged and converted to radiance using CCDCAL Version 2, provided by Bob Reid of the University of Arizona. This version incorporates corrections for saturated pixels, shuttering, dark current, flatfield, and bad pixels. To convert to reflectance relative to the radiometric calibration targets (R^{λ}) [7], the UA program SPECTCAL Version 3 was used [7,9,10]. Radiometric target sequences close in time and, in most cases, sol were used to facilitate the computation of target and scene radiance under nearly identical illumination conditions.

Reflectances of APXS spots were retrieved using the IDL program IMPSPCT (developed by co-author J. Bell). The dimensions of each box measured were proportional to the size of the areas measured by the APXS as seen from IMP. To account for slight reflectance offsets between the same filters in the left and right eyes of IMP, all spectra were "scaled" to the average of either the 440 nm or 670 nm reflectances.

To quantitatively determine the 3-D geometry of APXS

spot surfaces, the x-y-z positions of several points around each spot were determined using stereo images in the JPL program "Showstereo." The points were then fitted to a plane with strike and dip components. These data, combined with IMP and solar orientation information read from the image labels, were used to compute the true incidence angles of the APXS spot surfaces.

Results

The orientations and 750/440 nm ratios are shown in Table 1. Strikes are relative to true north on Mars. The 750/440 ratio is listed for all cases, including sequences that are in shadow. Sites A-2 and A-5/182C are averages of regions near the actual APXS spot. Site A-4/182A is an average of disturbed and undisturbed material. Incidence angle (measured relative to surface orientation) has a significant effect on spectral properties, consistent with previous work at the Viking landing sites [11].

Some of these data were compared to spectra from spots in the same location using CCDCAL and SPECTCAL Version 1. Reflectances generally differed by ~1-20% between the versions, with the resulting differences in 750/440 nm ratio being as great as 20% or more, but in most cases less than 10%. This indicates that the new IMP calibration algorithms yield results that, although similar to Version 1, are different enough to warrant their use.

The 750/440 nm ratio of rock APXS sites compared to APXS-derived SO_3 content is shown in Figure 1. (Data from the Insurance Pan is not included in this plot, because it was still undergoing further calibration at the time of this writing). There is a good correlation between the Version 3 750/440 nm reflectance ratio and SO_3 content, with an R^2 of 0.77 when relative reflectances from the same spot are averaged. This correlation is consistent with previous investigations using Version 1 data [2,4,5].

Red/blue ratio vs. sulfur for soils is shown in Figure 2. As demonstrated in previous investigations using IMP Version 1 data [3,4,5,12], there is no obvious correlation between these and other spectral parameter/oxide components for soils. Although all these sites are commonly classified as "soils" [3], two have specific attributes that should be considered when interpreting APXS data:

A-2: Because the rover blocked a view of the exact APXS deployment location, the position of site A-2 cannot be determined precisely. Rather, it could consist of one or more heterogeneous components consisting of fine drift, rock, or windtail materials. A sampling of these components shows that considerable spectral diversity may characterize A-2.

A-5: Multispectral cubes of this site prior to disturbance by the rover are only available in the Insurance Pan, which is still undergoing Version 3 calibration. To characterize undisturbed A-5 material, two spots near the site that had a similar appearance to the A-5 site in the Insurance Pan were measured.

The spectral diversity of other soil sites is largely due to differences in incidence angle and soil state (undisturbed or

disturbed) among different IMP sequences.

Discussion

Previous APXS/IMP studies have shown that there is a good correlation between 750/440 nm ratio and APXS-derived SO₃ content [2,4,5]. This has been attributable to a coating of sulfur-rich, red dust on rocks that has a composition similar to that of Pathfinder soils [2-5]. The reproduction of this finding using IMP Version 3 reflectances further demonstrates that dust is a pervasive component of rock spectra and surficial chemistry. The lack of correlation for soils also is consistent with previous work [3-5,12]. The heterogeneity among soils points to a variety of components and physical states making up Pathfinder soils [3] that cannot easily be correlated to APXS-derived chemistry. These IMP and APXS observations support a model of

the Pathfinder landing site consisting of a complex assemblage of rocks, dust, and soil materials partially mixed by aeolian processes [3], similar to interpretations of the Viking 1 landing site [13]. The difficulties in untangling compositional from photometric effects in these data illustrate the need for rock corers and detailed, high precision multispectral cameras being planned for future Mars missions.

TABLE 1 - Photometric Properties of APXS Spots

| Spot | Sequence | Strike | Dip | | 750/440 |
|------|----------|--------|------|----------|-----------|
| | | | | | 40 |
| A-2 | 182A | 75.7 | 6.3 | W | 5 |
| A-3 | 33C | 37.4 | 53 | E shadow | 2.5 |
| | 172B | | | | 2.7 |
| | 182A | | | | 5.1 |
| A-4 | 33C | 66.7 | 6 | E | 4.2 |
| | 172F | | | | 5.9 |
| | 182A | | | shadow | 5.3 |
| A-5 | 33C | 44.2 | 5.4 | E | 3.6 |
| | 182A | | | | 4.5 |
| | 182C | | | | 5.1 |
| A-7 | 33C | -41.2 | 68 | W | 2.6 |
| | 172F | | | | 5 |
| | 181F | | | | 6.6 |
| | 182A | | | | 4 |
| | 182C | | | | 3.2 |
| A-8 | 172E | -5.4 | 16.1 | W | 5.7 |
| | 182C | | | | 5.2 |
| A-10 | 30B | -87 | 1 | E | 4.8 |
| | 172D | | | | 5.4 |
| | 172M | | | | 5.8 |
| | 181F | | | | 4.8 |
| A-15 | 171B | -63 | 8.5 | E | 3.9 |
| | 185B | | | | 3.5 |
| A-16 | 32C | -37.4 | 26.3 | E | 4.2 |
| | 172D | | | | 2.8 |
| | 184A | | | | 2.8 |
| A-17 | 32C | -25.8 | 90 | V shadow | 3.5 |
| | 172M | | | | 3.2 |
| | 172P | | | | 2.4 |
| | 184A | | | | 2.2 |
| A-18 | 32C | -41.8 | 51.8 | E shadow | 3.3 |
| | 172M | | | | 2.9 |
| | 184A | | | | 2.6 |

FIGURE 1: Version 3 750/440 nm ratio vs. APXS-derived SO₃ content.

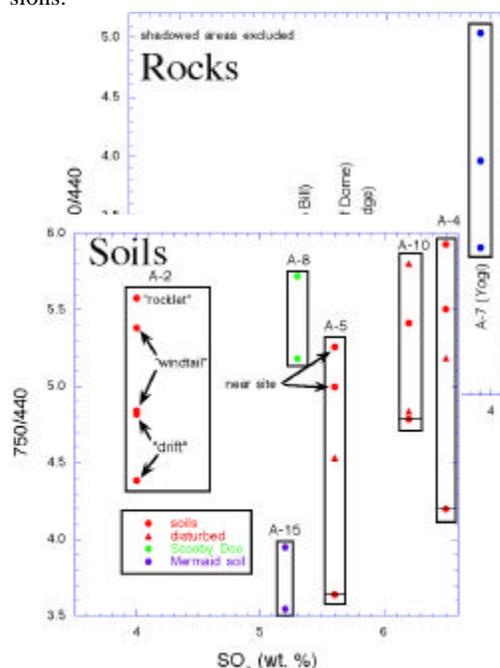


FIGURE 2: Version 3 750/440 nm ratio vs. APXS-derived SO₃ content. Symbols with horizontal slashes are from the Insurance Pan, which is still undergoing calibration.

[1] R. Rieder et al., *Science*, 278, 1771-1774, 1997. [2] H.Y. McSween et al., *J. Geophys. Res.*, 104, 8679-8715, 1999. [3] J.F. Bell et al., *J. Geophys. Res.*, in press, 2000. [4] N.T. Bridges et al., *Eos, Trans. AGU*, F402-403, 1997. [5] N.T. Bridges et al., *Lun. Planet. Sci.* XXIX, 1534, 1998. [6] N.T. Bridges and J.A. Crisp, *Lun. Planet. Sci.* XXX, 1927, 1999. [7] R.J. Reid et al., *J. Geophys. Res.*, 104, 8907-8925, 1999. [8] P.H. Smith et al., *Science*, 278, 1758-1765, 1997. [9] R.J. Reid et al., *5th Inter. Mars Conf.*, 6177, 1999. [10] R.A. Yingst et al., *5th Inter. Mars Conf.*, 6199, 1999. [11] E.A. Guinness et al. et al., *J. Geophys. Res.*, 92, E575-E587, 1987. [12] J.F. Bell and D. Bustani, *Lun. Planet. Sci.* XXX, 1388, 1999. [13] J.B. Adams et al., *J. Geophys. Res.*, 91, 8098-8112, 1986.