OLD DESERT VARNISH-LIKE COATINGS AND YOUNG BRECCIAS AT THE MARS PATHFINDER LANDING SITE. S. Murchie[1], O. Barnouin-Jha[1], K. Barnouin-Jha[2], J. Bishop[3], J. Johnson[4], H. McSween[5], and R. Morris[6], [1]Applied Physics Laboratory, Laurel, MD 20723, [2]Proxemy Research, Inc., Greenbelt, MD, [3]NASA/ARC, Moffett Field, CA, [4]USGS, Flagstaff, AZ, [5]University of Tennessee, Knoxville, TN, [6]NASA/JSC, Houston, TX.

Introduction: Many rocks at the Mars Pathfinder landing site exhibit evidence for desert varnish-like coatings that formed during an early, moist climate. Later eolian erosion partly stripped the coatings. Rocks excavated subsequently have shapes consistent with breccias or conglomerates.

Data and Data Processing: The Mars Pathfinder SuperPan [1,2] was collected as 8 12-color mosaics (octants) that together form a 360° panorama. The preprocessed SuperPan was corrected for registration errors and small frame-to-frame errors in relative calibration as described by [3]. Depths of the ferric absorptions at 530 and 660 nm were parameterized and analyzed in image form. 660-nm band depth was measured indirectly, as strength of the inflection or "shoulder" at its short-wavelength edge at 600 nm. Rocks were divided into shape classes relevant to lithology as summarized in Fig. 1, and band depths were measured in 15° azimuthal bins of each shape class.

Color Variations Between Shape Classes: Rock shapes fall into two major groups. Lobate and knobby rocks have shapes approximating agglomerations of smaller, rounded to subangular portions. Previously these rocks have been interpreted as conglomerates [4-6]. Together with pebbles, they account for 28% of classified rock surfaces. The remaining classes have shapes outlined by planar facets. The most common shapes, angular and tabular, grade into one another and may represent a more massive or layered lithology. This group accounts for 64% of classified surfaces. Flat rocks (8%) physically resemble upper surfaces of tabular rocks, and many transitional examples are evident.

The rocks' surfaces can by divided into four color categories, whose properties grade between rock and red soil or dust: relatively clean gray rocks (530-nm band depth <0.11), red rocks (530-nm band 0.11-0.17, 600-nm shoulder <-0.08), pink rocks (530-nm band >0.17, 600-nm shoulder <-0.08), and maroon rocks whose surfaces are undistinguished from red soils and dust (530-nm band >0.17, 600-nm shoulder >-0.08). Most shape classes are dominated either by relatively exposed gray or by thickly coated maroon surfaces, with 20% or less of the rock surfaces in the intermediate red and pink classes (Fig. 2c). However flat rocks are typically red or pink (Fig. 2a), and tabular rocks are intermediate in their color properties between flat rocks and other shape classes (Fig. 2b). This supports suggestions that flat rocks are partly buried tabular rocks [7] rather than indurated soil [5].

Azimuthal Spectral Variations: Not all spectral variations on rock surfaces can be explained by physical mixing of gray rock and red soil or dust. Variations in 530-nm band depth indicate variations in the relative abundances of ferric-rich altered soil and unaltered rock [7]. However enhancements in strength of the 600-nm shoulder are restricted to rocks with an intermediate 530-nm band depth, even though the 600-nm shoulder is weak both on the cleanest rocks and in rock-free red dust. Several possible explanations for the enhanced 600-nm shoulder are untenable: its occurrence or lack thereof on nearly rocks is inconsistent with illumination effects, and upward curvature of the shoulder is inconsistent with continuum effects due to coatings [8]. The simplest explanation is an enhanced concentration of a ferric mineral that has a strong 660-nm band. Rocks with an enhanced 660-nm band do not exhibit a greatly strengthened 530-nm band, as expected for hematite. The most plausible phases - goethite, akageneite, or schwertmannite - require liquid water to form.

Azimuthal distribution of strengths of the 530-nm band and 600-nm shoulder provide evidence for evolution of the coatings. Rocks of both major shape groups show a minimum in 530-nm band depth looking SW (Figs. 3a and 3c), consistent either with preferential removal of soil and dust coatings from rock surfaces that face upwind to the present NE prevailing winds, or with deposition in the rocks' lees [6]. Most rocks - angular, equant, and tabular rocks and large boulders (Fig. 3b) - exhibit a maximum in strength of the 600-nm shoulder on partly stripped, NE-oriented faces. These observations are well explained by Bishop *et al.*'s [9] model, in which ferric minerals in soil adhering to rock recrystallized in the presence of thin films of water to form cemented, desert varnish-like coatings. Subsequent eolian scouring of upwind surfaces largely removed the adhering soils, but left a stain rich in a cementing phase with a 660-nm band stronger than in either the bare rock or the original adhering soil.

Origin of Lobate and Knobby Rocks: Lobate and knobby rocks and pebbles lack an enhanced 600-nm shoulder on their upwind, NE-facing surfaces (Fig. 3d), in contrast to the enhancement on other shape classes (Fig. 3b). One possible explanation, a different composition of the major rock shape groups, is inconsistent with APXS results. Measurements of rocks in both shape groups were obtained and there is no evidence for a significantly different in mahor element composition [10]. Alternatively, the lack of an enhanced 600-nm shoulder on lobate and knobby rocks and pebbles could result from their having been emplaced subsequent to coating formation. This possibility is supported by stratigraphic relations. Where pairs of rocks have clear stratigraphic relations, and there is a difference in strength of the rocks' 600-nm shoulder, the younger rock consistently exhibits the weaker shoulder. This places lobate and knobby rocks high in the stratigraphic column, constraining the rocks' possible origin. One possible explanation for the rocks' protuberances - formation as pillow basalts [4] - is inconsistent with a young age (i.e., long after the period of outflows). Deep eolian erosion leaving resistant knobs [6] is inconsistent with preservation of thin coatings on nearby older rocks. The simplest explanation for the lobate and knobby shapes is that they reflect primary fabric, and that the rocks are in fact breccias or conglomerates, representing lithified local regolith probably excavated by a nearby crater.

References: [1] L. Gaddis *et al.*, *J. Geophys. Res.*, *104*, 8853, 1999. [2] M. Golombek *et al.*, *J. Geophys. Res.*, *104,* 8523, 1999. [3] S. Murchie *et al.*, submitted to *Icarus*. [4] H. Moore *et al.*, *J. Geophys. Res., 104,* 8729, 1999. [5] A. Ward *et al.*, *J. Geophys. Res.*, *104*, 8555, 1999. [6] R. Greeley *et al.*, *J. Geophys. Res., 104,* 8573, 1999. [7] H. McSween *et al.*, *J. Geophys. Res., 104,* 8679, 1999. [8] E. Fischer and C. Pieters, *Icarus*, *102*, 185, 1993. [9] J. Bishop *et al.*, *J. Geophys. Res.*, *107*, 10.1029/2001JE001581, 2002. [10] C.N. Foley *et al.*, *J. Geophys. Res*, in press.

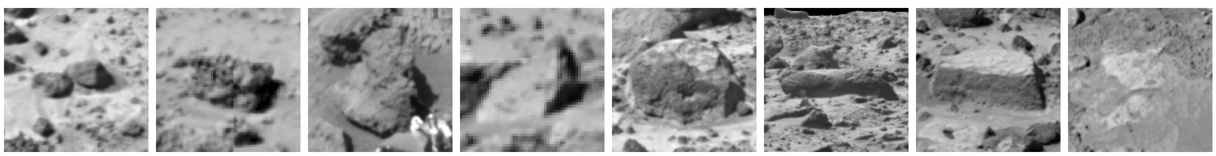

Fig. 1. Type examples of rock shape classes.

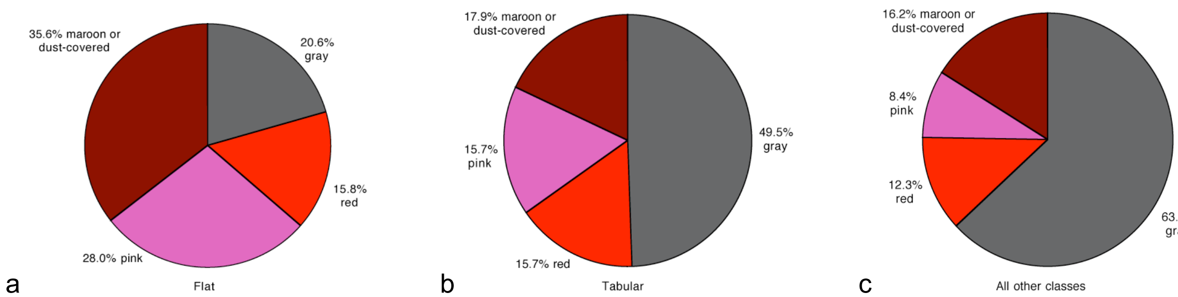

Fig. 2. Fractions of rock surfaces in different color classes: (a) flat, (b) tabular, (c) all other classes

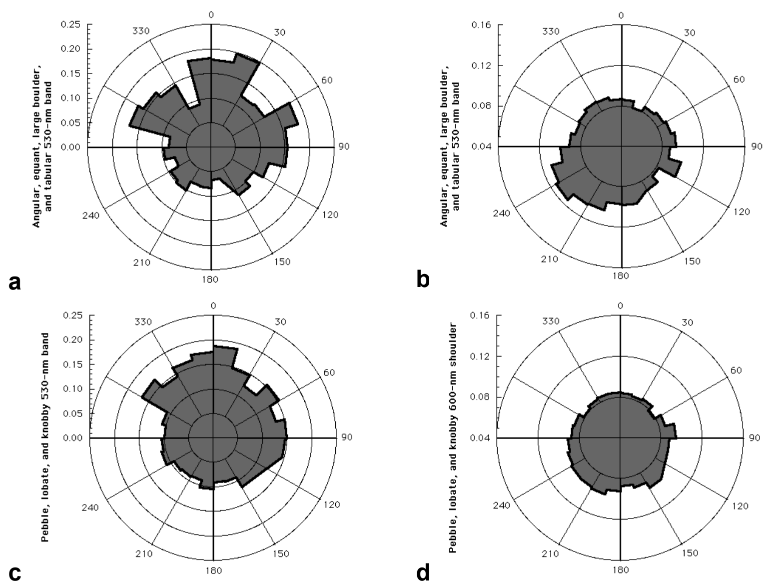

Fig. 3. Azimuthal variation in rock spectral properties. Azimuths shown are camera look directions. For a rock face at any given look azimuth, the rock face's exposure is 180° away. For example, a rock face seen at a SW look direction has a NE exposure. (a) 530-nm band depth for angular, equant, and tabular rocks and large boulders. (b) Same as (a), except showing 600-nm shoulder strength. (c) 530-nm band depth for pebbles, lobate, and knobby rocks. (d) Same as (c), except showing 600-nm shoulder strength.