OPTICAL SCATTERING PROPERTIES OF TERRESTRIAL VARNISHED BASALTS COMPARED WITH ROCKS AND SOILS AT THE VIKING LANDER SITES. E. A. Guinness [1], R. E. Arvidson [1], M. K. Shepard [2], and I. Clark [1]. [1]Department of Earth and Planetary Sciences, McDonnell Center for the Space Sciences, Washington University, St. Louis, MO 63130, [2]Department of Geography and Earth Science, Bloomsburg University, Bloomsburg, PA 17815.

Measurements of bi-directional reflectance (red wavelength) as a function of incidence and emission angle were made along the principal plane for basalt samples from the Pisgah Volcanic Field, California. Data were collected for a varnished surface, a surface coated with a ferric oxide rich coating, and a fresh cut surface. Data were fit with a scattering function that includes specular reflections from rough surfaces and volume penetration and reflection. Model results are consistent with optical properties of the minerals present and the textural configurations, including the presence of discrete grains in the varnish and measured surface tilt distributions. Application of the model to atmospherically corrected Viking Lander images shows that rocks at the two landing sites have similar scattering properties. Rocks are smoother than soils and have single particle phase functions and opposition effect heights consistent with the presence of varnish-like coatings. The Pathfinder IMP system is predicted to find rocks with similar properties at Ares Vallis.

On July 4, 1996, the Pathfinder Lander will descend to the surface of Mars and begin to make multispectral measurements of rocks and soils at Ares Vallis. The Sojourner rover will traverse across the surface and acquire geochemical data for rock surfaces and color images. In March 1998, the Mars Global Surveyor will begin mapping operations from orbit, including acquisition of emission spectra from the Thermal Emission Spectrometer. Further, in the early part of the next century, rovers may be deployed to traverse many kilometers, making in-situ measurements of rocks and collecting samples for return to Earth. In this study we reexamine Viking Lander images acquired at Chryse Planitia and Utopia Plaintia with an eye toward determining whether rocks show differences between the two sites and the extent to which we can understand the optical and textural properties of rock surfaces. A key question is whether the rocks at the two sites are indistinguishable in scattering properties and show evidence for coatings similar to the ubiquitous desert varnishes on Earth, which are derived from aerosols and thus homogenize and obscure underlying rock surfaces.

The first step in our work was to develop a scattering model that explains the specular reflections evident from rocks at both landing sites and the strong opposition surge that makes the rocks become brighter than the soils as the 0° phase angle is approached [1]. Examination of Viking Lander images shows that these effects exist at both landing sites. A model was developed that includes a Gaussian distribution of tilted facets, specular reflections with real and imaginary indices [2], and the Hapke function with surface roughness [3]. To understand the extent to which the model explains surface characteristics, samples of basalts with varnished surfaces exposed to the wind, surfaces protected from wind abrasion and covered with thick (10 micrometers) red coating, and a surface that was cut to expose fresh surfaces were studied (Figure 1). Reflectance measurements were made within the principal plane as a function of emission and incidence angles at the University of Pittsburgh (Bruce Hapke's laboratory). Representative data are shown in Figure 2, along with model fits. Table 1 shows the parameters derived from the data for each sample. The model results show strong inverse correlations between single scattering albedo and the complex index of refraction with values consistent with the mineralogy. Roughness is lowest for the cut sample. The large opposition surge for the varnished sample is interpreted to be due to the presence of numerous feldspar and mesostasis fragments embedded in the varnish, thereby providing good corner reflector returns and generating an opposition height parameter above unity. Opposition surges are smaller for the red coated and cut samples, with values consistent with the lack of high porosity. In summary, the model is consistent with, to first order, the properties for our three samples.

Next we applied the model to Viking Lander image data acquired within the principal plane. All Primary Mission Viking Lander red filter images containing the principal plane were used to extract values of reflectance for soil patches and the tops of rocks along the principal plane. Model results for the soil and rocks show similar trends for both landing sites. Rocks have lower model roughness values (9-18° vs. ~30°) and single particle phase functions that are more backscattering than the soil. Strong backscatter and an opposition height parameter near 2 for the rock surfaces are consistent with a translucent coating containing embedded scattering surfaces [3]. The similarity of rock coating scattering properties at the two widely separated landing sites suggests a global process for coating formation. Rocks at the Mars Pathfinder landing site should thus exhibit varnish-like coatings similar to those found at the two Viking sites. Finally, the inferred textural properties for rocks at the landing sites are comparable to those associated with the varnished basalt sample suggesting coating of wind abraded surfaces by varnish-like deposits, although the higher single scattering albedo for Mars rocks (0.65-0.69) as opposed to the varnished basalt (0.20) demands greater coating transparency.

References: [1] Guinness et al. (1996) LPSC XXVII, 471-472; [2] Shepard et al. (1993) JGR, 98, 18,707-18,718; [3] Hapke (1993) Theory of Reflectance and Emittance Spectroscopy, Cambridge Press.

Table 1: Model values for terrestrial coated, varnished, and fresh basalt samples

Sample	w	n	θ	h	B_0	b1	b2
Red Coated	0.52	1.92	21.99	0.03	0.73	0.71	-0.03
Varnished	0.20	3.33	21.41	0.13	1.71	0.02	-0.01
Fresh Cut	0.29	2.41	12.08	0.05	0.96	-0.07	0.08

Notes: w is single scattering albedo, n is real part of index of refraction (values for imaginary part were all close to 0), θ is the Hapke roughness parameter, h and B_0 are the opposition effect width and height parameters, and b1 and b2 are coefficients for the first and second terms of Legendre polynomials.

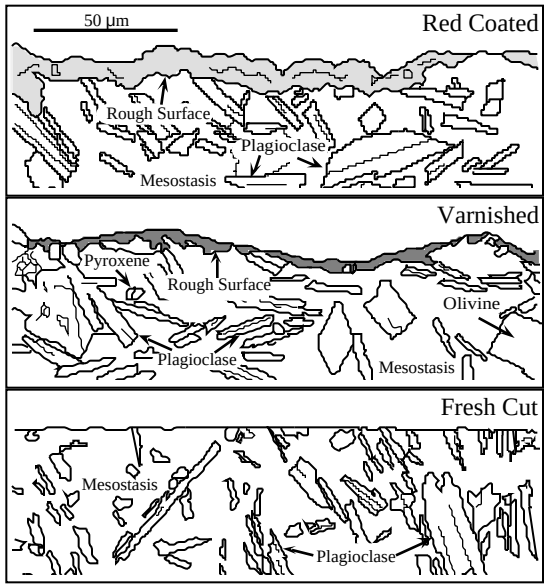
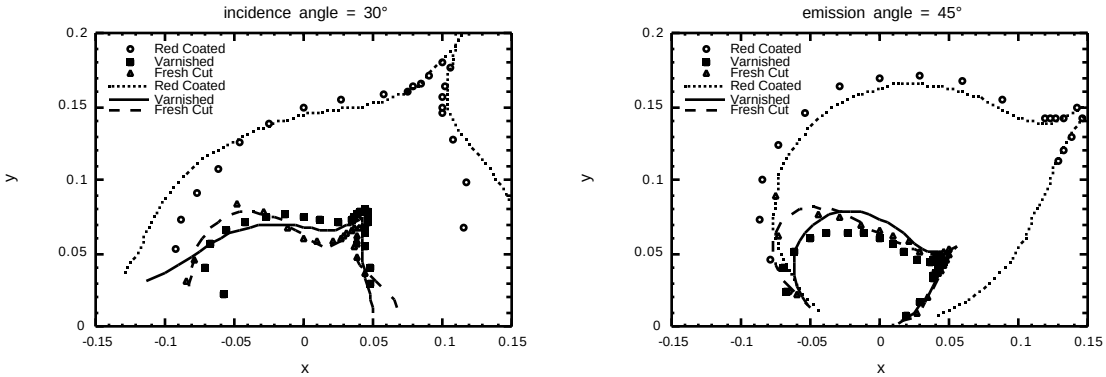


Figure 1: Sketches of coated, varnished, and fresh cut terrestrial basalts samples from photomicrographs of thin sections oriented parallel to the principal plane of the reflectance measurements.



Figures 2: Data and model fits to the coated, varnished, and fresh basalt samples. Points are the measured values and lines are model fits to the measurements. The plot is a scattering indicatrix with the x and y axes along the principal plane. The distance of a point or line from the origin is the radiance factor value and the orientation relative to the origin and a vertical line (y-axis) is the incidence or emission angle. The plot to the left shows data acquired at constant incidence angle (30°) and varying emission angles, whereas the plot to the right shows data acquired at constant emission angle (45°) and varying incidence angles. The backscattering direction is in the +x quadrant. Thus, the narrow peaks in data and fits are the opposition effect and the broad peak for the fresh cut sample in the -x quadrant is the specular reflection peak.