THE MINERALOGY OF THE MARS PATHFINDER LANDING SITE. D.T. Britt[1], R.Anderson[2], J. F. Bell III[3], J. Crisp[2], T. Economou[4],K.E. Herkenhoff [2], M. B. Madsen[5], H.Y. McSween[6], S. Murchie[7], R. Reid[1], R. Rieder[8], R. B. Singer[1], L. Soderblom[9]. [1]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721; [2]Jet Propulsion Laboratory, 4800 Oak Grove Dr., Paadena, CA 91109, [3] Cornell University, 424 Space Sciences Building, Ithaca, NY 14853; [4]University of Chicago, Chicago, IL 60637; [5]Niels Bohr Institute, Orsted Laboratory, Copenhagen, Denmark; [6]University of Tennessee, Dept. of Geological Sciences, Knoxville, TN 37996; [7]Applied Physics Laboratory, Laurel, MD 20723; [8]Max Planck Institut fuer Chemie, Mainz, Germany; [9]USGS, 2255 North Gemini Dr., Flagstaff, AZ, 86001.

The Mars Pathfinder landing site in the Ares Vallis amply lived-up to expectations on roughness, rock abundance, fluvial features, and spectacular scenery. The team had chosen this site as a potential grab-bag of different rock mineralogies supplied by catastrophic flood transport of highlands material to the distal portions of the Ares outflow channel. Analysis of the site mineralogy was based on three primary data sources: (1) Imaging by the Imager for Mars Pathfinder (IMP) of the entire site using 12 spectral filters over the wavelength range of 0.44 to 1.0 microns. (2) Analyses of five selected rocks and six soils by the rover-mounted Alpha-X-ray-Proton Spectrometer. (3) Analysis of the dust pattern on the Magnetic Properties Experiment array of five magnets that sampled the magnetic component of the Martian airborne dust [1,2,3].

Rock Mineralogy: Rock compositions are discussed in more detail in abstract by McSween et. al.[4]. Perhaps the most surprising finding by Pathfinder was the consistant pattern of high-silica rocks [3]. The SiO_2 compositions ranged from 52.2-61.2 wt. %. However, SiO_2 was strongly anti-correlated with sulfur content, suggesting that the lower silica rocks were depleted by a weathering process that increased the sulfur content of the surface rind [3]. All the analyzed rocks at the site fit on a trend line of increasing silica with decreasing sulfur which can be extrapolated to a "sulfur-free" composition of 62 wt. % SiO_2. There is a similar spectral correlation with the higher-silica, less sulfur-rich rocks appearing refresher, darker, and less weathered. Shown in **Figure 1** are representative spectra of rocks. The dark rocks such as Barnacle Bill are more silica-rich, while the Bright Rocks such as Yogi and Wedge are more sulfur-rich and probably more weathered. Another factor to consider is the rock morphology. The more weathered sulfur-rich Bright Rocks tend to be the meter-and larger diameter boulders that show morphologies consistant with flood deposition. The less weathered, sulfur-poor Dark Rocks are smaller, more angular and have distributions and morphologies consistant with deposition as part of an impact ejecta blanket. The implication of these data are that the rocks of the Pathfinder site have very similar compositions and may be from the same geologic unit. The variation in reflectance spectra and APXS results are probably due entirely to the effects of differing exposure to local weathering.

A second surprising result the was the lack of well-defined spectral features in the rocks (and the soils). There are no apparent orthopyroxene features in the 0.9-1.0 micron region, as might have been expected from shallow bands seen in the Martian Dark Region spectra. APXS analysis suggests that the rocks are iron rich and may have a mineralogy with significant high-iron clinopyroxene which has band minima outside the IMP wavelength range. These rocks are mineralogically and morphologically consistant with an igneous origin although a sedimentary origin cannot be ruled out [1,3].

Soil Mineralogy: The IMP also saw no spectral evidence for absorptions from orthopyroxene or well-crystalline hematite [5,6]. APXS results are consist with Viking Lander soil compositions. When compared with the rock compositions, the soils again fall on a "weathering" trend that depletes silica and aluminum while enriching titanium, magnesium, and sulfur relative to the rock mineralogies. The soils can be divided into approximately six units based on reflectance spectra and appear to broadly contain two major components. The first is the very red global airfall dust and the second are weathering products derived from the local rocks.

Interpretation: The reconstruction of the geologic history of the Pathfinder site is still very preliminary. The key clues to the origin and evolution of the site include:

- The "igneous" rocks at the site divide generally into two groups based on reflectance spectra. The dark rocks are relatively less weathered and the bright rocks appear to be much more weathered [1].
- Analysis of APXS data of the two rock groups suggests that they have the same (or very similar) mineralogy. Perhaps they formed as part of the same geological unit, but were mobilized and deposited at the Pathfinder site at different times and under different weathering conditions [1,3].
- The morphology of the boulders deposited at the site and models of flood transport suggest a relatively nearby source region. Flood transport may have been limited to only 10's of kilometers [1].
- The morphology and size frequency distribution of the smaller cobbles at the site are consistant with many of these rocks being deposited as impact ejecta from the nearby "Big Crater", a 1.6 kilometer diameter crater 2.2 kilometers from the site.
- Streamlined islands upstream from the Pathfinder site show what may be erosional features. These islands are approximately 40-50 kilometers from the landing site.
- The major element composition of the rocks are consistant with an igneous high-silica "Icelandite" which suggests an origin as a late stage fractionated magma.
- The regional geologic setting of the Pathfinder site includes major units of Noachian-aged highlands material (probably a mixture of lava flows, pyroclastics, and impact breccias) and Hesperian-aged Ridged Plains

material (formed from extensive flows of low-viscosity lava).

Shown in **Figure 2** is the preliminary reconstruction of the stratigraphy of the Pathfinder area. The local bedrock is represented by samples brought up by the "Big Crater" impact event in rocks like Barnacle Bill and Shark. The contact of this unit is probably an erosional unconformity caused by the catastrophic flood(s). Evidence of local erosion is seen in the structure of the Twin Peaks and regional erosion is evident in Viking Orbiter imagery of nearby streamlined islands. The flood(s) deposited a layer of sedimentary debris including the boulders seen in the site. The thickness of this layer is not known but may be at least 10's meters since only the hills like Twin Peaks appear remain unburied. These boulders are likely derived from the nearby upstream streamlined islands [1].

The similarity in sulfur-free composition between the large flood deposited boulders and the smaller impact ejecta suggest that the rocks at the Pathfinder are not the hoped-for highlands material, but are part of a locally extensive unit composed of late stage fractionated magma similar to Icelandite. These are magmas with silica contents in the Andesite range but not associated with subduction processing, but rather fractionated basaltic volcanism that can be laterally extensive but volumetrically relatively minor. This unit may be associated with the nearby Ridged Plains Material of Hesperian Age.

On top of the flood unit is what appears to be a chemically cemented hardpan material that may have been formed soon after the flood event(s). The development of hardpans in the soil profile is common in terrestrial arid regions. The terrestrial hardpans tend to be a formed a few 10's of centimeters deep in the soil profile and can be up to few meters thick. Weathering rings on the boulders suggest that the local soil has been deflated about 5-7 centimeters, down to the level of the hardpan. The type hardpan material are represented by the Scooby-Doo and Baker's Bench material.

On top of this erosional deflation surface are the discontinuous deposits of "Big Crater" ejecta. The final unit is a range of as many as six soil units of aeolian that are primary aeolian depositions of global and local weathering products.

References: [1] Smith, P. et al. (1997) Science, 278, 1758. [2] Rieder, R. et al. (1997) Science, 278, 1771. [3] Hviid, S. et al. (1997) Science, 278, 1768. [4] McSween, H.Y. et al. (1998) this volume. [5] Ghosh, A. et al. (1998) this volume. [6] Bell, J.F. (1998) this volume.

Figure 1: IMP Rock Spectra

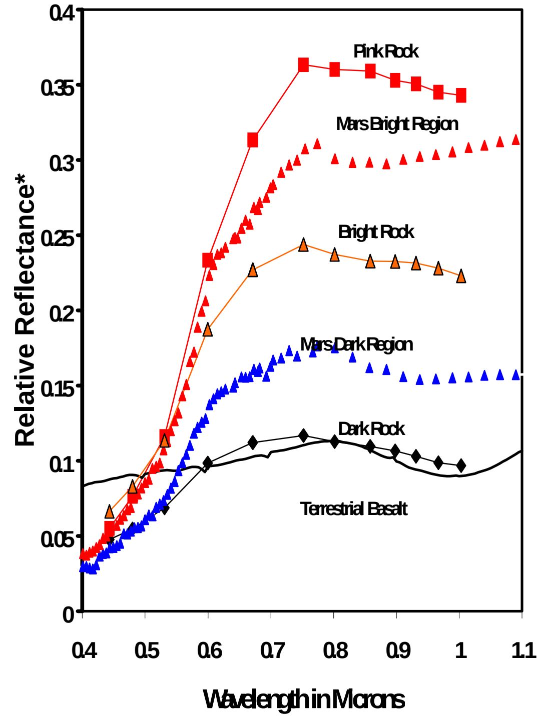

Figure 2: Preliminary Stratigraphic Column for the Pathfinder Landing Site