ROCKS AT THE PATHFINDER LANDING SITE, MARS: IDENTIFICATION AND SIZE DISTRIBUTION. E. Hauber, R. Jaumann, C. Mosangini, N. Russ, F. Trauthan, K.-D. Matz, O. Fabel, DLR, Institute of Planetary Exploration, Rudower Chaussee 5, D-12489 Berlin-Adlershof, Germany (Ernst.Hauber@dlr.de).

INTRODUCTION AND OBJECTIVES: At July 4th 1997, Mars Pathfinder (MPF) landed at the northern end of Ares Vallis (19.33°N, 33.55°W). More than 16,000 images of the lander camera were transmitted to Earth. They show a slightly undulated surface covered by rocks. Areas between rocks and partly the rocks themselves are covered by fines, most probably dust and sand.

Since the size distribution of material can be used to place constraints on sediment emplacement mechanisms, we measured sizes, heights, and positions of rocks within a distance from about 3m to 6-7m around the lander. For that purpose, we developed an interactive tool to determine these values directly in panoramic image mosaics. Wherever available, images with a minimum of data compression were used to avoid errors caused by compression artifacts. Additionally, an algorithm was developed to distinguish automatically between rocks and soil, making use of the blue/red ratio of color filters and the height information in a digital elevation model. The results were compared to the size distribution of material at the landing sites of Viking-1 and 2 (VL-1, VL-2) and to a rocky terrestrial site thought to be analogous to Mars.

METHODS: In order to measure the dimensions of rocks, we generated an image panorama and a Digital Elevation Model (DEM).

DEM production incorporated three main tasks: (1) Digital image matching techniques were applied to the stereo image pairs (left and right eye) in order to derive tiepoints. (2) Line-of-sight vectors from each pair of image coordinates were used to compute the point of intersection (object point) in the Mars local level coordinate system. (3) The cloud of object points was then interpolated to a regular grid, i.e. a DEM image.

In order to produce the image panorama, we used "super panorama" images with a minimum of data compression and a maximum of overlap between single image frames. The pointing data (i.e. the azimuth and elevation data) for the images were corrected relative to each other. Sunrise and sunset images were used as calibration for the absolute orientation of the images relative to North [1]. Where gaps existed in the super panorama, they were filled with data of lesser quality . The resulting semi-controlled image mosaik was transformed to a cylindrical projection.

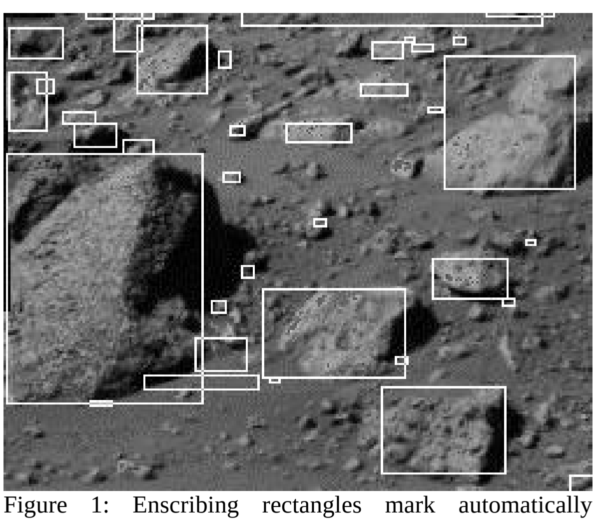

Figure 1: Enscribing rectangles mark automatically identified rocks.

Based on the image panorama and the object point coordinates for each pixel, the rocks were analyzed using an interactive tool to measure the locations, heights, and visual widths of rocks. The visual width of rocks was measured perpendicular to the viewing direction which is radial from the lander. Since only one axis of the rocks could be measured, the rocks were assumed to be circular.

To support the detection of rocks and their separation from dust and soil, a program for automatic rock identification was developed. It is based on the analysis of two color channels (blue to red ratio) and on the topographic information derived from stereo imaging. A rock is first identified with the blue/red ratio, then the result is verified by cross-checking with its height. Rocks are marked by polygons or rectangles and their dimensions are written to a database (Fig. 1).

RESULTS: A total of 1890 rocks was measured (Fig. 2). The results of the size measurements have been compared to the Viking sites and to Mars Hill (MH) in Death Valley, a terrestrial analog site [2,3].

A plot of rock diameter vs. the number of rocks shows a strong, single peak at small diameters und a unimodal size distribution. For diameters smaller than 20 cm, it is almost identical to the measured at MH. The same result is obtained when plotting the cumulative number of rocks

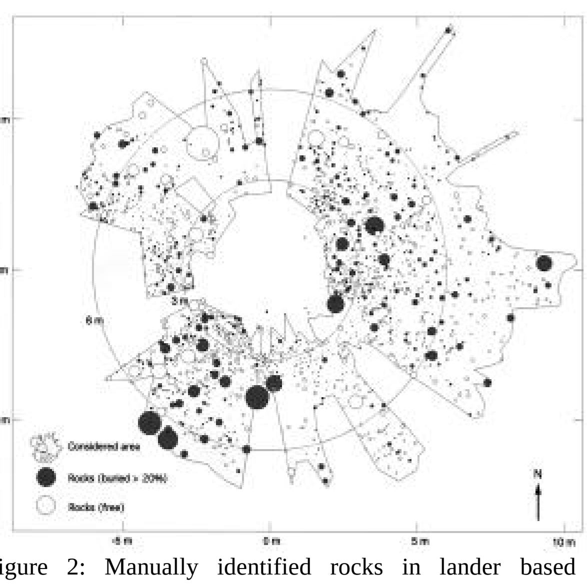

Figure 2: Manually identified rocks in lander based coordinate system. We distinguished between partly buried rocks and rocks lying on the surface. We measured in the superpan stereo data only, gaps as indicated in the map will be filled later.

versus the rock diameter (Fig. 2). Again, the Pathfinder curve is almost parallel to the MH curve. The values for the Viking sites are lower, however, especially for small diameters. Either there is an abundance of cobbles and pebbles at the Pathfinder landing site relative to the Viking sites [4], or too many small rocks have been measured at the MPF site, e.g. due to image artifacts or due to the fact that albedo markings have been confused with rocks. The curve for the rocks which have been automatically identified has the same shape, indicating that the results closely match the real size distribution.

The cumulative fractional area covered by rocks with diameters •2cm is 11.6% (Fig. 3). Note that the coverage is not uniform over the landing site: A high fractional coverage in the "Rock Garden" is contrasted by a low one near Yogi (cf. Fig. 1). Values for VL-1 and 2 are 5.6% and 14.1%, respectively [5,6]. The shape of the curve for the MPF landing site closely resembles that for the Viking landing sites und plots between the Viking-1 and the VL-2 populations, being closer to VL-2. A sample area on Mars Hill is very similar to that of the MPF landing site and falls between VL-1 and 2, too. This corresponds to measurements of terrestrial rocks [7]. When the rocks were transported by a fluid, they show a similarly shaped rounded curve on log-log axes.

The cumulative fractional area covered by rocks with heights • H is plotted versus the rock diameter for the MPF and both Viking landing sites (Fig. 4). Again, the Pathfinder curve falls between VL-1 and 2 and is more similar to VL-2. Heights of rocks were plotted against their diameter (Fig. 5). The best linear fit for the Pathfinder landing site is given by $H = 0.532\ D + 0.003$. This result is very similar to that given for the Viking 2 landing site ($H = 0.506\ D + 0.008$; [3]) and indicates that rocks have heights that average to 1/2 their diameter. At the Viking 1 landing site the rocks are generally less high with respect to their diameter ($H = 0.359\ D + 0.008$).

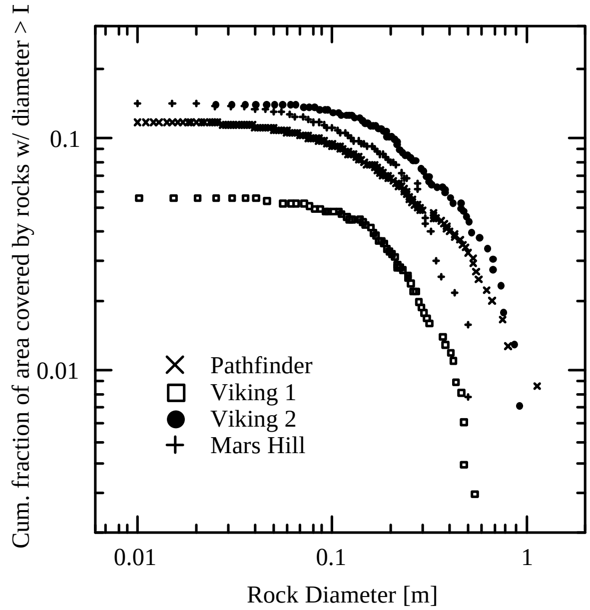

Figure 4: Rock Diameter vs. Cum. Area covered by Rocks.

ACKNOWLEDGEMENTS: We thank Henry Moore (USGS) for providing his measurements of Viking rocks.

REFERENCES: [1] Oberst, J. *et al.* (1998) submitted to JGR. [2] Mutch, T.A. *et al.* (1977) JGR, 82, 4452-4467. [3] Golombek, M.P. and Rapp, D. (1997) JGR, 102, 4117-429. [4] Rover Team (1997) Science, 278, 1765-1768. [5] Moore, H.J. and Keller, J.M. (1990) NASA-TM 4210, 533-535. [6] Moore, H.J. and Keller, J.M. (1991) NASA-TM 4300, 160-162. [7] Malin, M.C. (1989) NASA-TM 4130, 363-365.

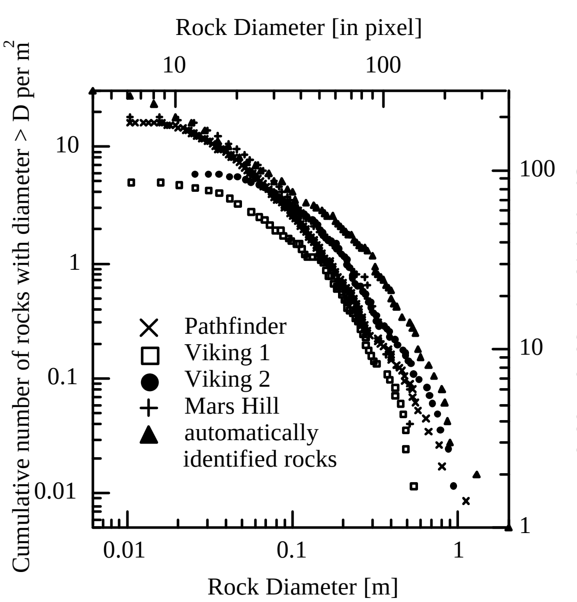

Figure 3: Rock Diameter vs. Cumulative Number of Rocks. Top and right axes refer to automatically detected rocks (corrected for different distances in pixel space).

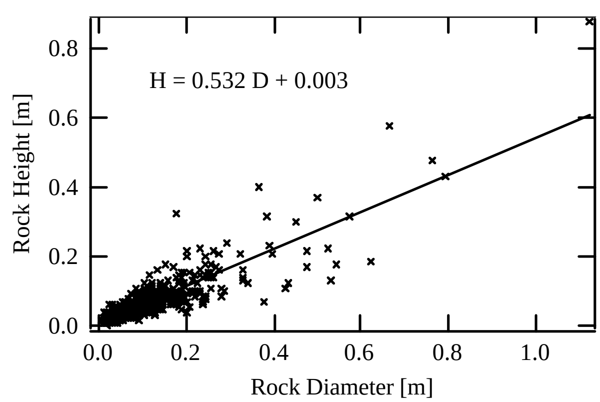

Figure 5: Rock Diameter vs. Rock Height.