SIZE-FREQUENCY DISTRIBUTIONS OF ROCKS ON THE NORTHERN PLAINS OF MARS IN HiRISE IMAGES WITH SPECIAL REFERENCE TO PHOENIX LANDING SITES. M. P. Golombek[1], R. E. Arvidson[2], T. Heet[2], L. Barry[2], J. R. Matijevic[1], and A. S. McEwen[3], [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, 91109, [2]Department of Earth and Planetary Sciences, Washington University, St. Louis, MO 63130, [3]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721.

Introduction: Targeted HiRISE (High Resolution Imaging Science Experiment [1]) images of candidate Mars Phoenix landing sites in the northern plains show that many areas are covered with boulder fields [2] that preclude acceptable probabilities of safe landing. Although rocks were identified as dark spots around degraded craters in Mars Orbiter Camera (MOC) images [3], HiRISE images clearly show these dark spots are the shadows of rocks and that rocks are present throughout the areally extensive Vastitas Borealis Formation [4]. Acceptable landing sites have been identified [2] on the Scandia and Marginal Vastitas Borealis Formations [4], where rock abundances are an order of magnitude lower. HiRISE images allow, for the first time, measurement of rocks to a small enough diameter that rock distributions derived from orbital images can be compared favorably to those derived from lander images. This abstract focuses on rock size-frequency distributions measured in HiRISE images of the northern plains, compares surface and HiRISE rock distributions of the Viking Lander 2 (VL2) site, relates orbital and model rock distributions, and assesses the probability of the Phoenix lander encountering potentially hazardous rocks on northern plains surfaces with different rock abundances.

HiRISE Images: Rocks show up distinctly in the low sun HiRISE images with bright sunlit sides and dark shadows (Fig. 1A). We measured rock diameter by the length of the terminator, perpendicular to the solar azimuth and the rock height by the length of the shadow along the solar azimuth. Visual inspection of several dozen HiRISE images in the northern plains shows surfaces with high, intermediate, and low rock abundance (Fig. 1). Counts were made over areas of 10,000-30,000 m^2 areas to get statistically representative (order 100) numbers of rocks. Rocks measured had diameters of 0.03 to 5 m. Size-frequency distributions were plotted in two common formats: cumulative fractional area and cumulative number versus diameter. Rocks have height diameter ratios of about 0.5, similar to rocks at the landing sites [5,6,7] and so can be modeled as hemispheres for engineering purposes.

Rock Size Frequency Distributions in HiRISE Images: Cumulative fractional area versus diameter distributions of rocks in HiRISE images plot generally at larger diameter and lower area covered than distributions measured from the existing landing sites (Fig. 2). At large rock diameter the distributions parallel exponential model rock distributions derived from fits to VL1 and VL2 data [5]. Similar rock distributions were also measured at a wide variety of rocky locations on the Earth [5] as well as the Mars Pathfinder and Spirit landing sites [6,7] (Fig. 2A) and are explained by fracture and fragmentation theory [see discussion and references in 5,6]. These distributions form a family of non-crossing curves (Fig. 2) that flatten out at small rock diameter at a total rock abundance of 5-40% [8].

HiRISE rock distributions at large rock diameter parallel models for cumulative fractional area covered by 5% to 90% rocks, where the greatest density of rocks in fields around craters have 30-90% rock coverage, less

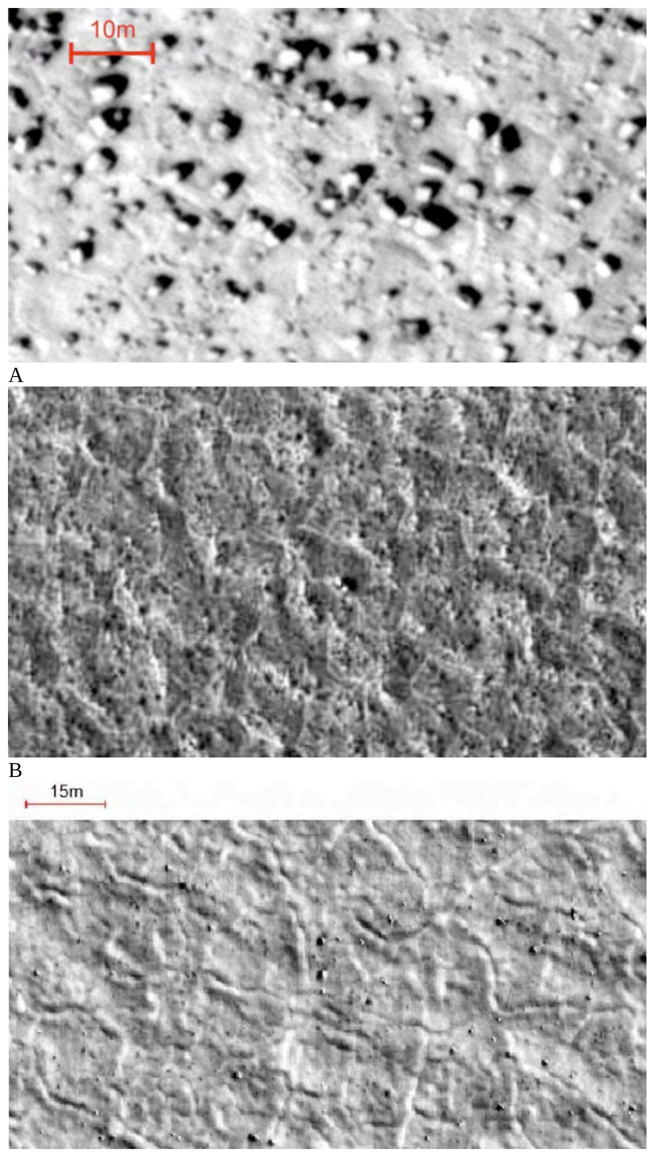


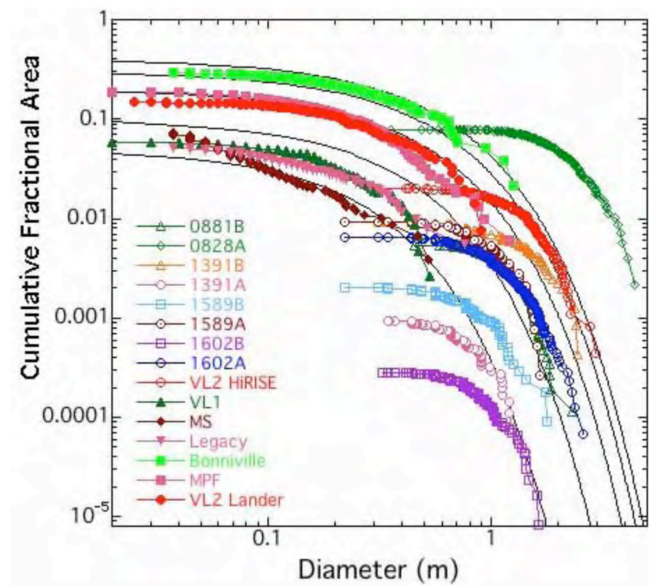
Figure 1: HiRISE images of (A) high (TRA_0828_2495), (B) intermediate (PSP_001501_2280) and (C) low (PSP_1589_2470) rock abundance surfaces in the northern plains. VL2 (~3 m) is in the middle of B.

dense fields around craters have 10-30% rock coverage, and background terrain away from craters have 0-20% rock coverage. At rock diameters between 1-2 m, HiRISE distributions flatten considerably well below lander rock distributions or the models. This appears similar to a resolution roll off (common in crater counts), where it become difficult to recognize all objects less than 5 pixels across. The same general relationships are found in cumulative number of rocks greater than any given diameter versus diameter plots (Figure 2B), where model distributions are derived by numerically integrating the model cumulative fractional area curves [6].

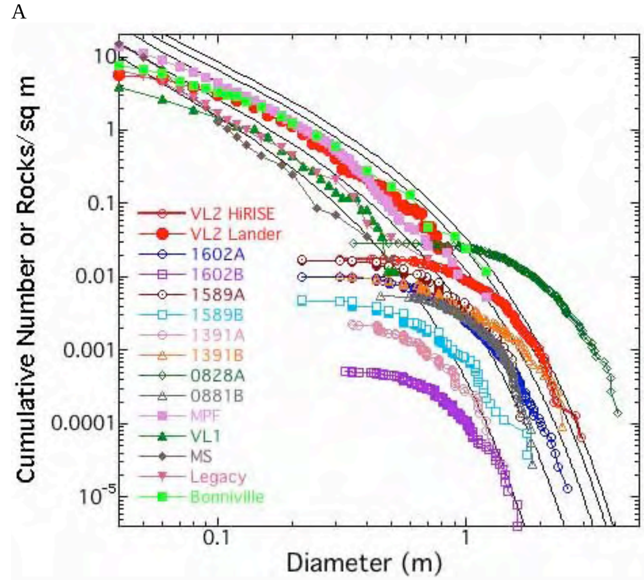
VL2: Rock counts in a 15,299 m^2 area centered on VL2 in a HiRISE image (Fig. 1B) yield a size distribution that parallels the 30% model cumulative fractional area curve at diameters >1.5 m. At smaller diameter the counted rocks fall below the model. Rock counts from VL2 over ~84 m^2 [9] parallel the 20% model cumulative fractional area curve. The continuity of these distributions indicate that both the HiRISE and landed counts are sampling the same distribution of rocks and that the roll off in the HiRISE distributions at about 1.5 m diameter is a resolution roll off. The difference in rock coverage at the HiRISE versus lander counts is likely a sampling effect from the very different areas counted. Visual comparison of the area counted from the lander with other areas in the HiRISE image indicates a variation of ±10% rock coverage is easily obtained by moving the smaller lander counting area around in the image. These results from VL2 demonstrate that rock distributions on Mars can be extrapolated along model curves to smaller diameters from counts in HiRISE images.

Implications for Phoenix Landing Sites: Rock distributions of candidate Phoenix landing sites show large variations in cumulative fractional area from HiRISE counts fit to model distributions (5-90%). Areas with low rock density have <5% of the surface covered by rocks. Areas with medium low, medium high and high rock density, have <10%, <20% and >20% rock abundance, respectively. Extrapolating along the models to the cumulative number of rocks of diameter >0.7-0.9 m and >1.2 m, corresponding to rocks higher than 0.35-0.45 m potentially hazardous to the base of the lander (~1.8 m^2), and rocks higher than the 0.51 m clearance of the solar panels (6 m^2), respectively, allows the calculation of the formal probability of encountering potentially hazardous rocks using the method described in Golombek et al. [6]. Results indicate the probability of encountering a large rock by the Phoenix lander and solar arrays is <1%, <3%, <6% and >6% for areas with <5%, <10%, <20% and >20% rock coverage. Areas for siting the Phoenix lander in the Scandia and Marginal Vastitas Borealis Formations are dominated by surfaces with <5% and <10% rock coverage are thus likely to have a high probability of success with respect to encountering potentially hazardous rocks.

References: [1] McEwen A. S. et al., JGR-Planets, in press. [2] Smith P. et al. (2007) *LPS XXXVIII*, this volume. [3] Malin M. & K. Edgett (2001) *JGR*, *106*, 23,429-23,570.; Marlow J. et al. (2006) *LPS XXXVII*, Abs. #1094. [4] Tanaka K. et al. (2005) USGS SI Map 2888. [5] Golombek M. & D. Rapp (1997) *JGR 102*, 4117-4129. [6] Golombek M. et al. (2003), *JGR 108*(E12), 8086. [7] Golombek M. et al. (2005) *Nature*, *436*, 44-48. [8] Christensen P. (1986) *Icarus*, *68*, 217-238. [9] Moore H. & J. Keller (1991) NASA TM 4300, 533-535.



A



B

Figure 2: Cumulative fractional area (A) and cumulative number of rocks (B) versus diameter plots of rocks in the northern plains from HiRISE, at the landing sites, and at VL2 from orbit and the surface (in red). HiRISE images TRA_0881_2475, TRA_0828_2495, PSP_1391_2465, PSP_1501-2280 (VL2), PSP_1589_2470, and PSP_1602_2510, where A designates the rockiest area and B designates the least rocky area. Lander data are: VL1, Viking Lander 1; VL2; MPF, Mars Pathfinder; and Spirit - MS, Mission Success; Legacy; and Bonneville. Solid lines are model distributions for 5, 10, 20, 30, and 40% surface rock coverage [5,6]