**CLASSIFICATION AND DISTRIBUTION OF MARS PATHFINDER ROCKS USING QUANTITATIVE MORPHOLOGIC INDICES.** R. A. Yingst[1], K. L. Biederman[1], A. M. Monhead[1], A. F. C. Haldemann[2], M. R. Kowalczyk[3]. [1]University of Wisconsin-Green Bay, Natural and Applied Sciences, 2420 Nicolet Dr., Green Bay, WI 54311, yingsta@uwgb.edu. [2]Jet Propulsion Laboratory, MS238-420, 4800 Oak Grove Dr., Pasadena, CA 91109-8099. [3]University of Wisconsin-Madison, Computer Sciences Department, Madison, WI 53715.

**Background:** The Mars Pathfinder (MPF) landing site was predicted to contain a broad sampling of rock types varying in mineralogical, physical, mechanical and geochemical characteristics. Although rocks have been divided into several spectral categories based on Imager for Mars Pathfinder visible/near-infrared spectra, it has not been fully determined which of these stem from intrinsic mineralogical differences between rocks or rock surfaces, and which result from factors such as physical or chemical weathering. This has made isolation of unique mineralogies difficult.

Efforts in isolating and classifying spectral units among MPF rocks and soils (e.g. [1-9]) have met with varying degrees of success, and the current understanding is such that many factors influencing spectral signatures cannot be quantified to a sufficient level so they may be removed. The result is that fundamental questions regarding information needed to reveal the present and past interactions between the rocks and rock surfaces and the Martian environment remain unanswered. But it is possible to approach the issue of identifying distinct rock and rock surface types from a different angle.

**Approach and Method:** Morphology is another characteristic that is dependent upon the intrinsic properties and geologic and weathering history of rocks, among other things. Rock morphologies can be assessed quantitatively and compared with spectral data, to identify and classify rock and rock surface types at the MPF landing site. As a first step, we report on the creation of a database of morphologic indices calculated for the MPF Rock Garden region.

Because rock morphology and placement at the MPF site generally resemble the depositional plains left by terrestrial catastrophic floods [10], and have been interpreted as a plain composed of materials deposited by the Ares and Tiu floods (e.g. [11, 12]), the shape of rocks at the MPF site have commonly been classified using roundness, flatness/tabularity or angularity (e.g. [10, 13, 14]). Similarly, morphologic indices appropriate for rocks in this investigation include apparent size, sphericity (how closely rock shape resembles a sphere), roundness (how sharp the corners of a rock are) and elongation (a measure of major to minor axis length). We have examined the morphology of rocks in the Rock Garden region of the MPF landing site in terms of these indices, with the goal of comparing this database of rock characteristics with associated rock surface spectra, to improve our ability to discern between rock and rock surface types. Along with the comprehensive examination of the diverse rocks within the vicinity of the Rock Garden, a sampling of other rocks was chosen that represented a range of shapes, textures and associated spectral signatures of interest. Due to resolution limitations, only rocks within 10 m of the lander and greater than ~8x8 pixels were included.

**Results.** Rock location and size were derived from previously published work [15, 16]. Elongation was calculated by dividing the minor by the major axis of each rock [17], while sphericity was estimated by taking the outline of each individual rock and determining the largest inscribed and smallest circumscribed circle of the resulting polygon. These values yielded a measure of sphericity by using □ = $D_{ins}/D_{cir}$, where $D_{ins}$ is the largest inscribed circle and $D_{cir}$ is the smallest circumscribed circle [18]. Roundness was determined by measuring the angle of the smallest corner of the rock outline, calculating the associated radius and using $P = 2r/A$, where A is the major axis length and r is the radius of the smallest corner [18]. A database of rock characteristics was created and values of each index were compared.

These morphologic indices have been commonly utilized in a terrestrial setting in two-dimensional (cross-sectional) space, and are therefore appropriate for our work using the 2-D outlines created from IMP images. However, elongation measurements used [15, 16] are in 3-D space and are thus not fully comparable. We are currently endeavoring to measure axes within the flat plane of IMP images, so these can be directly compared to morphologic indices. The elongation values presented are accurate in three dimensions, but should be directly compared to cross-sectional morphologic values with caution.

**Statistics and Truthing.** There are approximately 1000 rocks within the study region; of these, 296 rocks were determined to be within the size, distance and resolution limits noted above.

Rocks range from 0.014 m to 1.3 m major axis length, with ~50% less than 10 cm major axis length. Rock sphericities range from 0.369 to 0.931; 92% have sphericities between ~0.65 and 0.9, and 66% have sphericities greater than 0.75 (higher numbers indicate greater sphericity; Figure 1). In terms of elongation, only 23% have elongation ratios of 0.5 or less, so that the majority of rocks have low elongation (Figure 2).

**Figure 1. Sphericity Histogram**

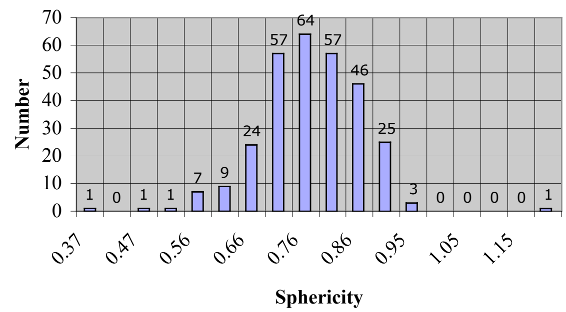



**Figure 2. Elongation Histogram**

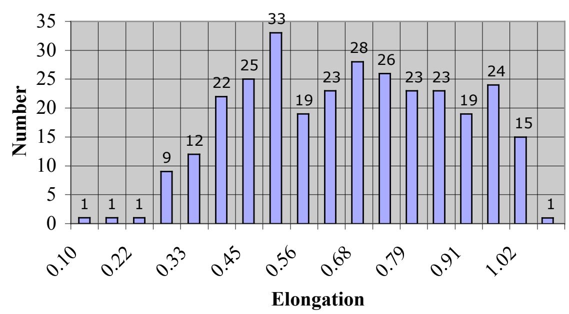
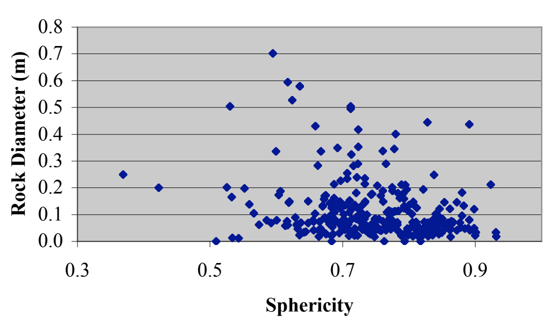



**Figure 3. Rock Diameter vs. Sphericity**




There is currently no indication that these indices are biased by rock size or resolution. For example, Figure 3 shows approximate rock diameter compared with sphericity. Increased sphericity with decreasing size might indicate that rock morphology appears more spherical as resolution decreases. Instead, a random distribution of rocks is the result, with clustering of values showing only the preponderance of small rocks in the dataset. This may also indicate that any geologic activity responsible for shaping MPF rock morphology worked on all rock sizes efficiently. Similarly, we should expect little to no correlation between morphologic indices and distance from the lander. If such a correlation was seen, it would indicate that morphologies are tied to resolution, or some other artificial construct. Instead, values have a random distribution.

**Geologic interpretations.** Direct comparison with terrestrial morphologic indices is somewhat problematic, as these indices are typically used to categorize rocks in a much narrower range of sizes. With this caveat, we note the following generalities.

The MPF rocks have a broad distribution of sphericities, as shown in Figure 1, unlike terrestrial rock fragment populations that can be traced back to a specific geologic process or set of processes (e.g. [17-20]). However, the average value for sphericity is similar to that for terrestrial stream gravel or glacial till pebbles [20]. Somewhat surprisingly, nearly 34% of all rocks have sphericities compatible with terrestrial values for crushed grains, that is, grains not directly associated with either a fluvial or glacial environment. In future work, we will continue our analysis of morphologies in terms of geologic interpretation, as well as compare this database of morphologic indices with corresponding spectral signatures. In this way, we hope to reveal any correlations between morphology and spectral signature that might constrain the number of rocks/rock types at the MPF landing site.

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