A Mars Analog Study of 2D Textural Image Analysis: Effects of Shadows, Image Resolution, and Comparisons to Actual Sediment Textures from Aeolian Dune Sand, Moses Lake, WA. M. A. Eibl[1] and C. M. Fedo[2], [1,2]The University of Tennessee, Knoxville (meibl@utk.edu).

Introduction: The textural properties of martian sediments are used to aid interpretations of sedimentary environment and processes on Mars [1,2,3]. Until sediment samples are returned from Mars, rover and lander images provide the only means by which sediment textures can be determined. These images allow for detailed textural analyses of sediment, but the analysis of imaged sediment significantly differs from the textural analysis of actual sediments. Images are two-dimensional (2D) and require different analysis methods than physical samples. Images also preserve shadows present at the time of imaging, which may obscure neighboring grains, and image resolution and detail is predetermined by camera capabilities and standoff distance. The goals of this research are to determine how these factors affect the results of textural image analysis and to show how closely 2D textural image analysis represent reality in a Mars analog study from the Moses Lake dune field.

Methods: Grain size, roundness, and sphericity were measured in 2D images and in sediment collected in the field. The methods used to obtain textural data are consistent with those used in Eibl et al., (2015), with the exception of image grain size measurements, which in this work were measured using the Di dimension.

Sediment images and samples were collected from a fine-grained, well sorted, basaltic, aeolian dune field near the city of Moses Lake, WA. In the field, images were taken in shade for a shadow-free, even illumination, control image and at incident solar angles of 60°, 40°, and 20°, to obtain images with increasing clast shadow lengths. Following imaging, the sediment surface was sampled such that the physical sample collected was representative of the imaged sediment.

To understand the isolated effect of shadow length on textural image analysis and minimize the effect of resolution, the images containing different shadow lengths were analyzed at the highest resolution capable of the Nikon D3200 used in this study (11 μm/pixel). Similarly, to study the effect of image resolution on textural image analysis, without any effects due to shadows, the even illumination image was decomposed and analyzed at the target resolutions of 20, 30, 40 and 50 μm/pixel.

Influence of Shadow Length on 2D Textural Analysis: At incident solar angles less than 90° from the sediment surface, grains cast shadows with lengths that increase with decreasing solar angle. Shadows of increasing length should hide parts of, or entire, neighboring grains within their shade and potentially affect textural analyses.

Regardless of incident solar angle, the grain-size distributions (GSD) appear similar. The greatest discrepancies are at the peak of the distribution, where the maximum variation between any two data points is about 7%. Because the error on frequency is approximately 5% [5], the determined variation between the GSDs is considered negligible.

Frequency histograms of roundness show an increase in roundness with increasing shadow length, specifically a decrease in roundness 3 and increase in roundness 4 and 5. Furthermore, the even illumination image has the highest frequency of roundness >4. With increasing shadow length, roundness estimates more closely approximate those of the control image, suggesting that long shadows have a similar influence on textural image analysis as images taken under even illumination.

For each image, average sphericity was calculated at each size fraction. Average sphericity differs by a small amount (0.1) at the largest grain size bin (0.5 phi) and at small grain sizes (3-4 phi). The differences in sphericity values at the small grain sizes may be an effect of shadows. However, because sphericity does not change systematically with increasing shadow length the differences are more likely explained by greater variability in measuring grain size close to the limit of resolution. Furthermore, because average grain size accuracy increases with the number of grains analyzed [5], the difference in average sphericity at the largest grain size is likely due to the low measurement frequency (0.25%) of 0.5 phi grains, rather than an effect of shadow length.

Influence of Resolution on 2D Textural Analysis: The quality of textural analyses is likely to reflect decreases in image resolution as textural properties depend on fine-scale details. To understand how each of the textural properties is affected by resolution, textural parameters were determined at a resolution interval of 10 μm up to 50 μm/pixel.

The GSDs show greater differences than what was observed in the shadow length study. The 11 and 20 μm/pixel GSDs are very similar, with larger differences apparent in the 30 and 40 μm/pixel grain size analyses. However, these GSDs have frequency differences of only about 7% from the 11 μm/pixel image (not substantially large considering the 5% error in frequency estimates). The GSD determined from the 50 µm/pixel image shows an approximate 13% frequency increase at the 2.0 phi mode from the 11 um/pixel resolution image. These results suggests that small differences in GSDs may begin to be observed at 30 µm/pixel resolution, but that substantial differences in GSDs do not appear until the image resolution is decreased to 50 um/pixel.

Frequency histograms of roundness values show the 11 and 20 µm/pixel images yielded very similar distributions. However, in the 30-50 µm/pixel image analyses, grains became increasingly angular, specifically increasing in roundness 3 and decreasing in roundness 4 and 5 (the opposite effect of shadows). On the contrary, the analysis of the 50 um/pixel image found a slight increase in grains of roundness 6, which is the expected result when angular edges cannot be resolved. However, in this aeolian sand, most grains are interpreted as more angular with decreasing resolution because size is close the limit of resolution.

The results for sphericity measurements are similar to the results for increasing shadow length. The greatest differences, not exceeding 0.1, occur at the smaller grain sizes (3.5-4.5 phi). At these grain sizes, variations in sphericity are most certainly a result of image resolution. However, a difference of 0.1 in sphericity, occurring at only a narrow range of grain sizes, is not considered substantial.

Comparison of Textural Image Analysis (2D) to Textural Analysis of Actual Sediment (3D): Determining textural properties of 3D sediments from 2D images has an effect on image analysis that cannot be improved or removed. Grains can be overlapping, hidden, and foreshortened in images, which changes the way 3D grains are perceived in 2D space [7].

For grain size, the sieve data for the 3D sample is considered in two ways, the original raw sieve GSD, and a converted GSD. The conversion is based on a sediment sampling model [6], which states that GSDs determined from sieved and weighed sediment is not analogous to GSD determined from grain counts on gridded images. However, because this model is based on a theoretical poorly sorted sediment, the validity of its application to the well sorted sediment studied here, is questionable. Therefore, both the converted and original sieve data is presented.

Due to the small grain sizes of the studied aeolian dune sand, only textural analyses of grain size and roundness could be determined in 3D. The highest resolution, even illumination image was used as the ideal image for 2D analysis as effects of shadows are removed and effects of resolution are minimized.

Grain sizes were measured and plotted into GSD in two ways, by the largest grain diameter (Dc) and by the smaller diameter (Di). Both GSDs were compared to the 3D sieve GSD. The Di GSD has substantially more agreement with the 3D sieved GSDs. This is because many grains on a surface will be lying in the most gravitationally favorable orientation (long and intermediate axis in the image plane, short axis perpendicular). Consequently, it should be expected that the smaller of the two visible grain axes (Di) would be the intermediate axis, the same axis measured by sieve analysis [8]. Though the Dc diameter is commonly used in 2D analyses, such as thin section point counting, in image-based grain-size analysis, the Di measurement is the more appropriate grain size measurement.

The raw sieve and converted GSD have similar shapes, with the largest difference being a higher peak at the 1.5 phi mode in the converted GSD. The greatest difference in frequency between the 2D and 3D GSDs is between the converted 3D and the 2D GSD, where the 3D GSD shows the sediment may actually have a 25% higher frequency of grains in the 1.5 phi bin.

The mode of the 2D GSD is about 0.5 phi smaller than the raw and converted GSDs, has a lower kurtosis, and is fine skewed. The finer peak and the increased estimate of grains in phi bins ≥2.0 is likely due to overlapping, hidden, and foreshortened grains, all of which cause 2D grain-size measurements to be smaller than their actual grain size [7].

Two main observations can be made from the 2D roundness frequency histogram. First, many grains were estimated to be more angular, with a greater proportion of grains having a roundness of 3 than was found in the actual sediment. Second, a smaller proportion of grains were found to be more round, showing an increase in roundness 5 and 6. These results are consistent with the findings that inadequate image resolution may cause most grains to seem more angular, with few appearing more round. Furthermore, the increase in angularity may also be attributed to the overlapping and hiding of grains, which may cause true rounded edges to be obscured, and false edges to be perceived as more angular due to the position of the neighboring grains.

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