THE ACCURACY OF 2D ROVER IMAGERY FOR REPRESENTING 3D SEDIMENTARY TEXTURES OF BASALTIC MARS ANALOG SEDIMENT M. A. Eibl[1], C. M. Fedo[1], M. E. Friday[2] and H. Y. McSween[1], [1]Department of Earth and Planetary Sciences, University of Tennessee, Knoxville TN, 37966, USA, (maryeibl@utk.edu), [2]Department of Earth Sciences, Syracuse University, Syracuse NY, 13210, USA.

Introduction: Sedimentary textures provide a rich source of information from which sediment transport and processes can be inferred. Until samples are returned from Mars, textural analysis relies on 2D imagery [1-3]. With images lacking a third dimension, textural image analysis techniques need to be evaluated for their accuracy in representing 3D sediments. The collection of reliable textural information is critical to building accurate sedimentological interpretations. The purpose of this research is to compare the results of a 2D textural image analysis of two Mars analog basaltic sediments, at two image resolutions, with their actual 3D sedimentary textures.

Methods: An aphyric basalt from the Cima Volcanic Field, CA and a porphyritic, vesicular olivine basalt from the Kilauea Volcano, HI were each comminuted in a jawcrusher in order to simulate impact fall-out sediment proxies. The crushed sediment was rapidly dumped onto a flat surface, outdoors, under bright, evenly illuminated light and imaged orthogonal to the sediment surface. Following imaging, the sediment was sieved and individual grains were measured to develop the 3D characteristics.

2D Analysis. The images were manipulated to two resolutions, 140 and 37 µm/pixel. An alphanumeric grid was placed over the images and textural parameters (grain-size, rounding, and sphericity) were described for grains under grid intersections, until at least 400 grains were documented for each image.

Using ImageJ software, the largest inscribing circle (Di) and the smallest circumscribing circle (Dc) were measured, in mm, for each grain [4, 5]. These parameters were used calculate grain size (phi) and Riley sphericity, the sphericity calculation for 2D representations [5, 6]. 3D and 2D calculations of sphericity yield values from 0 to 1, where 1 represents a perfect sphere. Rounding was assessed on the Power's roundness scale (1-6), where 1 is very angular and 6 is well rounded [7].

3D Analysis. Grain size was determined by sieving the sediment into 0.5 phi sizes. Fifty grains from each phi size were assessed for roundness and sphericity using an incident-light microscope and digital caliper. The caliper was used to measure long, intermediate, and short grain axes for grain sizes from 0.0 to -3.5 phi in order to calculate sphericity [5, 6]. Rounding was determined on the Power's roundness scale.

Inter- and Intra-user Measurement Study: The Cima and Kilauea basaltic sediments were texturally analyzed by two different individuals and repeat analyses by one user in order to evaluate user variability for measurements performed on the same sediment grains. Di and Dc measurements recorded by two users (inter-user), and repeat measurements from a single user (intra-user), were compared for 40 grains in each the Cima basalt 140 and 37 µm/pixel images.

When measuring the same grains, two users, and single-user repetitions, record near equivalent Di and Dc values. Figure 1 shows that intra- and inter-user measurements have high positive correlations, with essentially 1:1 equality. As a result, we have confidence that measurements are reproducible and that the analytical approach can be done consistently and accurately.

Regardless of image resolution, a small number of measurements had significant discrepancies both between users and within repetitions of the same user. The largest source for these differences occurs as vagaries in identifying grain boundaries where there is (1) considerable overlap between adjacent grains or (2) unusual grain morphologies. Such problems are inherent using the 2D analysis technique in both lithified and unlithified material.

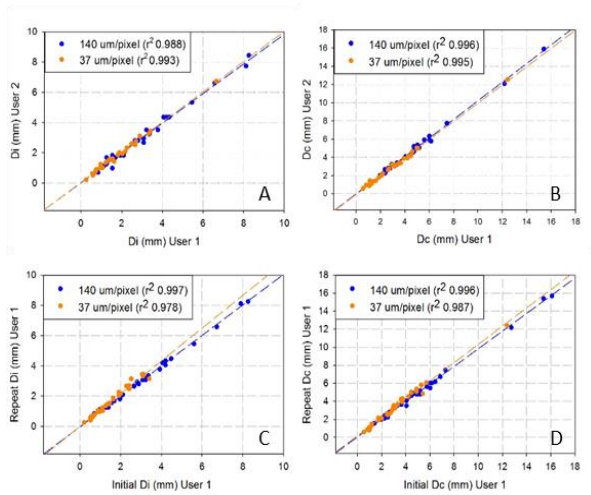

Figure 1: Inter-user (A and B) and intra-user (C and D) Di and Dc measurement correlations for Cima basalt 140 (blue) and 37 (orange) µm/pixel images.

2D and 3D Results: *Cima Basalt.* The 3D grain-size distribution has a mode at -1.0 phi, while the 2D grain-size distributions, at both resolutions, has a mode at -1.5 phi (Fig. 2). 3D data show that the sediment has grain sizes smaller than the 2D analysis could resolve

and that the 2D analyses identified sediment with grain sizes larger than the actual 3D sediment. Though both 2D analyses overestimate the overall grain size distribution, the higher-resolution 37 µm/pixel 2D analysis estimates the 3D sediment with greater accuracy.

3D data range in sphericity from 0.35 to 0.89 and average 0.63. Both 2D resolutions yielded higher averages at about 0.75 and narrower sphericity ranges. The sphericity range obtained from the 37 µm/pixel analysis is closer to the range obtained by the 3D analysis, though both 2D analyses did not resolve the lower sphericities present in the 3D analysis. No 3D grains were scored greater than a 3 in roundness and the average rounding score was just over 1. Roundness in the 37 µm/pixel image ranged from 1 to 5 and had an average of about 2, where the 140 µm/pixel image ranged from 1 to 6 and had an average of about 3.

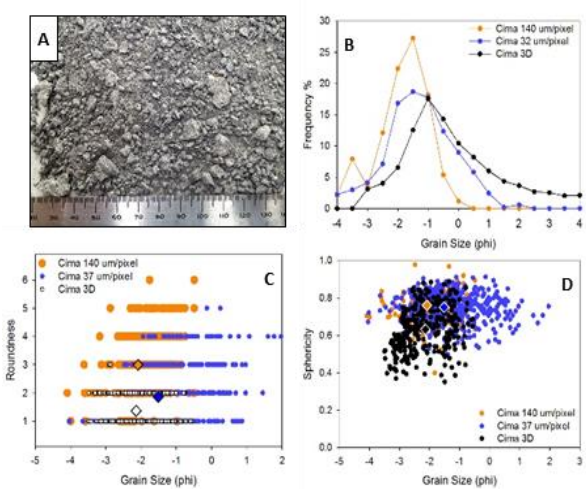

Figure 2: Results of 3D and 2D textural analysis of Cima basalt. (A) Original photograph of Cima sediment used for 2D image analysis, small ticks on scale represent 1 mm. (B) Grain size distribution frequency histogram. (C) Sediment grain rounding data. (D) Sediment grain sphericity data. 3D sediment sphericity could only be measured down to -0.5 phi.

Kilauea Basalt. The 3D grain-size distribution has a mode at -1.0 phi, while the 2D grain-size distributions have modes at -2.0 and -1.5 phi for 37 and 140 µm/pixel, respectively (Fig. 3). Similar to the Cima basalt, 3D data shows the sediment has grain sizes smaller than the 2D analysis determined and that the 2D analyses identified sediment with grain sizes larger than the 3D sediment. Unlike that observed in the Cima sediment, the 37 µm/pixel analysis did not better represent the 3D sediment than the 140 µm/pixel; both resolutions produced similar results.

3D data range in sphericity from 0.34 to 0.95 and average 0.67. Both 2D resolutions yielded a comparable average of 0.69 and Figure 3D shows striking overlap of the 2D and 3D analysis sphericities. In comparison to the Cima sediment, the greater accuracy at which sphericity was estimated by the 2D analyses of the Kilauea sediment suggests that igneous rock textures may play an important role in the 2D analysis.

The highest rounding score given to the 3D sediment was a 2 and the average rounding score is 1. The 37 µm/pixel 2D analysis has a roundness range of 1 to 5, and an average rounding of approximately 1. The 140 µm/pixel 2D analysis has a roundness range of 1 to 6, and an average of about 2. Roundness results from the Cima and Kilauea basalts show that image resolution significantly affects the accuracy at which the image analysis estimates the 3D roundness averages and ranges.

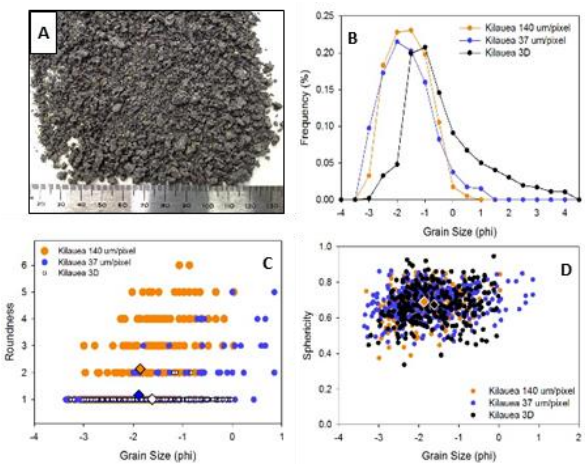

Figure 3: Results of 3D and 2D textural analysis of Kilauea basalt. (A) Original photograph of Kilauea sediment used for 2D image analysis, small ticks on scale represent 1 mm. (B) Sediment grain size frequency distribution histogram. (C) Sediment grain rounding data. (D) Sediment sphericity data. Sediment sphericity could only be measured down to 0.0 phi.

Conclusion: The accuracy of 2D imagery to represent 3D textures depends on image resolution and igneous rock texture. Grain size and sphericity measurements can be reasonably determined in images, although low-resolution images adversely impact rounding scores. Igneous texture, such as the presence of phenocrysts and vesicles, may have a considerable effect on the 2D analysis as well.

References: [1] McGlynn I. O. et al. (2010) *JGR, 116*. [2] Yingst A. et al. (2013) *JGR Planets*, Vol. 118, 1-20. [3] Yingst R. A., et al., (2008), *JGR*, 113. [4] ImageJ U. S. National Institutes of Health, http://imagej.nih.gov/ij/, 1997-2014. [5] Folk R. L. (1980), 2nd Ed., Hemphill, 182 pp. [6] Boggs S. (2006), 4th Ed. Pearson Prentice Hall. [7] Powers M. C. (1953), *J. Sed. Res*., 74, 160-165.