ESTIMATING SURFACE POROSITIES OF ANALOG SAMPLES USING MICROSCOPIC IMAGING ANALYSIS

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Background

- The shape and position of thermal infrared spectral features of a mineral are dependent on mineral chemistry, albedo, particle size, porosity, and near-surface thermal gradients [e.g., 1-6].
- On the lunar surface, the lack of an atmosphere and low surface gravity result in delicate structures of stacked surface particles, resulting in a highly porous structure compared to terrestrial standards (commonly known as "fairy castle structure").
- This high porosity modifies the thermal infrared spectra observed by orbiting spacecraft and in situ instruments; thus it is imperative to properly characterize these surface particle structures.
- Several laboratory studies have created samples with a range of porosities-these porosities are normally given relative to each other. Attempting to accurately quantify these porosities has yet to be attempted [e.g., 1, 7, 8].
- Here we use a microscopic imaging technique to quantify the porosity of a sample prepared with different porosities.

Methods

- **In this study we prepared three different observable porosities: low, medium and high porosity**
- **Low Porosity** – sample is compressed under a 20 kg mass (Fig. 2a).
- **Medium Porosity** – sample is poured and then leveled with a straightedge (Fig. 2b).
- **High Porosity** – sample is poured into a sieve and gently shaken above the sample cup (Fig. 2c).
- Using an imaging microscope, we take an image of the center of the sample under a 20X magnification.
- Two light sources illuminated the sample from approximately + and - 40° from zenith (where zenith is directly above the sample).
- This process was repeated ten times for each sample by rotating the cup in relation to the light sources and any significant outliers were removed. We did this to help diminish the effects of any one image being atypical and skewing the overall results.
  - We used the ENVI ROI tool on the green band of the image to generate a mask over the dark pixels (pixels considered to be voids rather than particles); the threshold of a dark pixel was manually determined for each set of images.
- The number of masked (black) pixels is divided by the total number of pixels in the image and the average of all measurements is recorded as the sample's porosity.

Fig 1.

Figure 1. Aven Mighty Scope digital microscope and stage above a packed sample cup of flour.

Fig 2a.

Fig 2b.

Fig 2c.

Figure 2. Prepared flour samples under 2.5X magnification **(a) low porosity** – packed into sample cup under a 20 kg mass, **(b) medium porosity** - gently poured into sample cup and leveled, **(c) high porosity** – sieved into sample cup.

References

[1] Salisbury. J. W. and J. W. Eastes (1985) Icarus, 64, 586-588. [2] Salisbury. J. W. and Wald A. (1992) Icarus, 96, 121-128. [3] Sprague, A. L. et al., (1992) Icarus, 100(1), 73–84. [4] Hapke B. (1993) Theory of Reflectance and Emittance Spectroscopy, p. 224. [5] Carrier W.D. et al., (1991) In Lunar Sourcebook p. 475–594. [6] Donaldson Hanna K. L. (2017) Icarus, 283, 326–342. [7] Wang X. et al., (2016) GRL, 43, doi:10.1002/2016GL069491. [8] Blum J. et al. (2006) Astrophys. J., 652, 1768–1781. [9] Cannon, K. M. et al. (2019) *Icarus, 317*, 470-478. [10] Britt, D. T. et al. (2019) MAPS, doi:10.1111/maps.13345.

Acknowledgments

Supported under NASA Cooperative Agreement 80NSSC19M0214 to the Center for Lunar and Asteroid Surface Science.

Fig 3a. Low Porosity

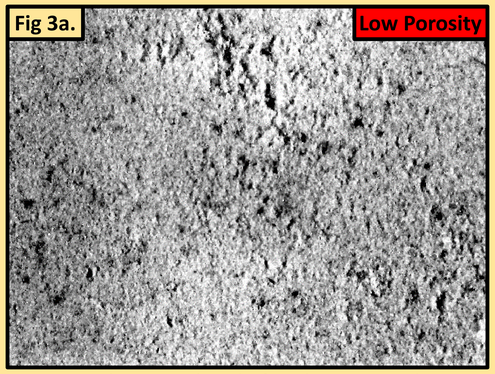

Fig 3b. Medium Porosity

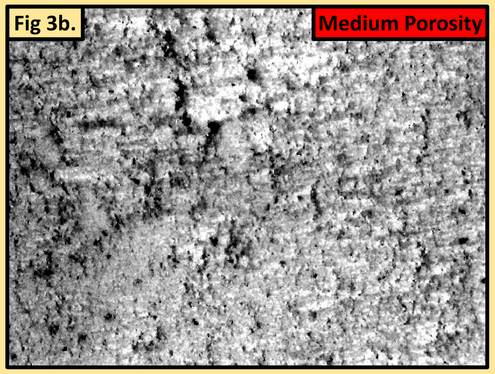

Fig 3c. High Porosity

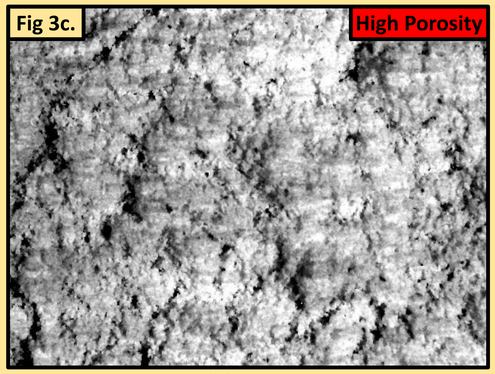

Figure 3. The green band of each image under 20X magnification (a) low porosity – packed into sample cup under a 20 kg mass, (b) medium porosity - poured into sample cup and leveled, (c) high porosity – gently sieved into sample.

Fig 4a. Low Porosity

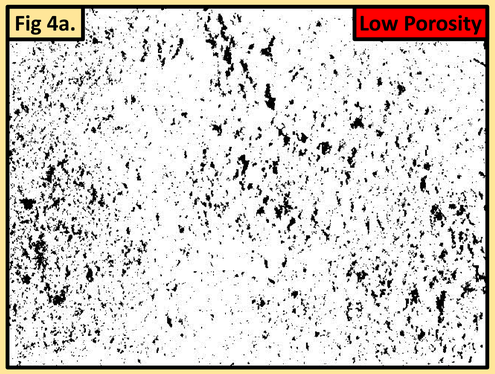

Fig 4b. Medium Porosity

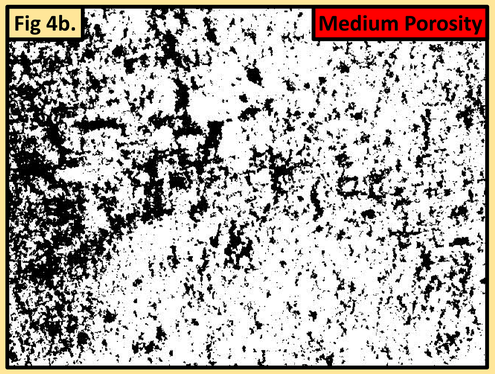

Fig 4c. High Porosity

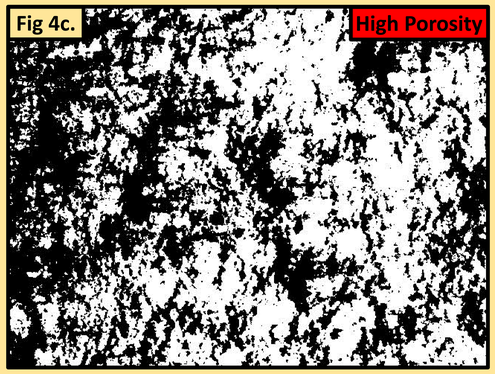

Figure 4. Particle masks generated within ENVI for Figure 3 images. Black regions represents void space, while white regions represent particles. Note that with increasing porosity we see an increase in void space (black).

Table 1

Sample Type	Dark Pixels	Porosity
Average Packed	30,425	10%
Average Leveled	86,853	28%
Average Sieved	153,513	50%

Table 1. Table listing the sample type, the number of dark pixels included in the mask, the corresponding average porosity for each of the 10 measurements per sample. Each image comprised of 307,200 pixels. Note: a porosity of 0% designates a material completely free of any pore space, while a porosity of 100% represents a pure void.

Future Work

- Next, we will use these sample preparation and microscopic imaging techniques to a finely ground San Carlos olivine sample (> 45 µm).
- We will then investigate how the thermal infrared spectra of olivine changes for these porosities.
- Eventually we will create physical mixtures of San Carlos Olivine with a range of particle sizes more reminiscent of the lunar regolith [e.g., 6].
- Finally, we will use this method on other lunar analogs including lunar simulants generated by the University of Central Florida's CLASS Exolith Lab [9,10].

Results

- Microscopic image processing can be used to estimate the porosity of surface samples.
- Precisely determining the boundary between particles and voids is difficult to accomplish, thus determining the absolute porosity of each sample is challenging.
- This added challenge forces a human component into the process of selecting particle-void-boundaries, which introduces the possibility of bias.
- Porous samples introduce further complications due to their textured surface; this leads to portions of the image remaining unfocused.
- Two light sources allows for increased particle/void discrimination. However, the introduction of a secondary light source can introduce asymmetric illumination undetectable to the human eye, which may dominate porosity masks, appearing as a horizontal illumination gradient in the images.
- The packed images are most effected by this asymmetric illumination due to their relatively condensed pixel value range; the illumination gradient will be much more apparent.
- Increasing the magnification makes image processing more difficult. Numerous tiny voids in packed samples achieve results akin to large voids in puffier samples.