LAVA FLOW MORPHOLOGY CLASSIFICATION BASED ON MEASURES OF ROUGHNESS. H. C. Mallonee[1], S. E. Kobs Nawotniak[1], M. McGregor[1], S. S. Hughes[1], C. D. Neish[2], M. Downs[3], D. Delparte[1], D. S. S. Lim[4, 5], J. Heldmann[4], and the FINESSE team [1]Dept. of Geosciences, Stop 8072, Idaho State University, Pocatello, ID, 83209; hester.mallonee@gmail.com, [2]Dept. of Earth Sciences, University of Western Ontario, London, ON, Canada, [3]NASA Kennedy Space Center, Merritt Island, FL., [4]NASA Ames Research Center, Moffett Field, CA, [5]BAER Institute, NASA Ames Research Center, Moffett Field, CA.

Introduction: Lava flow surface morphology reflects the conditions affecting the flow during emplacement. Thus, mapping lava flow textures gives us insight into the eruptive history of a volcano. Lower viscosities or shear strain result in smooth textures; rough textures are the result of higher viscosities, higher shear strain, or disruption of the rapidly cooled surface [1-5]. Lava flow textures on Earth and other planets are frequently mapped using qualitative observations of aerial and orbital imagery [e.g. 5]. This study uses quantitative measures of roughness to distinguish lava flow textures based on high-resolution topographic data.

The Craters of the Moon (COM) basaltic lava field in southeast Idaho was chosen as an analogue field site due to its wide variety of lava flow textures, including smooth, hummocky, and rubbly pāhoehoe (Figure 1a) and an a'a-block flow (Figure 1b). COM lies in the eastern Snake River Plain [6], the type location for plains-style volcanism and long considered useful as a planetary analog [7, 8].

Data collection and processing: Aerial imagery was collected with Unmanned Aerial Vehicles. High-resolution Digital Surface Models (DSMs) were constructed using the Structure-from-motion workflow [9]. These DSMs were downsampled to a consistent resolution, 0.5 m, using ArcGIS. Measures of roughness were calculated across the datasets using a 1.5 x1.5 m moving window. In this work, we used two measures of roughness: RMS height and Area ratio.

RMS height: The root-mean-square (RMS) height measures the standard deviation of heights around the mean [10]. The RMS height has been used as a measure of roughness to study lunar impact melts [11] and the surface of Mars [12]. The RMS height was measured at a 1.5 m scale.

Area Ratio: The Area Ratio is the two-dimensional map area divided by the three-dimensional surface area [13, 14]. While not used as commonly as the RMS height to analyze lava flows, it has been used to describe a wide variety of topographic surfaces, including valley networks and corals [15-17].

Results: The RMS height (Fig 2) shows distinct differences between the ‘a‘ā-block and pāhoehoe textures, with ‘a‘ā-block material registering as far rougher. Hummocky, smooth, and rubbly pāhoehoe are distinguishable from one another, though the eastern rubbly is noticeably rougher than the western. This change in rubbly pāhoehoe captures the presence of large-scale inflation features preserved in the east. The inflated rubbly pahoehoe has a signal similar to the western hummocky pahoehoe in this view.

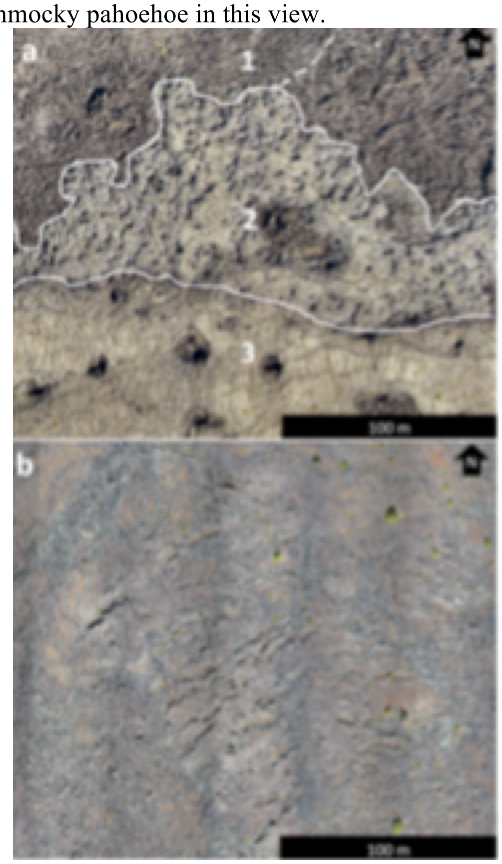

Figure 1: Flow textures examined in this study: (a1) rubbly pāhoehoe (Big Craters flow), (a2) hummocky pāhoehoe (North Crater flow), (a3) smooth pāhoehoe (North Crater flow), (b) ‘a‘ā-block (Highway flow). Dashed line marks approximate boundary between two rubbly textures.

The area ratio (Fig 3) further confirms the distinctions between the flow morphologies. Additionally, it indicates that the oval patch in the middle of the hummocky pahoehoe is better classified as inflated rubbly pahoehoe (Figure 1a). Using the Area Ratio, it is easier to distinguish between the inflated rubbly pahoehoe and western hummocky pahoehoe than in the RMS.

Discussion: Both methods distinguished lava flow textures from one another. The inherent 0-1 scale used by the Area Ratio made it easier to distinguish between transitional textures. Classification breaks (Table 1) are dependent on data resolution (see Mallonée 2, this meeting).

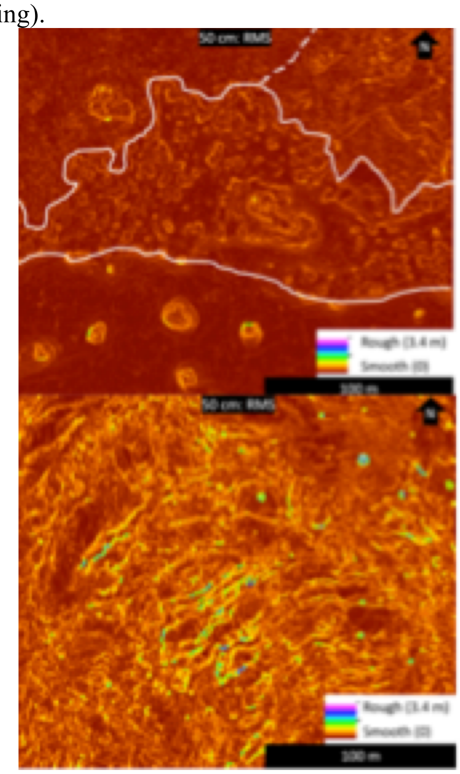

Figure 2: The RMS height of the same views as in Fig 1 panels a and b. Vertical scale is related to features and resolution.

Conclusion: Both the RMS height and the area ratio can be used to distinguish flow textures. The area ratio, in particular, did well distinguishing between intermediate lava flow textures, while the RMS height was useful for end-member textures. These methods will be refined with the addition of the Allen variance, the RMS slope, and the Hurst exponent into a combined model to capture scalability and data resolution. The RMS height and area ratio could be used to analyze any topographic surface, including both terrestrial and planetary lava flows.

Table 1. Typical RMS height and area ratio for the selected areas at 0.5 m/pixel. Unusual topographic changes (ex, lava-rise pits, trees) were removed prior to computing statistics.

Texture	Mean RMS height (m)	Mean Area ratio
Smooth	0.0638 +/- 0.0538	0.9790 +/- 0.0710
Hummocky	0.1281 +/- 0.0841	0.9370 +/- 0.0805
Rubbly	0.1789 +/- 0.1129	0.9315 +/- 0.1243
‘A‘ā-blocky	0.3018 +/- 0.2181	0.7777 +/- 0.1709

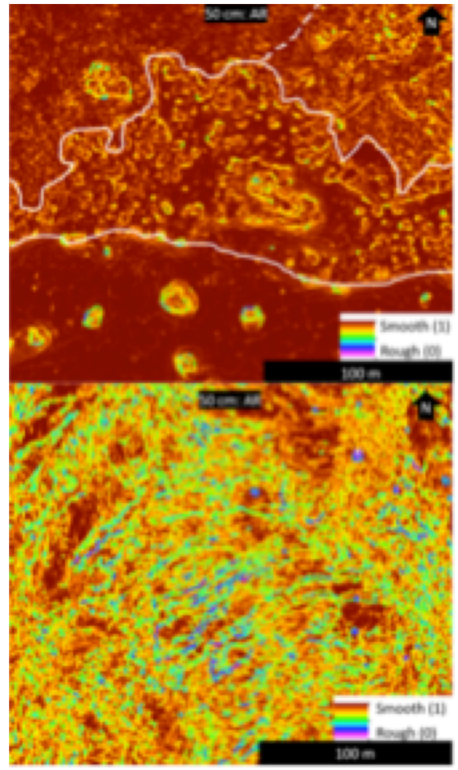

Figure 3: The area ratio of same views as Figure 1, panels a and b. Vertical scale is always limited to 0-1 by method.

References: [1] Peterson and Tilling (1980) *JVGR, 7*:271-293. [2] Rowland and Walker (1990) *Bull. Volc, 52:*615-628. [3] Cashman et al. (1999) *Bull. Volc, 61:*306-323. [4] Guilbaud et al. (2005) *GSA Spec. Pap. 396:*81-102. [5] Keszthelyi et al (2004) *Geochem. Geophys. Geosyst, 5.* [6] Kuntz et al. (2007) *USGS Map* [7] Hughes et al (1999) *Guide. to Geol. of East. ID,* 143-168. [8] Greeley (1982) *JGR, 87:*2705 – 2712. [9] Westoby et al (2012) *Geomorph., 179*:300-314. [10] Shepard et al (2001) *JGR, 106*:777-795. [11] Neish et al. (2017) *Icarus, 281:*73-89. [12] Orosei et al. (2003) *JGR, 108*:1-10. [13] Grohmann et al. (2011) *IEEE Trans. on Geosci. And Rem. Sen., 49:*1200-1213. [14] Jenness (2004) *Wildlife Soc. Bul., 32:*829-839. [15] Huaxing (2008) *Adv. in Digital Terrain Analysis,* 159-176. [16] Leon et al. (2015) *Geomorph, 242:* 21-28. [17] Mallonee et al. (2016) *LPSC XXXXVII,* Abstract 2403

Acknowledgements: This work was funded by SSERVI FINESSE (PI J. Heldmann). UAS flights were conducted under NPS Permit #CRMO-2014-SCI-0004. We thank Craters of the Moon Natl. Mnmt. and the people of Arco, ID.