LAVA SURFACE ROUGHNESS AND MORPHOLOGIES: A NEW REMOTE-SENSING METHOD TO ESTIMATE PHYSICAL PROPERTIES OF LAVA FLOWS ON EARTH, THE MOON AND MARS.

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Introduction: Lava flow morphologies record the conditions of volcanic emplacement. For example, pāhoehoe morphologies are constrained to high-temperature volcanism, whereas \`a\`ā flow surfaces indicate sufficiently cooled lava becoming highly viscous largely due to crystallization. The conditions at which this transition is expected to occur in Hawaiian lavas has been determined [1,2,3]. In theory, lava flow morphologies contain information about the physical properties of the lava (e.g., crystallinity, density, porosity), and therefore may be extractable from morphology observations.

However, surface morphology interpretations and classifications may vary between observers. A mathematical description of surface roughness would eliminate such uncertainties. We present our progress in quantifying surface roughness of a basaltic lava flow at Craters of the Moon (COTM) National Monument and Preserve (Idaho), and the correlation with surface morphology and physical properties of the lava.

Methods: Samples were collected along a ~2.75 km channelized lava flow transitioning from pāhoehoe to \`a\`ā morphologies. Crystallinity, density, and porosity were measured in the laboratory. An unoccupied aerial vehicle (UAV) imaged the lava flow, from which a high-resolution digital terrain model (DTM) at 5 cm per pixel was derived. This DTM was used to calculate the surface roughness at the sampling sites using ArcGIS. The surface roughness is defined as the ratio of 3D/2D surface area (ε). The DEM was further degraded to resolutions of 10, 15, 20, 25, 50, and 100 cm per pixel to evaluate the influence of DEM resolution on roughness calculations. Moreover, we varied the radius of the circular area around the sample sites to vary the number of available pixels for roughness calculations and also to capture small to large-scale topography (e.g., single blocks vs ridges).

Results: Pāhoehoe surface morphologies are constrained to $\varepsilon < 1.02$, whereas \`a\`ā surface morphologies are constrained to $\varepsilon > 1.06$ (Figure 1). Best correlation between surface roughness and crystallinity is found at 5 cm per pixel resolution with a circular area using a radius of 8 meters. Decreasing the resolution only slightly degrades these correlations, whereas area size (i.e., radius) has a much larger effect (Figure 2). Correlations between surface roughness and density and/or vesicularity were moderate.

Discussion: Surface morphology and crystal content are broadly consistent with observations for Hawaiian lava [1]. Based on the calibration at 5 cm per pixel resolution and using an 8 m radius, crystal content can be estimated to about ±5 vol%.

Conclusions: Our results show that 3D/2D roughness calculations may be suitable to estimate the crystal content of mafic lavas on Earth. The degraded DEM resolutions are comparable to those for other planetary surfaces, such as the Moon and Mars, and the application of this method may therefore be extended to these planetary surfaces. However, further studies are necessary to confirm our results for other terrestrial mafic lava flows, and corrections for regolith mantling and micro-cratering processes on the Moon and Mars, which essentially smooth the surface, need to be incorporated.

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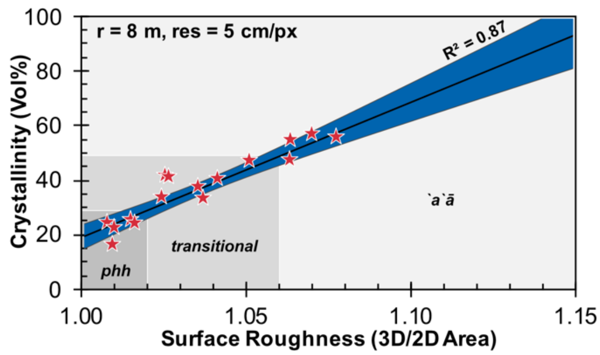

Figure 1: Correlation between surface roughness and crystallinity for surface samples (red stars) located near the center of the lava channel. 95% confidence band is shown in blue. Boundaries for endmember surface morphologies (pāhoehoe, transitional and \`a\`ā) based on surface roughness calculations and field observations.

Perimeter radius, r (in meter)	DEM resolution (per pixel)						
	100 cm	50 cm	25 cm	20 cm	15 cm	10 cm	5 cm
0.5	0.34	0.28	0.33	0.33	0.34	0.32	0.37
1	0.39	0.40	0.42	0.41	0.43	0.41	0.48
2	0.50	0.52	0.51	0.51	0.51	0.52	0.56
3	0.53	0.56	0.56	0.56	0.56	0.58	0.58
4	0.61	0.63	0.63	0.63	0.63	0.64	0.63
5	0.71	0.73	0.73	0.73	0.73	0.73	0.71
8	0.79	0.83	0.85	0.85	0.85	0.85	0.87
10	0.71	0.77	0.79	0.79	0.79	0.80	0.83
15	0.69	0.76	0.79	0.79	0.79	0.79	0.83
20	0.62	0.68	0.70	0.70	0.70	0.70	0.73
25	0.64	0.68	0.68	0.68	0.68	0.68	0.71
30	0.54	0.59	0.59	0.59	0.59	0.59	n/a
35	0.42	0.46	0.47	0.47	0.47	0.41	n/a
40	0.24	0.28	0.29	0.29	0.29	0.30	n/a
50	0.03	0.05	0.06	0.06	0.06	0.06	n/a

Figure 2: R^2 between surface roughness and crystallinity as a function of DEM resolution and radius around sample location.