LAVA, DEBRIS, AND PYROCLASTIC FLOW DEPOSITS: ANALYSIS AND IDENTIFICATION USING CURVATURE SPECTRA;
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Summary. Evidence of rhyolite, andesite, basalt, debris or pyroclastic flow deposits on planets such as Mars and Venus can give important clues to the nature of volcanic processes, crustal evolution and volatile abundance and history. The positive identification of lahars or debris flows on Mars is evidence for the presence of water. Despite this importance, it is often difficult to recognize flow deposit type with confidence from remote observation.

Our research focuses on the margins of terrestrial flow deposits of the above-mentioned types. We wish to assess the scale and degree of lobateness, digitateness, or sinuosity of the flow deposit margin in an objective and quantitative manner . The underlying assumption is that in most examples the sinuosity or curvature of the margin of a gravity-driven flow is predominantly a function of flow rheology, emplacement mechanism, and basal slope. The "curvature spectra" produced by our algorithm are a measure of the abundance of all orders of *radius of curvature* (RC) within a margin. This provides us with a unique signature related to flow properties, and enables us to distinguish among rhyolite, andesite, basalt, debris flow and pyroclastic flow deposits on Earth.

Background. Previous attempts to quantify planform morphologies of flow deposits have focused primarily on lava flows. Lava flow lengths have been used to infer effusion rates and durations [1], lobe widths have been related to lava silica content [2], and fractal analyses of lava flow margins have been used to assess lava flows of different rheologies [3].

Both Fourier and fractal analyses were considered for evaluating margin curvature. Fourier analysis tends to be ineffective for evaluating curves that are recumbent and convoluted to an infinitely small scale. Techniques to remediate these problems are problematic and scale-limited because they require multiple, biased reference points. Fractal analyses are primarily effective for determining a fractal dimension, one value describing the convolutedness of the margin at all scales. We are, instead, interested in quantifying curvature at many scales because it gives us a large suite of information about the flows.

Methodology. Air photos with resolutions greater than 1m were obtained for each type of flow deposit. Flows were selected which are relatively pristine, unconfined by valleys, free of large obstructions, and on basal slopes between 1° and 30°. Because they are easily eroded, pyroclastic and debris flow deposits were imaged soon after their emplacement.

Once the margins of the flow deposits are digitized from enlarged airphotos, our algorithm generates the "curvature spectra". The algorithm takes the digitized stream of points and determines RC for every set of three points (Fig. 1a). This is simply the radius of the unique circle that fits the three points. The algorithm then compares each "margin RC" with a given threshold RC. If the margin RC is less than the threshold the center point of the three points moves inward until an RC forms that is equal to the threshold RC. This "smoothing" takes place throughout the entire margin until all RC are greater than or equal to the threshold RC. This process is repeated for increasingly larger thresholds from the smallest possible threshold up to the largest possible threshold (Fig. 1b). The largest RC threshold causes the margin to smooth to a line between the two endpoints. Before and after each threshold's smoothing event, a total margin length is measured. As the flow becomes smoother the total length becomes less. The end result is a plot (Fig. 1c) of *change* in margin length (y-axis) verses RC threshold (x-axis). These "curvature spectra" are in essence the magnitude of curvature verses the abundance of this curvature in the flow margin. Values for large RC thresholds reflect the large-scale shape of the flow, while small RC threshold values reflect small convolutions and thin digitate fingers.

Results. A comparison of curvature spectra shows that there are characteristic patterns defining each type of flow deposit. Dacite (Fig. 2a) and Andesite (Fig. 2b) flows are distinct from other types of flow deposits because of their lack of small RC. A relationship derived from [4]

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allows approximate yield strengths to be calculated from the curvature spectra for the more silicic lava flow deposits if basal slope is known. In some cases this may allow for identification of silicic lava flow deposits of various compositions (i.e. andesite, dacite, rhyolite). Basalt (Fig. 2c, 2d), debris (Fig. 2e) and pyroclastic (Fig. 2f) flow deposits, which all contain small RC features, can be distinguished from one another by certain differences in their spectral patterns. Debris flows and pyroclastic flows have large, narrow spikes in their spectra, related to their longer, more digitate fingers. Basalts have larger areas under their curves for small RC. Each of the three appear to have the peak of their small RC spectra at different RC. Pahoehoe and aa basalts may be able to be differentiated, but results are preliminary. We intend to better quantify these differences, test more examples, and administer blind tests.

REFERENCES: [1] Walker,G.P.L. (1973), *Philos. Trans. Roy. Soc., Ser. A, 274,* 110-118. [2] Wadge, G. and R.M.C. Lopez (1991), *Bull. Volc., 54,* 10-24. [3] Bruno, B.C. et. al., (1994), *Bull. Volc.*, 56, 193-206. [4] Blake, S. (1990), *IAVCEI Proc. Volcanol. 2,* 25-46.

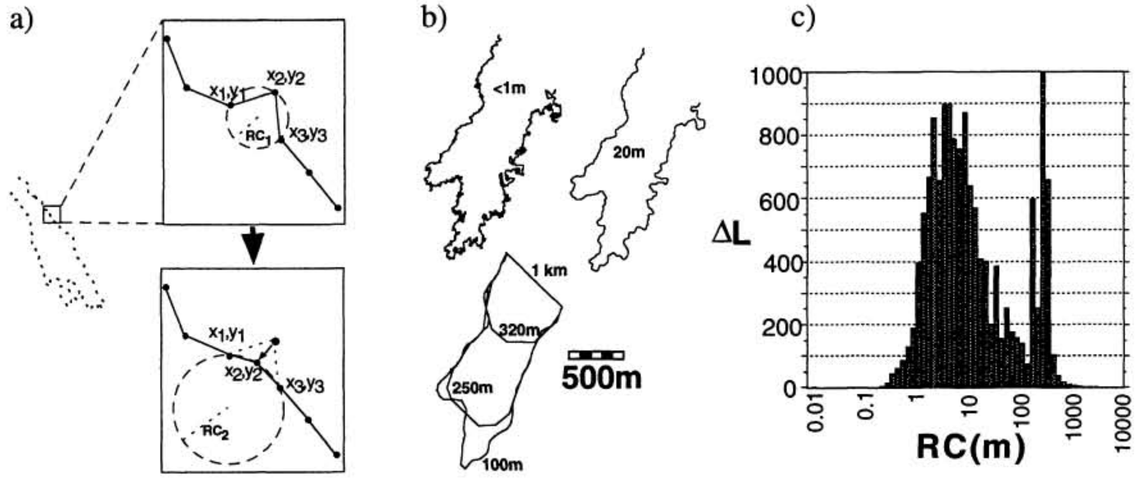

Figure 1. a) The algorithm changes the position of data points to smooth curves to the threshold RC (RC_2). b) The appearance of the margin of a pahoehoe flow after smoothing by the specified threshold. c) The curvature spectra plot of change in margin length verses RC threshold for the pahoehoe flow.

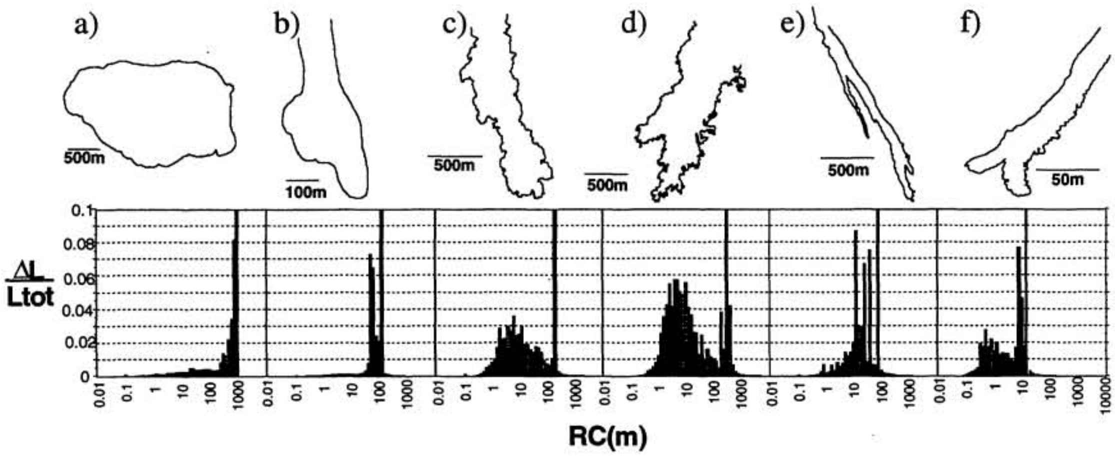

Figure 2. Curvature spectra for a) Rock Mesa rhyodacite flow, South Sister Peak, OR.; b) andesite flow in the Worm Flows, Mount St. Helens, WA.; c) basaltic aa flow, Mauna Ulu, HI; d) pahoehoe flow, Mauna Ulu, HI; e) lahar flow, Mount St. Helens, WA; f) pyroclastic flow, Mount St. Helens, WA.