

FIELD CONSTRAINTS ON REMOTE OBSERVATIONS OF DEBRIS FLOWS AND LAVA FLOWS; Kelin X. Whipple<sup>1</sup> and James R. Zimbelman<sup>2</sup>, <sup>1</sup>Dept. of Geological Sciences, AJ-20, University of Washington, Seattle, WA 98195, <sup>2</sup>Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, Washington, DC 20560

Landforms produced by various types of flow processes (e.g., lava flows, debris flows, landslides, floods, ice flows, etc.) are important aspects of both terrestrial and nonterrestrial landscapes. Identification of flow processes which have produced these features on planetary surfaces is a critical aspect of reconstructing geologic histories on planetary bodies. On Earth, investigations of flow features might include *in situ* studies of deposit properties, internal zonation, and compositional or textural relationships, as well as deposit morphology. On nonterrestrial surface, however, field studies presently are not possible and interpretation of surficial features is usually based solely on deposit morphology. Here we focus on discrimination between debris flows and lava flows. Debris flows and lava flows can both be reasonably modeled as Bingham materials, but they have markedly different rheological properties and down-flow rheologic variations, as indicated by recent field studies. These differences predict distinct patterns of down-flow morphologic variation which could be helpful in discriminating between these very different flow types, even when levees or pressure ridges are not resolvable.

Debris flows are active in many terrestrial environments and contribute significantly to the terrestrial landscape mostly through the formation of debris-flow fans. The morphology of these landforms is largely dependent on the rheology of the debris flows, as indicated in a recent study of fans on the western slope of Owens Valley, California (1,2). Rheologic information obtained included estimates of yield strength from many well-preserved debris-flow deposits and estimates of apparent viscosities for several surges of one debris-flow event. Yield strengths were estimated from the depth-slope product at the time of deposition and apparent viscosities were derived from mud-line super-elevations at channel bends (3). Calculated rheologic properties are consistent with published results for other debris flows (4), with yield strengths ranging from 0.1 to 6 kPa and apparent viscosities from 0.05 to 1 kPa-s. A monotonic decrease in both apparent viscosity and yield strength was observed with distance down-fan. These down-fan variations also correspond to a decrease in the overall thickness of the deposit, as well as a decrease in the average size of the largest materials transported. This pattern reflects rheologic differences between debris flows or between the individual surges of a single debris flow rather than thixotropic behavior of the debris flows: low-yield-strength debris flows are more mobile and achieve greater runout distances (3). Rheologic variability can be explained by the differences in bulk sediment concentration of individual debris flows (5,6).

The behavior of debris flows and the character of their deposits can be compared to similar observations of lava flows

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derived from field studies of the rheologic properties of basaltic lava flows in Hawaii (7,8). In these studies, yield strengths were calculated from surveyed profiles of the lava flows using equations derived for Bingham materials and apparent viscosities were obtained from flow front velocities and Jeffrey's equation (8). Values ranged from 0.3 to 40 kPa for yield strength and 0.06 to 400 kPa-s for apparent viscosity. Significantly, calculated rheologic properties for the Hawaiian lava flows show a consistent increase in both yield strength and apparent viscosity with distance down-flow. This likely reflects progressive cooling of the lava with a corresponding steady increase in the overall thickness of the flow margin.

The rheological differences between debris flows and lava flows predict two major morphological differences between their deposits which may allow discrimination with remotely-sensed data: 1) the greater yield strength of basaltic flows implies greater flow thickness and greater relief at flow margins than would be expected for debris-flow deposits; and 2) a down-flow increase in flow thickness is anticipated for lava flows, a condition not generally observed for debris flows. Although the latter may in some cases provide an opportunity to definitively establish a volcanic rather than a debris-flow origin for some features, the former is probably the more fundamental distinction; at the degree of spatial resolution presently obtainable in planetary studies, the low yield strengths of debris flows will generally render them indistinguishable from fluvial landforms, since relief on lobes and levees of debris flows are generally less than 2 meters.

Two terrestrial examples of landscapes on which both debris flows and lava flows occur are the debris-flow fans of Owens Valley and the flanks of Mt. St. Helens. These landscapes illustrate the distinction of debris-flow deposits and lava flows in remotely sensed data. A 'field-calibrated' eye is needed to distinguish the subtle features characteristic of debris-flow deposits that are visible on TM images of the Owens Valley; in general, the surface appears to be alluvial. Lava flows erupted onto fan surfaces from cinder cones, however, are distinct owing to their greater thickness, rougher surface texture, and greater extent for individual flows. Similarly, on aerial photographs of the southern flank of Mt. St. Helens, thick andesitic lava flows with well-developed levees and pressure ridges are clearly recognizable but recent debris-flow deposits are visible only by lack of vegetation along the debris-flow track.

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