

SMALL-SCALE VOLCANIC LANDFORMS INDICATIVE OF DISTRIBUTARY TUBE SYSTEMS; E. Theilig, National Research Council at Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA

Surface features tens to hundreds of meters in size on martian lava flows are revealed in high resolution Viking Orbiter images (1,2). Many of these morphological features form in response to certain flow emplacement mechanisms, eruptive styles, or rheological properties of the lava. Insight into the relationships between lava flow morphology and the emplacement and characteristics of magma is an ongoing area of research and allows constraints to be placed on interpretation of martian volcanism. This report focuses on pressure ridges, tumuli, and pressure plateaus which comprise a suite of features characteristic of compound pahoehoe lava flows. Similar ridges and mounds have been identified in the Tharsis region of Mars (2).

Elongate pressure ridges, circular tumuli, and large irregular pressure plateaus are arched or domed shaped and are characterized by open wedge-shaped cracks at their summits. The similar morphology suggests a single formational mechanism for all of these features. Previous studies, primarily based on observations of Hawaiian lava flows, have concentrated on tumuli and have proposed that these features formed by uplift of weak surface crust behind blocked lava tubes (3). Widespread occurrences of pressure ridges and plateaus, however, are predominantly found on sections of lava fields lacking evidence of master tube systems or large channels from which crusted over tubes could have formed. This apparent lack of correlation between large scale tube development and occurrence of pressure ridges and plateaus suggests a different mechanism than that previously proposed for tumuli.

Field observations on the McCartys flow, New Mexico, and the Wapi flow, Idaho (4) and theoretical modeling (5) indicate that pressure ridges and plateaus form as part of the flow process and can be used to interpret the emplacement mechanism (6). Each ridge or plateau occupies the central part of individual flow lobes or toes and, in plan view, mimics the lobe margins. The emplacement process described below only pertains to a single lobe a few to tens of meters wide and occurs contemporaneously in numerous lobes across the lava field. Lava effused from a bocca or series of boccas advances to form a small lobe. Flow advance slows or halts and continued influx of lava causes the lobe to inflate. Upward driving pressure of the lava is resisted by the strength of the crust and the amount of deflection is controlled by applied pressure, dimensions of the area being uplifted, and thickness of the crust. As the surface is deformed upward, cracks form where tensile stress is greatest and open downward over the center of uplift and upward around the edges. Molten lava from the interior fills the cracks and may break out through fractures penetrating the crust. Predominant secondary effusion of lava occurs through boccas at the base, where local hydrostatic pressure is greatest. If lava supply is uninterrupted, the process may repeat and another lobe forms.

Several aspects of this emplacement mechanism are consistent with tube-fed flow. For inflation to occur, lava must pond behind a slowly moving front and must be contained by a congealed crust. Columnar joint surfaces forming the upper part of crack walls suggest formation of a 0.2 to 1 m thick crust prior to uplift. Effusion of lava through cracks generated during deformation of the crust provides evidence of molten lava moving through the ridge/plateau interior. The budding lobe and toe mechanism of tube formation (7) probably operated during emplacement of the small lobes. The lobes were emplaced on the surface and inflation occurred along their entire length. As numerous lobes formed by continual repetition of this process, a distributary tube system developed.

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Flow rate and topographic slope probably control this style of flow emplacement. Increased viscosity and yield strength caused by cooling of the tube margins eventually results in slowing or halting flow advance. Cooling of the margins to halt a flow suggests a balance, expressed by the dimensionless Graetz number, between cooling rate and flow rate (8-10). Flow rates for lobes containing ridges and plateaus were calculated from a Graetz number analysis and were found to vary between 0.05 and 10 m³s⁻¹. These rates are on the lower end of measured values for Hawaiian flows (3,11,12). Onset of pressure ridge occurrence within a lava field is typically associated with a break in slope with most ridges restricted to slopes <1°. Low velocities would result from a combination of low flow rate effusion onto gentle slopes.

Flows characterized by pressure ridges and plateaus are different than those emplaced by tubes formed from crusted over channels. Instead of establishing well defined channeled flows, a complex distributary tube system forms across the entire field by budding. On low slopes, the flow advanced slowly through numerous lobes that constructed tubes as they extended. Within individual tubes, cooling of the margins caused the flow to stagnate and inflation occurred along the length of that tube. Uplift then created a ridge or plateau depending on the geometry of the initial tube. In contrast, tumuli may form as point source uplifts, either as a small inflated tube or behind a blocked buried tube. As such, tumuli are not indicative of a specific tube emplacement mechanism. Where pressure ridges and plateaus can be identified on Mars, they can be used to interpret the flow emplacement process.

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