A CLASSIFICATION SCHEME FOR THE MORPHOLOGY OF LAVA FLOW FIELDS. L. Wilson[1,2], H. Pinkerton[1], J.W. Head[2] and K. Magee Roberts[2]. [1]Environmental Sci. Div., Lancaster Univ., Lancaster LA1 4YQ, U.K. [2]Dept. Geological Sci., Brown Univ., Providence RI 02912 USA

Introduction: Analysis of the processes controlling the advance of lava flows[1-3] shows that, if no other factors intervene, thermal constraints will act to limit the maximum length of a flow being fed at a given volume or mass effusion rate from a vent. These constraints can be characterised through the Grätz number[4], which takes on a large value at the vent and decreases down flow. Early application of this principle[5] showed that, despite the many subtleties of modes of heat loss from flows[6], motion apparently ceases when the Grätz number has decreased to a value close to 300. Recent analyses of flow units from the 1983-86 Pu'u 'O'o eruption of Kilauea and of other, more silicic lava flow units confirm this finding[2].

Discussion: There are several factors which may intervene to prevent a flow reaching its maximum potential cooling-limited length. These factors are particularly important when they cause the formation of a compound flow field, the large-scale features of which may be more amenable to measurement than the geometries of individual flow units[7]. The presence of well-preserved and areally very extensive examples of such compound flow fields on Venus[8-10] has prompted us to attempt to classify as many as possible of the factors which are relevant to mapping such flow fields and to deriving eruption rate estimates from their morphologies. For this purpose we categorise flows as follows:

Classification Scheme:

Cooling-limited flows: Effusion from the vent is steady; the flow front thickens and slows as the lava rheology responds to progressive cooling; the flow front eventually stops due to this cooling and the central channel of the flow does not drain. If the vent remains active, a break-out flow must form from some point on the margin of the initial flow unit.

Volume-limited flows: The steady advance of the front of the flow stops when effusion from the vent stops; the central channel of the flow unit may drain, in which case part of the original flow front continues to advance, but at a decreasing rate (and forming a thinner and narrower flow unit) as the channel drains. No normal break-out flows are associated with a volume-limited flow. A volume-limited flow is by definition shorter than a cooling-limited flow formed at the same effusion rate.

Accidentally-breached flows: If the central channel of a flow becomes blocked due to the breaking off of parts of the levee or channel wall, a break-out flow will form from a point somewhere upstream of the blockage. The accidentally-breached parent flow will be shorter than if it had not been breached.

Break-out flows: These form either from the sides or fronts of cooling limited flows if effusion at the vent continues after the front of the first flow unit has stopped due to cooling, or from the sides of accidentally breached flows. A break-out flow may itself become cooling-limited, volume-limited, etc.

Captured flows: If pre-existing topography down slope of a vent confines a flow unit to a channel which is narrower than the width which the flow would have adopted (by forming its own cooled levees) if it had been erupted on a flat inclined plane, the flow will be deeper than it would otherwise have been, and will also reach a greater cooling- limited length than if it had not been captured. If topographic data and morphological measurements are available at sufficiently high resolution, captured flows may be distinguished from other flow types by having differing patterns of correlation of flow width and thickness with substrate slope: for non-captured flows, the total flow width, central channel width and flow thickness will all increase systematically with decreasing substrate slope[11].

Tube-fed flows: These are flows fed by a roofed-over tube system. This may be just the interior of a single, parent, cooling-limited flow unit, the central channel of which has become completely solid, or may be a more complex system of earlier flow units. Once magma has emerged from the roofed-over tube system, the flow units formed obey the same rules as those given above for flows fed from a primary vent. The only significant difference may be that, although magma cools only slowly within a tube system, the lava forming tube-fed flows may be systematically slightly cooler than lava emerging from a primary vent on the same volcano; the consequent higher initial viscosity of tube-fed lava will lead to cooling-limited flow units that are somewhat shorter than those fed from a primary vent at the same effusion rate.

Applications: Where a compound flow field consists of many flow units which have been produced by a long-lived eruption, much of which may have taken place at a relatively constant effusion rate, it is to be expected that many of the flow units will be cooling limited, each such flow being connected to one or more break-out flows which is itself cooling-limited. The last flow unit in such a sequence will, of course, be volume limited. The first step in the analysis of a compound flow field must be the application of traditional mapping methods, identifying discrete units, determining superposition relationships between units or groups of units, and looking for continuity relationships between adjacent units. Once a connected group of units has been mapped, a histogram of the lengths of the units may be plotted, and the following relationships are expected. In the simplest circumstances, there will be a high peak in the distribution corresponding to the length, L, of a single cooling-limited flow unit. There may also be significant peaks at lengths which are integer multiples of this basic length (2L, 3L, etc.), corresponding to groups of two or more flow units where each is a break-out flow from the front of an earlier unit but has not been recognised as such because of inadequate resolution in the images used. The sharpness of the peak(s) will depend on the constancy of the effusion rate: a declining effusion rate will lead to the formation of shorter cooling-limited flows, resulting in a skewing of the histogram peak towards lengths somewhat shorter than L. Superimposed on the simple pattern due to cooling limited flows will be a distribution of lengths arising from volume limited and accidentally breached flows (all of which must have lengths shorter than L by various amounts) and of captured flows (all of which have lengths greater than L). As long as the "noise" represented by these other flows does not swamp the main peak due to cooling-limited flows, it will be possible to use the flow length, L, at which the peak occurs to estimate the mean effusion rate feeding the flow field. Examples of several of these flow types and fields on Venus are described elsewhere[10].

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