SCALING OF PAHOEHOE FLOW FIELD FEATURES. S. M. Baloga[1], L. S. Glaze[1], D. A. Crown[2], [1]Proxemy Research (20528 Farcroft Lane, Laytonsville, MD 20882), steve@proxemy.com, [2]Plantery Science Institute, Tuscon, AZ.

Introduction. Pahoehoe flow fields are one of the most significant landforms in planetary and terrestrial volcanism [1-3]. Such flow fields often contain many different types of features, including toes, monofilaments of toes, channels at multiple scales, tubes, sheets, tumuli and lava rises, small and large lobes that may be a'a or pahoehoe. These features are generally intermingled or superimposed and often the appearance of overriding a'a lobes dominates the visual appearance of the flow field.

The issue we are beginning to address is how to simulate large pahoehoe flow fields in a planetary setting based on modes of emplacement from terrestrial experience. The complexity of pahoehoe flows seems to make modeling of flow field growth a formidable task. Clearly a host of random influences are present. Moreover, the features found in a pahoehoe flow field occur at different scales. This suggests that the physical processes occur at different scales as do the type and significance of the random effects that are present. For example, the budding of toes is governed by relatively microscopic phyics related to formation of a thin skin and its fracture while the emplacement of a large solitary lobe is governed by classical viscous fluid dynamics and an entirely different regime of heat transport.

Recently, through field and theoretical studies, progress has been made in describing the mode of emplacement for toes, smooth sheets, relatively small channels, tumuli, and lava rises, in the context of flow field growth. The field studies have indicated the conditions and factors under which certain modes, e.g., toes, are preferred, while the theoretical studies have focused on explaining different modes in the context of random walks [2-4].

The most important factors that influence the mode of formation are the total volume of lava, rate of emplacement, slope and momentum. A random walk model for pahoehoe toes has been used to describe the emplacement of small numbers of toes with a typical length of about a meter. It is easy to scale this model from monofilaments of toes to lobes and sheets. Inclusion of correlation in the random walk produces channels, similar to those observed in the field [2-4].

Statistical distributions of features. We have assembled and analyzed the statistical distributions of the features found in the terrestrial and planetary flow fields shown in Table 1. Each of these data sets have been carefully compiled with rigorous criteria applied to the qualification of the entrees by using a variety of geologic and measurement criteria [3-7]. Some such qualification procedure is necessary to be able to assess the type of distribution statistically. In addition, to assess the type of parent distribution, it is necessary to have enough data points. In practice, fifteen data points is an absolute minimum, 30-50 being more reasonable, and a higher number being preferred.

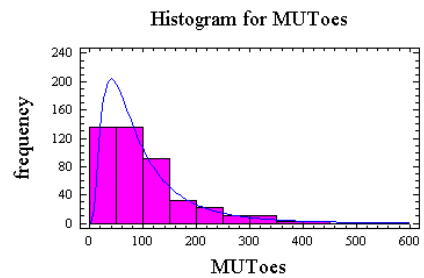

Figure 1. Mauna Ulu toe lengths (cm)

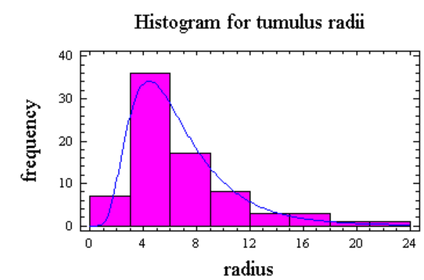

Figure 2. Mauna Ulu tumulus radii (m)

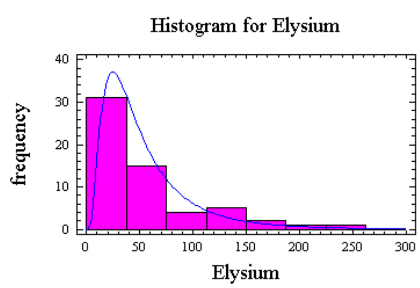

Figure 3. Lobate flow lenths (km)

Figures 1, 2, and 3 show the distributions of lengths for pahoehoe toes at Mauna Ulu, the effective radius of tumuli at Mauna Ulu, and the lengths of flows at Elysium Planitia. When geologic and measurement qualification criteria are rigorously applied to these mappable units, the following conclusions are found: 1) There is a distinct length scale that emerges for each type of feature. There is in fact a progression in flow field features that goes from the toe scale to larger mappable units, such as small channels and tumuli, to large lobes, which may have transitioned to a'a. 2) We see in all cases, as often occurs in geologic data, that the standard deviation is comparable to the mean value of the lengths shown. Typically what happens when the standard deviation is comparable to the mean value is that there is a significant long tail that skews the distribution toward larger values (e.g., Figs 1 – 3). This occurs in all the data sets shown in the table. This suggests the use of a lognormal distribution for fitting the individual data sets. 3) Although all distributions have long tails, the range of each is well constrained, e.g., there are no toes of lengths 10m, or 1cm. 4) The fitted statistical distributions of the toes, tumuli radii, and small channels can be confirmed as being lognormal. In the cases of the Mauna Loa and Alba Patera flow lengths, the lognormal cannot be precluded.

Interpretation. Motivated by theoretical considerations of the transitions suggested by the pahoehoe random walk model [2] and the above data analysis, we make the following assertion. The lengths of mappable features in large pahoehoe dominated flow fields are lognormally distributed. The long tails in these distributions represent a transition to a new style of emplacement, often with a new length scale, and generally new dominant physical laws.

Thus, we consider a complex pahoehoe flow field to be a mixture of lognormal distributions that can be numerically simulated. Figure 4 shows the results of one such simulation for a mixture of features. We have constrained the simulation to produce the same total length (500m) for each of three types of features, toes, channelized units, and small lobes. The mean values have been set at 1m, 10m, and 100m, respectively, with corresponding standard deviations. The mixture of the three lognormal distributions takes on a new character. One might be tempted to say the resulting distribution is fractal. However the process of flow field emplacement is clearly logistic. The natural log of the simulated distributon (Figure 4) is more peaked than the normal distribution.

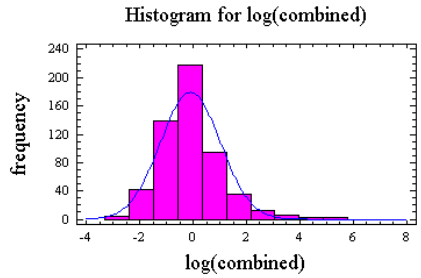

Figure 4.

The logistic distribution has a long history [8-9]. It is associated with the competition of one population or species with another. The results of our simulations show empirically how one type of feature competes with another (e.g., pahoehoe toes versus tumuli) for the available lava. Additional effort beyond [2] is needed to understand the parameters of this competition in terms of physical processes.

Conclusions. It is not feasible to model the details of emplacement of complex fields of pahoehoe flow fields due to the predominance of random influences. However, it now appears possible to quantify the distributions of features in different ambient settings for a range of eruption conditions. This would provide a method for unraveling the complex emplacement history when the statistical distributions of the individual features and the composite can both be identified.

References: [1] Self et al (1998) Ann Rev Earth Planet Sci 26: 81-110. [2] Baloga SM and LS Glaze, Pahoehoe transport as a correlated random walk, JGR in press [3] Crown, D and SM Baloga (1999) *Bull Volcanol, 61*:288-305. [4] Crown D et al. (1998) *LPSC, XXIX,* 1376. [5] Mouginis-Mark P. and Yoshioka M. T. (1998) *JGR, 103,* 19,389 – 19, 400. [6] Cattermole, P (1990) *Icarus, 83*, 453-493. [7] Malin, M (1980) *Geology, 8*, 306-308. [8] Verhulst PF (1838) *Memoirs de l'Academie Royal Bruxelles, 18,* 1-38. [9] Kingsland SE (1985) *Modeling nature,* University of Chicago Press, Chicago.

Table 1. Summary statistics for lava flow features.

Feature	Location	N	Range	Average	Std Dev
Pahoehoe Toe Lengths [3]	Mauna Ulu	445	0.1 – 5.3 m	1.0 m	0.8 m
Tumulus Radii	Mauna Ulu	76	2.2 – 21.8 m	6.7 m	4.0 m
Small Channel Lengths [4]	Mauna Ulu	110	1.6 – 52.5 m	9.3 m	10.3 m
Flow Lengths [7]	Mauna Loa	24	2 – 27 km	11.4 km	8.3 km
Lobate Flow Lengths [5]	Elysium	59	12 – 246 km	56.7 km	49.5 km
Sheet Flow Lengths [6]	Alba	40	10 – 200 km	93.8 km	56.5 km