EPISODIC MAGMA MOTION IN SHIELD VOLCANO RIFT ZONES. Elisabeth A. Parfitt and Lionel Wilson, Institute of Environmental and Biological Sciences, University of Lancaster, Lancaster LA1 4YQ, U.K.

Rift systems are characteristic of many terrestrial and martian volcanoes. The ongoing series of eruptions at the Pu'u 'O'o vent of Kilauea Volcano, Hawaii, although of exceptional length, is otherwise fairly typical of the eruptive behaviour of a terrestrial volcano possessing a major rift system. After the initial dike emplacement at Kilauea in January 1983, a cyclic pattern of behaviour quickly became established [1]: prior to an eruption the summit region inflates due to influx of magma from the mantle. When sufficient pressure has been generated, magma is forced into the rift, contraction of the summit occurs, and an eruption starts. Once the excess pressure has been relieved, eruption ceases and inflation begins again. The eruptions at Pu'u 'O'o gradually changed from relatively long episodes with low fire fountains and low eruption rates to shorter eruptions with higher fountains and higher eruption rates [1]. After episode 48, some major change in the dike properties led to a change involving the nearly steady transport of magma through the system. We are attempting to understand the dike geometry implied by these activity patterns.

Analytical Procedure: Using statistical significant difference tests (t-test and Mann-Whitney test) it is possible to show that the episode length, eruption rate, maximum fountain height, summit deflation time and average and maximum summit deflation rates have all changed very significantly through the eruptive series, possibly due to streamlining and/or widening of the dike system caused by the frequent movement of magma through it [2]. Episode to episode variations in each quantity are superimposed on this gradual change. Using correlation tests (Pearson test and Spearman rank-order test) it is possible to see how these variations interrelate. The variables used in the correlation were the erupted lava volume; the repose time between eruptions; the episode length; the summit inflation prior to an episode; the summit deflation during the episode; the time for which the summit is deflating; the average and maximum summit deflation rates; the eruption rate; the maximum fire fountain height; the net tilt (inflation - deflation) and the 'leakage' volume.

The leakage volume is the difference between the volume erupted (corrected for void space) and the volume of magma transferred into the rift during the eruption (calculated from the summit deflation using a tilt conversion factor [3]). The volume discrepancy which is calculated may represent a real difference in volume but could also result from uncertainties in the values used for the tilt conversion factor and the vesicularity. To check this, a significant difference test was used for a range of vesicularities (10-50%) and tilt conversion factors (3 to 6 mm/microradian). The test was initially used on the full eruptive series - episodes 2 to 48. However there is evidence that a change in behaviour occurred around episode 18 (for example offsets occur at episode 18 on plots of cumulative erupted volume, eruption rate, fire fountain height, summit deflation, etc.) so the test was then carried out on the early and the post-18 episodes separately. The results suggest that for the early episodes (2-17) there is no difference between the volume transferred into the rift from the summit region and the volume erupted at the vent. However, for the post-18 episodes there is a significantly higher volume of magma erupted than is pushed into the rift from the summit during the eruption. This conclusion is supported by the statistical results - for the early episodes the 'leakage' volume shows no correlations which are independent of the erupted volume or the summit deflation. But for the later episodes, the 'leakage' volume is correlated with the erupted volume but not with the summit deflation, and also produces correlations that neither the erupted volume or the summit deflation show. These results suggest that, in addition to the products of the direct 'push-through' mechanism, some of the erupted magma is magma stored in the rift by leakage from the summit reservoir during the repose period between episodes.

Correlation Results: The variables were correlated in pairs not only for the same episode but also with time shifts introduced to test for the possibility of time delays within the system which might have arisen due to the great lateral extent of the dike. (Calculations of dike size compared with the erupted volume show that magma must take several episodes to be transferred from the summit region to the vent.) The correlation results confirm that a change in behaviour did occur around episode 18, the short-term behaviour for the early episodes being distinctly different from that of the later episodes. For both sets of episodes the behaviour is fairly complex and only an outline is given here.

During the early episodes a long episode tends to accompany the eruption of a large volume of lava and a long summit deflation time. The length of an eruption is probably controlled largely by the dike width and the magma yield strength. A critical pressure must be generated in the summit region prior to an eruption. Once this is large enough to overcome the yield strength, magma flow will start. As the eruption proceeds the moving magma cools and increases its yield strength. Cooling occurs preferentially at narrow points within the dike system. Eventually, at some relatively narrow point in the dike, the pressure gradient will have declined to a level where it is no longer able to maintain flow and the eruption ceases.

An autocorrelation pattern is seen for the early episodes such that a short episode, erupting a small volume and having a relatively short deflation time, will be followed five episodes later by a relatively long episode which erupts a large volume of magma and is accompanied by a relatively long deflation time. A possible explanation for such a pattern is that a number of relatively narrow points exist within the dike and these effectively divide the dike into sections so that the volume that is erupted follows a fixed pattern. For example, consider that an eruption had ended by blocking at a narrow point in the dike. During the repose time prior to the next eruption it is the magma at this point which will cool most and so attain a higher yield strength than the rest of the magma in the dike. Eventually the summit pressure excess becomes large enough to overcome this blockage and magma begins to be pushed through the rift and an eruption starts. The cool blockage material moves through the dike until another relatively narrow point is reached: the relatively high yield strength of this material, combined with the partial relief of the summit pressure excess, causes motion to cease at this new point and the magma cools even further, and so on. In this case the volume of magma which has been erupted is equivalent to the volume of the dike section between the two blockage points. For the autocorrelation pattern which is seen for episodes 3-17, it is necessary to have a relatively short dike section separated from a relatively long dike section by four intermediate length sections of dike, the main blockage point moving progressively downrift with each eruption.

For the later episodes there is still evidence for this five episode delay pattern, but added to this the 'leakage' volume is correlated with the repose time six episodes in the past and with the volume, episode length and summit deflation seven episodes in the past. A long episode erupting a large volume tends to be followed by a long repose time, so this pattern is internally consistent. The correlation of the 'leakage' volume with the repose time suggests that this extra volume is produced by leakage of magma from the summit between eruptions (this is consistent with the declining accumulation rate seen for the summit region). The six episode delay implies that this leaked volume takes six episodes to be transferred from the summit and erupted.

This transfer can also be explained in terms of blockages at narrow points in the dike system: magma leaks from the summit region into the rift - the longer the repose time the greater the volume. This magma can only flow down the rift as far as the blocking point and must accumulate behind the blockage, inflating the dike section. An eruption starts and moves the blockage downrift. The flow of the magma may tend to hold the inflated dike section open; also the time constant for relaxation of the dike section may be longer than the eruption time, so that only after the eruption has ceased will the inflated dike section contract and transfer the extra magma downrift as far as the next blockage point and so on.

Summary: The feasability of this blockage explanation for introducing time delays into the eruption process requires further investigation using explicit dike geometry models, though the basic principle of magma cooling controlling eruption length has been discussed by Delaney and Pollard [4]. Episodic cycles of rift eruptions, a consequence of the delicate balance between summit stress accumulation, new dike propagation, and reactivated magma flow through cooling dike segments, permits greater effusion rates to occur (for short periods) than is possible when steady magma release occurs. Correlations between lava flow length, magma discharge rate and eruption duration [5] then determine the pattern of topographic evolution of a rift system as the flows from successive episodes accumulate; this in turn effects the subsurface stress fields controlling dike propagation. Several positive-feedback loops potentially exist in such complex systems, some of which are being revealed by the above statistical analysis. A better understanding of the dynamics of Kilauea's rift system will throw light on the evolution of the larger rift systems on, for example, the Tharsis volcanoes on Mars.

References: [1] Wolfe, E.W., Garcia, M.O., Jackson, D.B., Koyanagi, R.Y., Neal, C.A. and Okamura, A.T. (1987). Ch. 17 *in* U.S.G.S. Prof. Paper 1350. [2] Dvorak, J.J. and Okamura, A.T. (1985). J. Volcanol. geotherm Res. **25**, 249. [3] Dzurisin, D., Koyanagi, R.Y. and English, T.T. (1984). J. Volcanol. geotherm. Res. **21**, 177. [4] Delaney, P.T. and Pollard, D.D. (1982). Am. J. Sci. **282**, 856. [5] Pinkerton, H. & Wilson, L. (1988 - this volume).