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FRACTAL GEOMETRY OF SOME MARTIAN LAVA FLOW MARGINS: ALBA PATERA.

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Fractal dimension for a few lava flow margins on the gently sloping flanks of Alba Patera were measured using the structured walk method. Fractal behaviour was observed at scales ranging from 20 to 100 pixels. The upper limit of the linear part of log(margin length) vs. log(scale) profile correlated well to the margin length. The lower limit depended on resolution and flow properties.

Fractals are objects that look similar on all scales [1]. Many geological (as well as other natural) phenomena show fractal behaviour through a limited range of scales. Lava flow margin is one example of a fractal curve in nature. Recent work by Bruno et. al. [2] has confirmed that lava flow margins are fractals and the range of scales extend from tens of centimeters to a few kilometres for terrestrial flows and tens of kilometres for flows on other planetary bodies. They also found that lava flows on terrestrial planets can be roughly divided in two groups according to their fractal dimension indicating either pahoehoe or a'a type lava flows. Fractal dimensions were between 1.05 and 1.09 for a'a and between 1.13 and 1.23 for pahoehoe. This leads to an interesting question: what kind of constraints are needed to apply fractal behaviour on lava flows.

We calculated the fractal dimension for some lava flow margins at Alba Patera, Mars. Seven lava flow margins were drawn and measured on flanks of the volcano (fig. 1) using the structured walk method [3]and varying the scale, i.e. the yardstick length (r), from 1 to 100 pixels (appr. 100 m to 10 km). The lava flow margins were at least ten times longer than the largest scale. Two fractal dimensions were calculated by a linear regression procedure from log(margin length) vs. log(scale) plot, one for all data and another for the most linear part of the plot, which also gave the range, that is the upper and lower limit of scales where the most self-similar behaviour was observed.

A typical margin length curve (fig. 2) shows a rapid increase of length for small scale sizes, a slightly curved part of values which is gradually distorted and eventually scalloped as the scale length approaches the margin length. The lower limit of the linear part was determined by the beginning of upward curvature for small scales and the upper limit was put before the scalloped pattern in the length curve.

Results. 1.) A fractal behaviour of flow margins was observed at a range of scales. Lower limit was restricted by pixel size and precision of margin drawing. The upper limit correlated well to the margin length especially within flows of similar fractal dimension (fig. 3). In one occasion (A) the length curve showed two linear patterns with different slopes. This could be due to a change in the lava flow type caused by topography or change in the material properties. One lava flow (F) expressed no distinct linear part in the length curve causing difficulties in setting the lower limit for the linear part and decreasing the goodness of fit for the regression line.

2.) The lava flows were of type a'a except a short and wide one (B) clearly expressing pahoehoe behaviour (fig. 4). Fractal dimensions for of all data were considerably lower than those for the linear part of data (fig. 5), except for one curious lava flow margin (E) showing similar values for both all of the data and the linear part. This could indicate that the flow stopped on a slope or due to cessation of lava extrusion and only a few flow lobes formed.

3.) Narrow a'a type lava flows (A, E) seem to differ from the group of wide a'a flows and the pahoehoe flow in the previous fractal dimension comparison (fig. 5). This may indicate that a'a flow properties were quite similar when the flows stopped.

Discussion. The goodness of fit estimates (R^2) for the regression lines were of the order 0.75, which seems to be too low in a statistical sense. The larger scales were weighted because measurements were made linearly at two-pixel intervals.

References: [1] Mandelbrot B. B. (1977) Fractals. W.H. Freeman and Company. San Francisco. [2] Bruno B.C., Taylor G.J., Rowland S.K., Lucey P.G. and Self S. (1992) LPSC, XXIII, 171-172. [3] Longley P.A. and Batty M. (1989) Computers & Geosciences, 15, 167-183.

FRACTAL DIMENSION OF ALBA PATERA FLOWS: K. Kauhanen

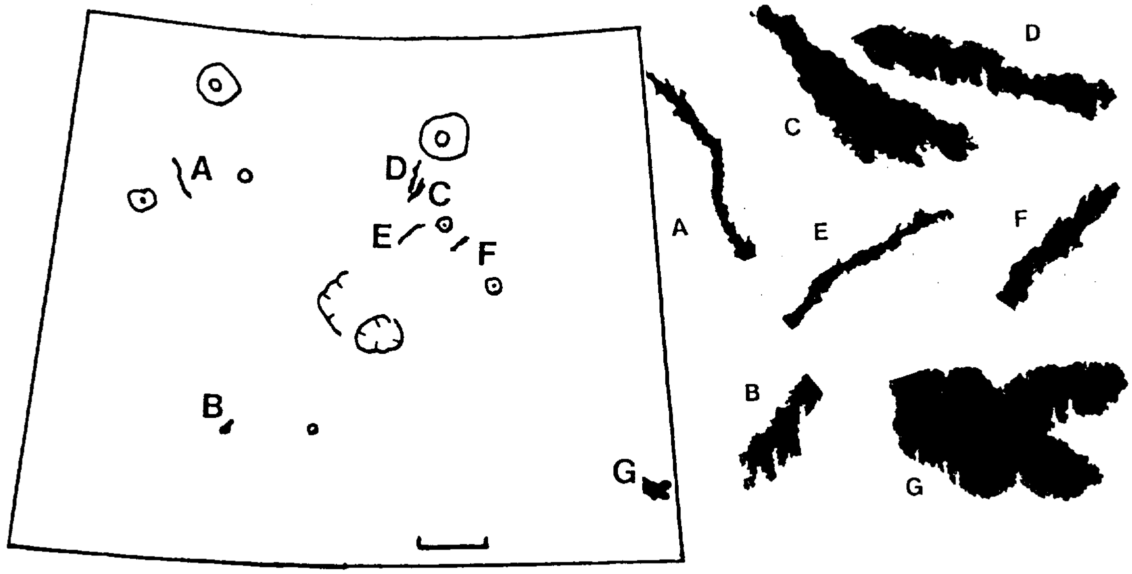

Figure 1. Location and outlines of the measured lava flows. Scale bar is 100 km.

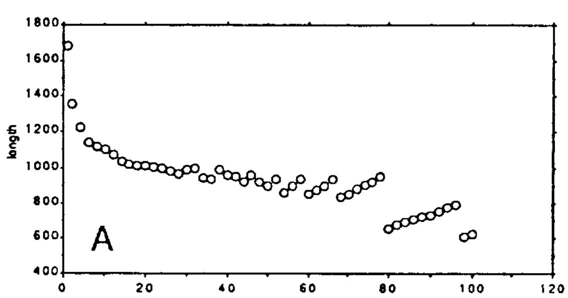

Figure 2. Lava flow margin lengths with increasing scale length.

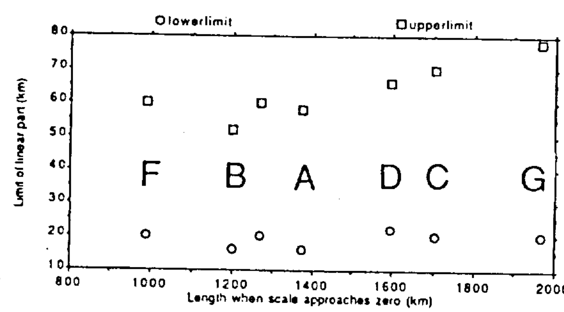

Figure 3. Upper and lower limits for the linear part of the margin length curve.

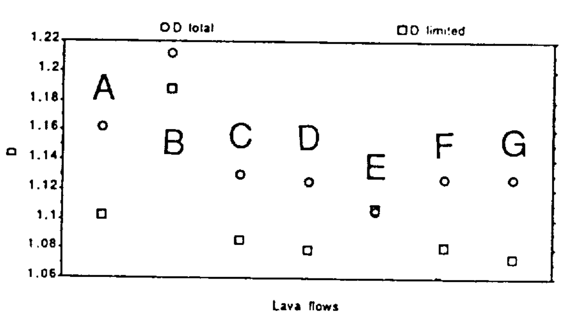

Figure 4. Fractal dimension for the flow margins. Square marks all data, sphere the linear part.

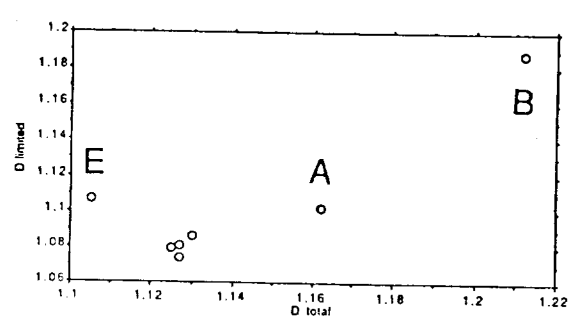

Figure 5. Fractal dimension comparison, the linear part vs. all data.