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Based on Pioneer Venus data, one might have expected the plains of Venus to be tectonically simple. The equatorial lowlands have little topography and are distant from previously identified major tectonic and volcanic structures. However, recent high resolution Magellan radar images have revealed complex systems of lineations which are developed over a wide range of scale-lengths. A physical interpretation of these features may lead to a better understanding of the rheological structure, tectonic forces, and deformation mechanics of Venus' lithosphere.

One of the most unusual terrains revealed in the first week of mapping consists of two nearly orthogonal sets of linear features at the northern edge of Guinevere Planitia, (30° N, 333.3° E) as imaged by the Magellan radar mapper during orbits 390 and 391 (JPL image P-36699) (see Solomon et al., [1]). One set trending roughly NE-SW are extremely straight and show a remarkably regular spacing of about 1 km. The orthogonal set which trend roughly NW-SE are much more irregular in both morphology and spacing.

The orthogonality of the two sets suggests that they may be tensile and compressive structures formed in a shear field, possibly in a relatively thin brittle layer which has been deformed by tractions on its base. This interpretation is supported by the morphological similarity between the extremely regular NE-SW set of lineations and the regularly spaced tensile fractures observed in the brittle surface coatings used by engineers to measure strain in metal parts. The more irregular set of NW-SE lineations are therefore interpreted as compressive structures (faults and/or folds). We have mapped this second set (Fig. 1) and have measured the lengths of the individual contiguous structures. The cumulative frequency is a power law function for lengths between about 4 and 20 km. (Fig. 2). The upper limit is imposed by the size of the image (37x80 km.). Power law distributions may be interpreted in terms of a fractal geometry, with this interpretation the slope in Fig. 2 gives a fractal dimension of $D_f = 1.67$.

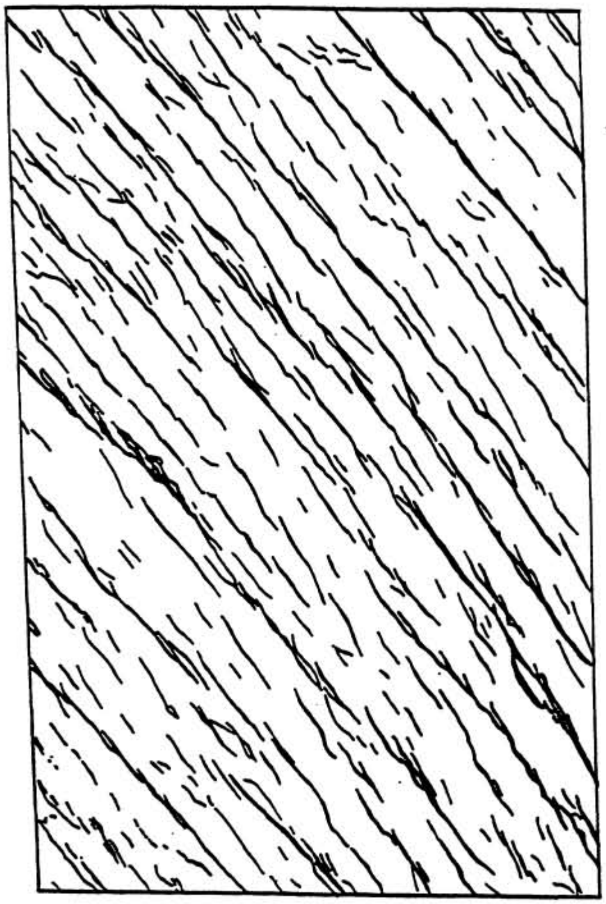

Fig.1. Map of NW-SE trending structures on Guinevere Planitia

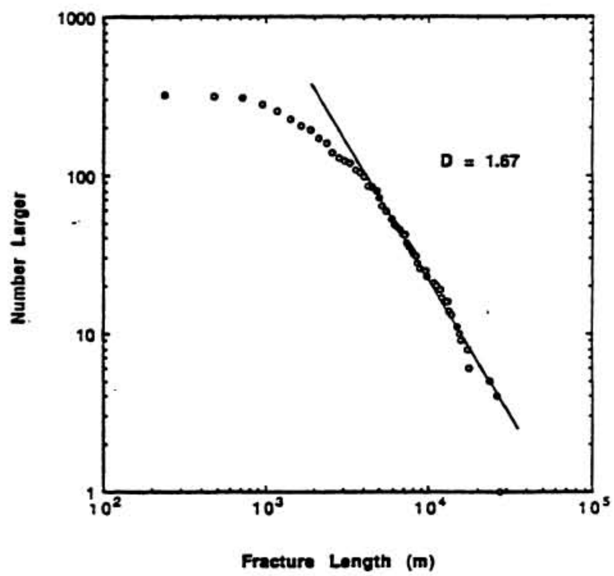

Fig. 2. Log of the number of structures larger than length L as a function of log L.

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This fractal dimension is similar to those observed for fractures and/or fragmentations in the Earth's crust. Sammis et al. [2] demonstrated that the cataclastic fragments in the size range 10 µm to 1 cm from the Lopez Canyon fault zone form a self-similar pattern with a fractal dimension of D_f=1.6 ± 0.1 in 2-D section. Blenkinsop and Sibson [3] obtained similar results over a more limited size range for fault strands intersected by a borehole near the San Andreas fault in southern California. Barton and Hsieh [4] and Barton [5] measured the fractal dimension of fracture patterns mapped on outcrops over scale ranges from centimeters to tens of meters. They mapped a total of 15 outcrops obtaining fractal dimensions ranging from 1.58 to 1.80 with a mean and standard deviation of 1.67 ± 0.07. Turcotte [6] collected fragmentation data from the literature for a wide variety of processes and found similar fractal dimensions for those processes which involved in situ crustal fracture.

Although the documentation of fractal fracture structures is interesting, the more significant question is: why are these fracture patterns fractal? What physical processes produce self-similar structures and what is the physical significance of the fractal dimension and the upper and lower fractal limits? Answers to these questions should give some insight into the mechanics and structure of the lithosphere of Venus.

Two mechanisms have been suggested for the formation of a fractal fracture pattern. The first was proposed by Sammis et al. [2] to explain the fractal fragmentation observed in fault zones. It is based on the selective elimination of same-sized neighbors at all scales which leads to a fractal dimension of D_f = 1.58. However, because it is based on the compressive loading of a well developed granulation, it may not be applicable to the pattern of fractures on Venus.

A second mechanism which may explain the fractal patterns on Venus was summarized by Bak and Chen [7] in their one sentence abstract: "Fractals in nature originate from self-organized critical dynamical processes." This idea was used by Sornette et al. [8] to explain the pattern of shear fractures produced by Davy et al. [9] in a layer of cohesionless sand floating on a viscous substratum of silicone putty. In their experiment, the India-Asia continental collision was simulated by the slow advance of a rectangular indenter from the south and a free boundary to the east. The pattern of conjugate shear fractures which formed to the northeast of the indenter was found to be fractal with D_f=1.7 ± 0.05, independent of the viscosity of the substrate. Sornette et al. [8] propose that these fractal patterns are the result of random growth in a critical system which is controlled by long-range screening and enhancement interactions between the growing fractures. The idea is that the development of a fracture pattern is a Laplacian growth phenomenon in the same general class as diffusion limited aggregation (DLA) and dielectric breakdown (see Stanley and Ostrowsky, [10]). In this view, entire domains of the brittle surface are loaded to a critical state in which all points are at the point of failure. The resultant fracture pattern is controlled by interactions between growing fractures and is independent of the initial heterogeneity. The observations by both Sornette et al. [8] and Barton [5] of D_f near 1.7 which is predicted by simple DLA models supports this hypothesis.

The observation of self-similarity in the fracture pattern on Venus has several implications. First, it implies a very uniform brittle surface layer such that criticality can be established over a wide area. Second, the lower fractal limit at about 4 km gives a measure of the thickness of this brittle layer. Finally, the overall pattern is consistent with a uniform shear of the more ductile substrate. In this sense the tectonics of Earth and Venus are quite different. While the Earth is characterized by boundary layer convection in which the rigid lithosphere exerts a significant control on mantle flow, the lithosphere of Venus is so thin that it fractures in response to, but may not affect, internal flow patterns.

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