temperature is quite significant compared with the effects of gaseous SO_2 and liquid H_2SO_4. Thus, we can state that the variations observed by de Pater et al. [1] are most likely due to the variations in the abundance of gaseous H_2SO_4 and not to liquid H_2SO_4 or gaseous sulfuric dioxide as previously suggested.

A plot of the calculated millimeter-wave spectrum of Venus based on the presence of one or more constituents is shown in Fig. 5. The results reported in this figure show the effect that H_2SO_4 (g) has on the MMW spectrum of Venus. In addition, the results show that there are specific millimeter-wave frequencies that are especially sensitive to the abundance of H_2SO_4 vapor in the lower atmosphere of Venus.

References: [1] de Pater I. et al. (1991) *Icarus, 90,* 282–298. [2] Fahd A. K. and Steffes P. G. (1992) *Icarus,* in press. [3] Fahd A. K. and Steffes P. G. (1991) *JGR, 96,* 17471–17476. [4] Steffes P. G. (1985) *Icarus, 64,* 576–585.

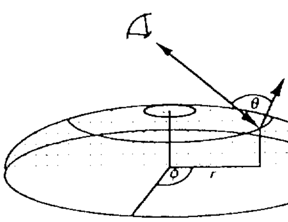
N93-14316

RADAR SCATTERING PROPERTIES OF PANCAKELIKE DOMES ON VENUS.

P. G. Ford and G. H. Pettengill, Center for Space Research, Massachusetts Institute of Technology, Cambridge MA 02139, USA.

Magellan radar images have disclosed the presence of a large number of almost perfectly circular domes, presumably of volcanic origin, in many regions of Venus [1], several with diameters of 30 km or more. Their high degree of symmetry has permitted measurements of their shape, as determined by the Magellan altimeter [2], to be compared with models of dome production from the eruption of high-viscosity magmas [3].

In this work, we examine in detail the radar images of domes in Rusalka Planitia (2.8°S, 150.9°E) and Tinatin Planitia (12.2°N, 7.5°E), selected for their circular symmetry and apparent absence of modification due to large-scale slumping or tectonic rifting. Assuming that these domes are shaped according to the model of reference [3], we can orthorectify the available Magellan SAR image swaths (F-BIDRs: Full-Resolution Basic Image Data Records) to generate three-dimensional plots of the radar scattering cross-section σ_0 (r, θ, ϕ) as a function of distance from center of dome (r), scattering angle (θ), and azimuthal coordinate (ϕ).



The behavior of σ_0 with respect to changes in θ has been determined from Pioneer Venus radar data for many broad classes of Venus surface type [4], and parameterized as a combination of a quasispecular scattering component σ_{qs} and a diffuse component σ_d:

$$\sigma_0(\theta) = \sigma_{qs}(\theta) + \sigma_d(\theta) =$$

$$\frac{\alpha C\rho}{2}(\cos^4\theta + C\sin^2\theta)^{-3/2} + (1-\alpha)\rho K\theta^{\nu}$$

where α represents the fraction of the surface that contributes to quasispecular scattering, C is the Hagfors parameter [5], ρ is the Fresnel reflection coefficient, and K and ν are functions of small-scale surface roughness. Average values of C, ρ, and α over an entire dome are extracted from altimeter measurements.

Variations of σ_0 with respect to radial distance r are interpreted as changes in the small-scale roughness of the dome, which would be expected from the radial dependence of the cooling rate of the lava, perhaps enhanced by subsequent weathering. The result of aeolian processes may also be seen in the dependence of σ_0 on azimuth angle ϕ, since fine-grained surface material that contributes to σ_d may be emplaced or rearranged by the prevailing surface winds.

References: [1] Head J. W. et al. (1991) *Science, 252,* 276–288. [2] Ford P. G. and Pettengill G. H. (1992) *JGR,* in press. [3] McKenzie D. et al. (1992) *JGR,* in press. [4] Ford P. G. and Senske D. A. (1990) *GRL, 17,* 1361. [5] Hagfors T. (1970) *Radio Sci., 5,* 189.

N93-14317

SEQUENTIAL DEFORMATION OF PLAINS ALONG TESSERA BOUNDARIES ON VENUS: EVIDENCE FROM ALPHA REGIO.

M. S. Gilmore and J. W. Head, Department of Geological Sciences, Brown University, Providence RI 02912, USA.

Tesserae are regions of elevated terrain characterized by two or more sets of ridges and grooves that intersect orthogonally [1]. Tesserae comprise 15–20% of the surface of Venus, but the nature of their formation and evolution is not well understood; processes proposed to account for their characteristics are many and varied [2]. Two types of tessera boundaries have been described: Type I are generally embayed by plains; type II boundaries are characterized by being linear at the 100-km scale and often associated with steep scarps or tectonic features [2,3]. Margins such as the western edge of Alpha have been described by these authors as type II. Some of the tessera have boundaries that display deformation of both the edge of the tessera and the adjoining plains [2,3]. This study focuses on the western edge of Alpha Regio in an effort to characterize one occurrence of this type of boundary and assess the implications for the style in general. Using Magellan SAR imagery, lineament lengths, orientations, and spacings were measured for ten 50 × 60-km areas spanning 500 km of the western boundary. Structural characteristics and orientations were compared to stratigraphic units in order to assess the sequence and style of deformation.

Alpha Regio is a 1300 × 1500-km prominent radar-bright upland feature in the southern hemisphere of Venus that averages 1 km above the surrounding plains [4]. Ridges and troughs within Alpha average 33 km long 20 km apart in the north and 35 km long 17 km apart in the south; their prominent orientation is N20°E [4]. The ridges and troughs on the western edge of Alpha have an orientation of N15°E, but differ from the interior ridges as their average spacing is 4 km (Fig. 1). These lineaments are joined by a second set of lineaments and graben trending N55°W and extending into the plains. The deformation producing these northwest-trending lineaments has occurred over a period of time separated by several stages of plains emplacement. Two plains units have embayed the western edge of Alpha: a radar-dark plains unit (Pl_1) that embays the edge of the heavily deformed tesserae, and a radar-bright unit to the west that embays the radar-dark unit (Fig. 2). The plains unit closest to the tessera (Pl_1) has fewer lineaments than the tessera, but a greater number of lineaments (spaced at an average of 3 km apart) than the younger plains unit (Pl_2), which embays and covers unit Pl_1. The

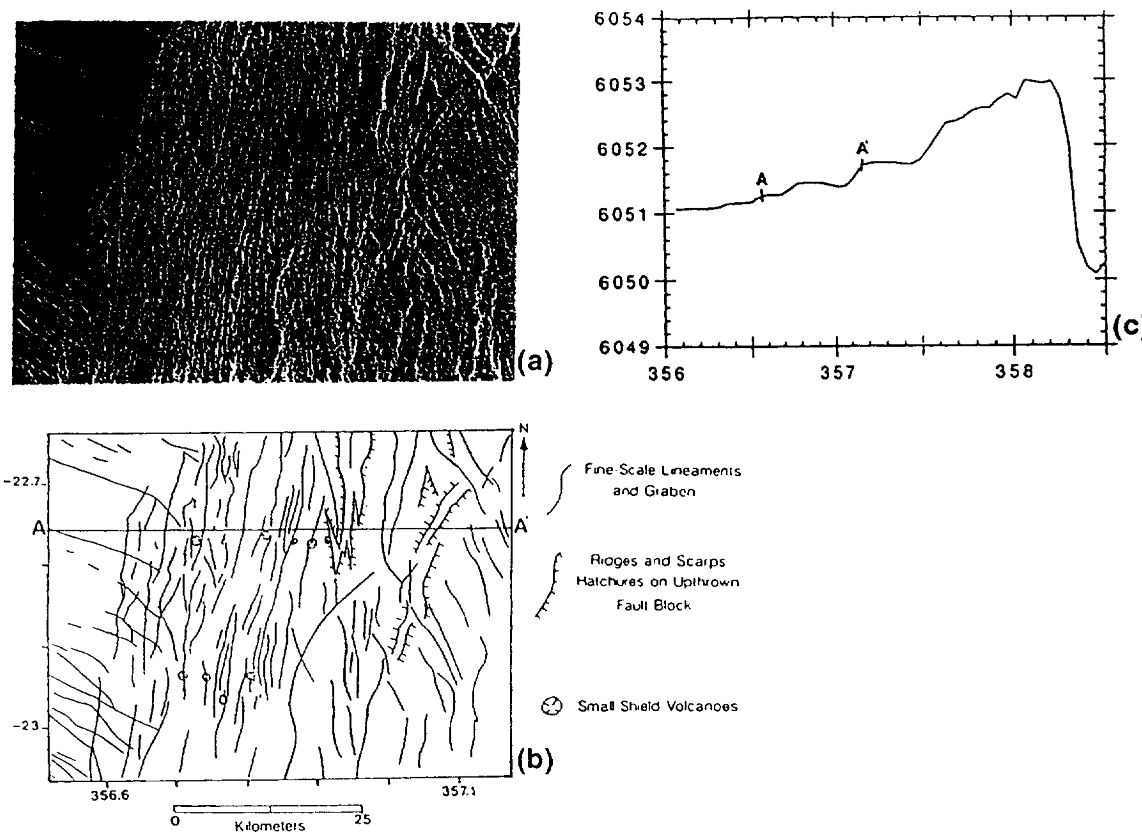


Fig. 1. (a) SAR image of portion of western Alpha Regio including plains, fine-scale lineaments, and ridges and troughs typical of Alpha tessera. The fabric of the fine-scale lineaments clearly differs from the more typical tessera fabric. (b) Sketch map of (a) emphasizing lineaments and volcanic features. Two sets of lineaments are seen here that increase in number from the plains into the fine-scale ridges. The northwest-trending lineaments and shields are confined to the fine-scale fabric. (c) Topographic profile of A-A' in (b).

northern part of Fig. 2 displays some lava flows from Pl_2 that were too thin to cover the northwest lineaments. The boundary between the plains units is also marked by a change in slope from 2° in the younger unit to 6°; the slope may then increase to as much as 25° at the plains-tessera border. This is interpreted to mean that the dark plains were emplaced along the margin of the tessera, tilted up, and deformed, followed by the emplacement of the bright plains, which also have been tilted upward and deformed. Deformation features are grabenlike and interpreted to be extensional in origin. The deformation of the plains follows one of the major trends in the tessera interior [4,5].

There is a range of interactions between the northeast- and northwest-trending lineaments; fine-scale ridges and troughs are common within western Alpha while large graben up to 6 km in width occur less frequently. In addition, the tessera along Western Alpha contains numerous domes, pits, and small shield volcanos that both predate (Fig. 1) and postdate the intense tessera deformation. These small shields are very similar to the array of shield volcanos that have been mapped on the Venus plains [6], and we interpret this to mean that these tessera regions are formed from adjacent volcanic plains. In addition, blocks (<100 km in length) of crust that have radar characteristics that make them indistinguishable from undeformed plains are observed in the tessera along the western margin. Each of these characteristics, in addition to the distinct difference in ridge spacing in western Alpha, suggests that western Alpha Regio may consist of plains that are sequentially deformed, tilted, and uplifted, ultimately being incorporated into the tessera. In addition, it has been proposed that fine-scale ridges like those of Western Alpha are produced by layering thought to exist within the plains [5].

We have considered two models to explain the characteristics of the edge of Western Alpha. The first is mantle downwelling and underthrusting of plains units due to compression at the edge of the tessera block [5,7]. Shortening and isostatic adjustments due to crustal thickening would cause uplift in Alpha and consequently cause deformation and uplift along the margins of Alpha. The second model is one of gravitational relaxation of the Alpha tessera block. Gravitational relaxation of a plateau is expected to produce extensional features within the interior of the crustal block that change to compressional features at the margins of the block [8,5,3]. This is consistent with the presence of relatively young and undeformed intertessera plains in Alpha and the fine-scale compressional features on its western margin. We favor the gravitational relaxation model for these reasons and because it is an ongoing process favored under Venus conditions of high temperatures and low erosion rates [9,10]. This model fails to explain, however, why the deformation seen on the western edge of Alpha does not extend over the entire margin of the tessera block.

In summary, the western border of Alpha Regio has two sets of lineaments that extend into the surrounding plains. This deformation has occurred over a time period marked by at least two sets of plains emplacement. Western Alpha also contains small shield

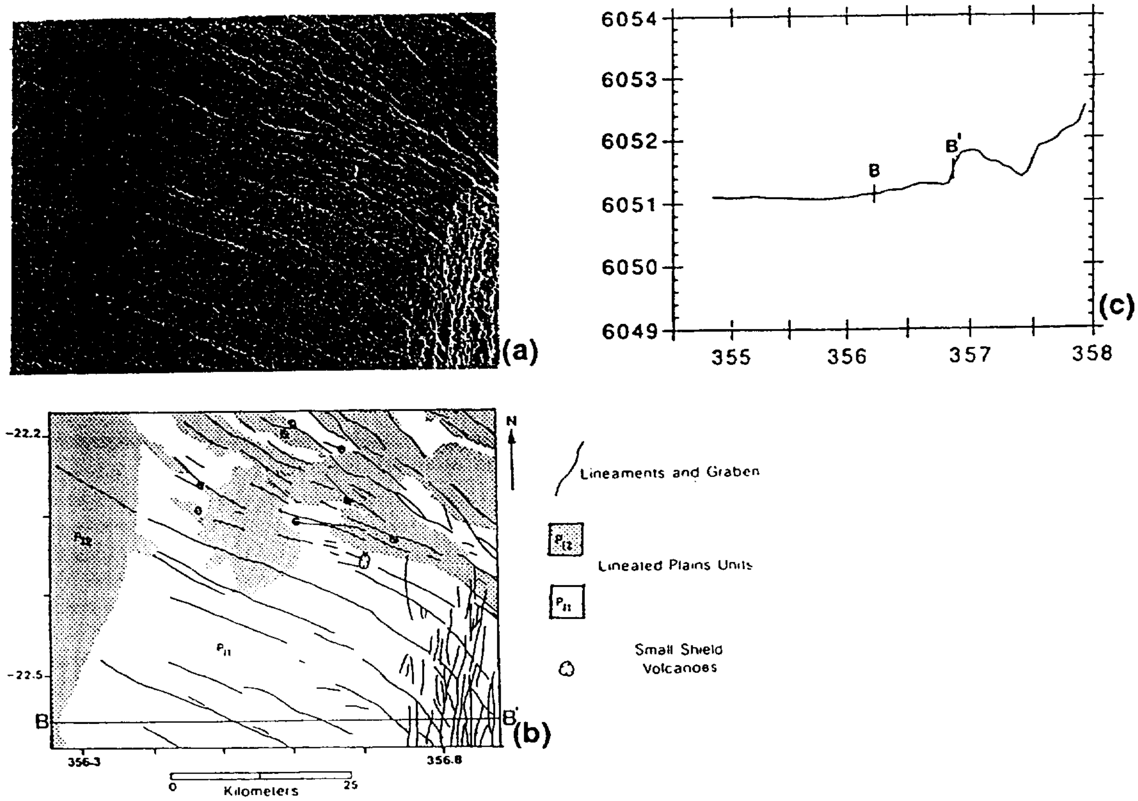


Fig. 2. (a) SAR image of a portion of western Alpha Regio including two units of plains and fine-scale lineaments. (b) Sketch map of (a) emphasizing the northwest-trending lineaments and graben and volcanos. In general, these lineaments are more abundant and have a closer spacing in the older unit Pl_1 than in the younger Pl_2. The younger unit has embayed the older, covering most lineaments. Continued deformation has caused fracturing to extend through both units. (c) Topographic profile of B-B' in (b).

volcanos and blocks of undeformed plainslike crust. Each of these features suggests that Alpha is deforming, uplifting, and possibly incorporating plains lavas onto its western edge. Gravitational relaxation of Alpha tessera may be the mechanism producing this deformation and may contribute to the features found at other type II boundaries on Venus. The total length of type II (deformational) boundaries on Venus is less than type I (embayed by plains lavas) boundaries, but type II boundaries occur at some point along many tessera blocks of all sizes [3]. We are continuing our investigation of this and other similar boundaries.

References: [1] Basilevsky A. T. et al. (1986) *Proc. LPSC 16th*, in *JGR, 91*, D399. [2] Bindschadler D. L. and Head J. W. (1991) *JGR, 96*, 5889. [3] Ivanov M. A. et al. (1992) *LPSC XXIII*, 581. [4] Senske D. et al. (1991) *Earth Moon Planets, 55*, 97. [5] Bindschadler D. L. et al. (1992) *JGR*, submitted. [6] Aubele J. et al. (1992) *LPSC XXIII*, 47. [7] Bird P. (1979) *JGR, 84*, 7561–7571. [8] Bindschadler D. L. and Parmentier E. M. (1990) *JGR, 95*, 21329. [9] Weertman J. (1979) *PEPI, 19*, 197. [10] Smrekar S. E. and Solomon S. C. (1992) *JGR*, in press.

N93-14318

VENUSIAN HYDROLOGY: STEADY STATE RECONSIDERED. David H. Grinspoon, Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder CO 80309, USA.

In 1987 Grinspoon proposed that the data on hydrogen abundance, isotopic composition, and escape rate were consistent with the hypothesis that water on Venus might be in steady state rather than monotonic decline since the dawn of time [1,2,3]. This conclusion was partially based on a derived water lifetime against nonthermal escape of approximately 10^8 yr. De Bergh et al. [4], preferring the earlier Pioneer Venus value of 200 ppm water to the significantly lower value detected by Bezard et al. [5], found H_2O lifetimes of $>10^9$ yr. Donahue and Hodges [6] derived H_2O lifetimes of $0.4–5 \times 10^9$ yr. Both these analyses used estimates of H escape flux between 0.4×10^7 and 1×10^7 cm^{-2} s^{-1} from Rodriguez et al. [7]. Yet in more recent Monte Carlo modeling Hodges and Tinsley [8] found an escape flux due to charge exchange with hot H^+ of 2.8×10^7 cm^{-2} s^{-1}. McElroy et al. [9] estimated an escape flux of 8×10^6 cm^{-2} s^{-1} from collisions with hot O produced by dissociative recombination of O_2^+. Brace et al. [10] estimated an escape flux of 5×10^6 cm^{-2} s^{-1} from ion escape from the ionotail of Venus. The combined estimated escape flux from all these processes is approximately 4×10^7 cm^{-2} s^{-1}. The most sophisticated analysis to date of near-IR radiation from Venus' nightside reveals a water mixing ratio of approximately 30 ppm [11], suggesting a lifetime against escape for water of less than 10^8 yr. Large uncertainties remain in these quantities, yet the data point toward a steady state. Further evaluation of these uncertainties, and new evolutionary modeling incorporating estimates of the outgassing rate from post-Magellan estimates of the volcanic resurfacing rate, will be presented.

If Comet Halley has a mass of 10^{18} g and is approximately 50% water ice, then impact of such an object provides roughly 10% the current atmospheric water inventory on Venus. The terminal Creta-