become close-packed. The maximum vesicle content that a lava can sustain without disruption is 75% vesicles; this represents the maximum viscosity increase achievable with this mechanism.

Model Comparisons: One difficulty with the chemical differentiation model involves trying to concentrate large volumes of silicic melt so that the eruption can occur as a single, steady effusion of lava before the magma freezes or is trapped in the crystal mush. It is uncertain whether the low melt fractions will be able to move through the crust to collect in a reservoir. Work by Wickham indicates a threshold of >30% melt for the efficient escape of silica-rich magmas from a crystal mush [12]. If this mechanism is active in forming dome lavas, then this is probably an indication that the dome lavas are of an intermediate composition.

The crustal remelting model has its difficulties, as well. First, the strong correlation of gravity with topography at the scale investigated by Pioneer Venus [13] argues against deep isostatic compensation for many features on the planet. If this is true for tessera blocks, then eclogite would not be expected at the depths necessary for the formation of high silica melts. It is possible that subduction could transport basaltic or eclogite crust to the depths necessary for garnet to be present in the residue [14,15], but it is difficult to invoke this mechanism to explain the global dome distribution. However, if amphibolite is present as the low-silica melt residue, deep crustal melting is not necessary to generate high-silica melts. An additional problem with this model is its inability to explain the presence of domes on the periphery of the tessera, but not in the tessera itself. It seems most likely that the domes would be emplaced directly above the melting region, not hundreds of kilometers laterally displaced from it. It is necessary to develop a mechanism that will transport high-viscosity, silicic magma to the plains surrounding tessera, while simultaneously discouraging the eruption of this same magma in the tessera. An alternative explanation might be that domes are formed in the tessera, but that subsequent tectonic strain has destroyed them, and the domes on the plains survive because they are emplaced in a less tectonically active environment.

The volatile enhancement mechanism will need to be examined more closely to resolve some of the difficulties inherent in the model. First, the exsolution of volatiles should increase pressure in the chamber and prevent further exsolution unless the excess pressure is released. At present, it is difficult to envision a mechanism that allows the concentration of the volatiles into a "foam layer" at the top of the chamber without allowing the volatiles to escape before eruption. Perhaps an uneven chamber roof could trap pockets of volatile-rich foam that are not drawn off by earlier eruptions that release pressure from the chamber. An additional problem is the altitude distribution of the domes. Modeling by Head and Wilson indicates that the necessary shallow magma chambers in which this volatile exsolution could occur are not likely to form at altitudes at or below the mean planetary radius [16].

We have also examined the case of partial melts from the mantle. If the mantle of Venus is similar to Earth's (of a peridotitic composition), it is impossible to generate a silica-rich melt from the direct partial melting of the mantle without some secondary differentiation process occurring. If a buoyant, depleted mantle layer forms under the crust, it will be even more refractory than pristine mantle and will tend to trap rising plumes. This will encourage melting of plumes at the base of the depleted layer, resulting in the production of MgO-rich low-viscosity melts [17].

Conclusions: We have shown that there are at least three plausible models for the petrogenesis of high effective viscosity magmas on Venus, and we have suggested geologic environments in which these different mechanisms might be active. Chemical differentiation and crustal remelting are common mechanisms for generating silicic, high-viscosity magmas on the Earth, and are consistent with dome associations with coronae and tessera respectively. In both cases, further research will be necessary to understand how the magma is able to escape the crystal mush and migrate to the surface. The crustal remelting model has the additional difficulty of the lack of domes in tessera, above the supposed melting region. The volatile exsolution model will require future research in order to determine if a layer enhanced in volatiles can form at the top of a magma reservoir, and if the shallow reservoirs necessary for volatile exsolution can form at the low altitudes at which the domes are found. Further research will focus on refining the models, examining their implications for crustal evolution, and developing tests to determine which are active in different environments on Venus.

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N93-14360

DIELECTRIC SURFACE PROPERTIES OF VENUS. G. H. Pettengill, R. J. Wilt, and P. G. Ford, Center for Space Research, Massachusetts Institute of Technology, Cambridge MA 02139, USA.

It has been known for over a decade [1] that certain high-altitude regions on Venus exhibit bizarre radar-scattering and radiothermal-emission behavior. For example, observed values for normal-incidence power reflection coefficients in these areas can exceed 0.5; enhanced backscatter in some mountainous areas in the Magellan SAR images creates a bright surface with the appearance of snow; and reduced thermal emission in the anomalous areas makes the surface there appear hundreds of degrees cooler than the corresponding physical surface temperatures. The inferred radio emmissivity in several of these regions falls to 0.3 for horizontal linear polarization at viewing angles in the range 20°–40°.

Several explanations have been offered for these linked phenomena:

1. Single-surface reflection from a sharp discontinuity separating two media that have extremely disparate values of electromagnetic propagation. The mismatch may occur in either or both the real (associated with propagation velocity) or imaginary (associated with absorption) components of the relevant indices of refraction, and the discontinuity must take place over a distance appreciably shorter than a wavelength. An example of such an interaction on Earth would occur at the surface of a body of water. At radio wavelengths, water has an index of refraction of 9 (dielectric permittivity of about 80), and an associated loss factor that varies

strongly with the amount of dissolved salts, but is generally significant. Its single-surface radar reflectivity at normal incidence is about 0.65, and the corresponding emissivity (viewed at the same angle) is therefore 0.35. Both these values are similar to the extremes found on Venus, but in the absence of liquid water, the process on Venus requires a different explanation. Two of the present authors (Pettengill and Ford [1]) have suggested that scattering from a single surface possessing a very high effective dielectric permittivity could explain many of the unusual characteristics displayed by the Venus surface.

2. Volume scattering that results from successive interactions with one or more interfaces interior to the planetary surface. If the near-surface material has a moderately low index of refraction (to ensure that a substantial fraction of the radiation incident from outside is not reflected, but rather penetrates into the surface), and a very low internal propagation loss, successive internal reflections can eventually redirect much of the energy back through the surface toward the viewer. The necessary conditions for this process to be effective are a low internal propagation loss coupled with efficient internal reflection. At sufficiently low temperatures, fractured water ice displays both the necessary low loss and near-total internal reflection. Scattering of this type has been seen from the three icy Galilean satellites of Jupiter, Saturn's rings, and the polar caps of Mars (and probably Mercury). The possibility that this mechanism might also be acting on Venus (but not, of course, involving ice) has recently been put forward [2].

How can one distinguish between these processes? Scattering from a single interface is usually modeled as a combination of quasispecular reflection, involving coherent processes [3] that may be described by the usual Fresnel equations, and a diffusely scattering component arising from rough surface structure of the order of a wavelength in size [4]. The combination of undulating surface and small-scale roughness allows this model to be adjusted to fit almost any observed variation in backscatter with the angle of incidence. What it cannot do is produce strong depolarization in the scattered power, since only the component of small-scale roughness can contribute to depolarization and that is a relatively inefficient process, typically yielding only about 30% of the total diffuse scattering as depolarized energy.

Volume scattering, on the other hand, does not favor backscattering near normal incidence, as quasispecular scattering generally does, but tends to backscatter efficiently without much variation over a wide range of angles of incidence [5, 6]. Moreover, volume scattering is a very efficient depolarizer, often returning a virtually unpolarized echo to the observer, it can even produce an inverted circular polarization ratio, i.e., favoring an echo having the same circular sense as the incident wave [6].

From the above considerations, it would seem that the two processes are distinguished most easily by their quite different effects on the polarization states of the scattered or thermally emitted radiation. Such observations have been attempted using ground-based radars, but have so far yielded only limited results. Unfortunately, the Magellan radar and radiometer instrument emits and receives only the same single linear polarization.

Radar scattering by the first process above, should yield only a modest amount of backscattered energy in the depolarized (often called the "unexpected") mode. For linear transmitted polarization, the depolarized mode is the orthogonally polarized linear state; for circular transmitted energy, it is the same sense, since coherent reflection reverses the circular sense while preserving the linear position angle. Preliminary analysis from observations made using the Arecibo 12.6-cm radar system [7] suggest that depolarization is virtually complete for circularly polarized radar echoes received from Maxwell Montes. Thus this evidence favors the internal volume scattering hypothesis. On the other hand, comparison of vertically and horizontally polarized emission data from low-emissivity areas in Beta Regio, which were obtained during a special test carried out by the Magellan spacecraft, show a substantially larger linearly polarized emission component in the vertical than in the horizontal, a result that can only result from the first process. Surprisingly, then, it seems that we may need to invoke a third process not yet conceived to explain the high backscatter and low emissivity observed in selected high-altitude regions on Venus

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N93-14361

TECTONIC CONNECTIONS TO INTERIOR PROCESSES ON VENUS.

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Introduction: The ultimate goal of geophysical/geological exploration of Venus is to relate the present tectonic (and volcanic) state of the lithosphere to interior processes, particularly mantle convection, operating both now and in the past. The Magellan mission has provided a spectacular view of the surface, and upcoming gravity measurements, particularly if the Magellan orbit is circularized, will provide significant constraints on the state of the interior. This abstract focuses on several controversial issues regarding venusian tectonics and its relationship to geodynamic mechanisms in the planet's interior.

Highlands: A major debate within the Venus science community concerns the origin of certain highland features on Venus [1,2,3]. While there is general agreement that the origins of highland regions on Venus must be linked directly to mantle convection, there is a strong dichotomy of opinions on the relative roles of mantle upwelling (hotspots) and downwelling (coldspots) [4]. In particular, do such areas as Ovda and Thetis Regiones and Lakshmi Planum, characterized as "crustal plateaus" [1], sit over upwellings or downwellings? One of the main objections to the hotspot model is that in its evolutionary cycle it must be capable of developing significant strain—as observed in crustal plateaus—and this has not been demonstrated. The chief criticism [3] of the coldspot model is that significant secondary crustal flow is required to turn a region over a convective downwelling into positive topographic relief of the magnitude observed. This issue has become more severe recently: It is now understood that experimental viscous flow laws heretofore used for the venusian crust are, because of the presence of hydrous phases, probably significantly weaker than the real planet [5]. Thus characteristic times to develop positive topography over downwellings may be unreasonable geologically—in excess of a few billion years. The coldspot model has been attractive because it was able to provide both high-standing topography and significant compressional strain, although convection must be particularly vigorous to explain Ishtar Terra. If secondary crustal flow is not an important process on Venus, then it is reasonable to investigate other models to understand their plausibility in meeting these