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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TECTONIC CONNECTIONS TO INTERIOR PROCESSES ON VENUS. R. J. Phillips, McDonnell Center for the Space Sciences and Department of Earth and Planetary Sciences, Washington University, St. Louis MO 63130, USA.

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 constraints. In the coldspot model, high-standing topography could also be created by convective shear tractions on the base of the lithosphere, leading to imbrication—the stacking of lithospheric thrust sheets. This process requires that new lithospheric surface area be created somewhere on Venus (e.g., lithospheric spreading); so far, this has not been observed. Addition of mass is usually required for compressional strain, and the hotspot model is actually attractive because new mass is provided vertically from the mantle by partial melting, and it is not necessary to obtain it horizontally from the lithosphere. Major strain associated with crustal plateaus might arise from crustal thickness instabilities [6,7] and from detachment [8] arising from eclogite formation in plateau roots.

Coronae: Coronae are large circular surface structures, which are observed in Magellan images to range up to 2600 km in diameter [9]; they are associated with both volcanism and tectonism. While it is generally agreed that coronae form in response to buoyantly rising material [9,10], there is no convergence of opinion on the nature of the diaper. Three endmember models are (1) thermal plumes from the mantle (which may then undergo pressure release partial melting), (2) compositional plumes that arise perhaps from melting induced by broader-scale thermal plumes, and (3) instabilities arising in regions that are partially molten or at the solidus [11,12]. In the last mechanism, the instability is triggered by an upward velocity perturbation, and on Venus such perturbations could arise from extensional strain events in the lithosphere associated with both upwelling and downwelling mantle flow. The coincidence of coronae with extensional features [9] provides evidence for this process.

Trenches and Subduction: On the basis of Venera 15–16 data, it has been proposed [13] that lithospheric convergence and underthrusting has occurred on the northern boundary of Ishtar Terra. The steep front and trench on the western side of Maxwell Montes also supports this idea. More recently, it has been suggested that trenches associated with the boundaries of certain large coronae mark the sites of "rollback" or retrograde subduction [14; see also 15]. In this hypothesis, the lithosphere associated with a corona extends outward and material is replaced by upward mantle flow (in analogy to terrestrial back-arc spreading). The expanding corona "consumes" lithosphere on its boundary (i.e., the surrounding lithosphere is subducted beneath the corona). The hypothesis for retrograde subduction is based on topographic and flexural analogy to terrestrial subduction trenches [14,15,16]. While evidence for outward migration of coronae is seen in the radar images, continuity of structures across proposed plate boundaries (i.e., trenches) argues against the subduction hypothesis [17].

Lithospheric subduction on Venus would require an active driving mechanism. No indication of spreading ridges is observed in the Magellan data, so "ridge push" can probably be discounted. Direct convective coupling from the underlying mantle may provide sufficient force, however [1]. The proposed retrograde subduction requires the lithosphere to be negatively buoyant. This may only be possible if garnet granulite or eclogite can form in the lower crust. The notion that the temperature gradient on Venus may be as low as 10°/km (or less) in places [16] has implications for a relatively thick crust [18,19,20] and for the existence of such high-density phases encountered at depth in the lower crust before solidus temperatures are reached. However, the proposal that coronae mark the sites of mantle upwelling argues against such a low temperature gradient.

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"PROBLEM" FOOTPRINTS IN MAGELLAN ALTIMETRY DATA. Jeffrey J. Plaut, Jet Propulsion Laboratory, MS 230–225, 4800 Oak Grove Drive, Pasadena CA 91109, USA.

Introduction: The intensity, time-delay, and frequency content of radar echoes from the Magellan altimetry system are reduced to several parameters that are of great use in addressing many geological issues of the surface of Venus. These parameters include planetary radius, power reflection coefficient (reflectivity, both uncorrected and corrected for diffuse scattering), rms slope, and scattering functions (the behavior of backscatter as a function of incidence angle) [1,2]. Because the surface of Venus often reflects radio energy in unpredictable ways, models of radar scattering and their associated algorithms occasionally fail to accurately solve for the above surface parameters. This paper presents methods for identifying possible "problem" altimetry data footprints, and techniques for resolving some key ambiguities.

Data Acquisition and Reduction: For each footprint, Magellan's nadir-pointing altimeter transmits 1.1-μs bursts containing 17 pulses coded with a "chip" duration of 0.442 μs. These constraints, combined with the delay response and the highly elliptical orbit, yield an effective along-track resolution of 8 to 20 km, and a cross-track resolution of 13 to 31 km [1]. The finest resolution is obtained near the periapsis latitude of 10°N, and the coarsest resolution is obtained at high latitudes. Processing in the frequency domain ensures that the along-track footprint dimension accurately reflects the sources of echo power. In the cross-track dimension, however, strong reflections from outside the footprint can contribute to the echo, leading to ambiguities in reduction to surface parameters [P. Ford, personal communication].

The primary standard data product generated from altimetry data is the Altimetry and Radiometry Composite Data Record (ARCDR) [3]. For each Magellan orbit, a separate file is produced for altimetry and radiometry data. For each footprint within the altimetry files, echo profiles, in range-sharpened and range-unsharpened formats, are included, along with the derived parameters such as radius, rms slope, and reflectivity, and best-fitting model echo "templates" from which the surface parameters are estimated. The radius estimate is from the template fit to the range-sharpened profile, while the rms slope and reflectivity estimates are from the template fit to the range-unsharpened profile. Examination of the echo profiles, and comparison to the templates selected to match the