Venus [4]. The convecting mantle that is tightly coupled to the high-temperature weak lithosphere through the high-viscosity upper mantle [2] may strongly deform the lithosphere, producing a mobile and semifree boundary layer on top of the convecting mantle.

The thermal convection models of a mantle that convects under a stress-free surface boundary condition [5] and is mostly heated from within, as favored for Venus by many investigators [e.g., 3,4,6], develop a strong thermal boundary layer at the surface but a weaker one at the base [7]. Strong instabilities in the near-surface boundary layer result in downwelling of cold plumes, whereas the upwelling zones are relatively diffused [8]. Such a mantle convection may not create sharp oceanic-type ridge systems, but it may result in distinct compressional features at the surface associated with the downwellings. The lack of distinct ridge systems on Venus, and the almost axisymmetric geometry of Lakshmi Planum and surrounding mountains that are interpreted as thickened crust over downwelling mantle convection [6], are in good agreement with the surface expressions of a convecting mantle that is mainly heated from within.

Another major characteristic of the mantle convection models is their time dependence. A time-dependent oscillatory convection at high Rayleigh numbers reduces to a steady-state slow convection as the Rayleigh number is decreased below a critical value. In Venus' mantle the local Rayleigh number probably decreases with depth due to decrease in the thermal expansion coefficient with depth [4,7]. The secular cooling of the core decreases the temperature drop across the mantle, and the secular cooling of the mantle increases its effective viscosity. It is therefore possible that the Rayleigh number decreases with time as the mantle cools. This would increase the thickness of the thermal boundary layers, especially the lower one, decrease the heat flux out of the core, and hamper the instability of the lower layer. The mantle becomes more like one that is heated mainly from within. The Rayleigh number may decrease below the critical value and a time-dependent, vigorous convection may suddenly change to a quasisteady and slow circulation [4].

The impact craters with diameters from 1.5 to 280 km compiled from Magellan observations indicate that the crater population on Venus has a completely spatially random distribution [9] and the size/density distribution of craters with diameters ≥35 km is consistent with a "production" population with an age of 500 ± 250 m.y. [10]. The similarity in size distribution from area to area indicates that the crater distribution is independent of crater size. Also, the forms of the modified craters are virtually identical to those of the pristine craters. These observations imply that Venus reset its cratering record by global resurfacing 500 m.y. ago, and resurfacing declined relatively fast. The fact that <40% of all craters have been modified and that the few volcanically embayed craters are located on localized tectonic regions [11] indicate that only minor and localized volcanism and tectonism have occurred since the latest vigorous resurfacing event ~500 m.y. ago and the interior of Venus has been solid and possibly colder than Earth's. This is because the high-temperature lithosphere of Venus would facilitate upward ascending of mantle plumes and result in extensive volcanism if Venus' upper mantle were as hot as or hotter than Earth's [12]. Therefore, the present surface morphology of Venus may provide useful constraints on the pattern of that vigorous convection, and possibly on the thermal state of the Venus' mantle.

We examine this possibility through numerical calculations of three-dimensional thermal convection models in a spherical shell with temperature- and pressure-dependent Newtonian viscosity, temperature-dependent thermal diffusivity, pressure-dependent thermal expansion coefficient, and time-dependent internal heat production rate. Both rigid and free boundary conditions are considered at the surface, whereas the boundary condition at the core/mantle boundary is assumed free as long as the core has not become completely solidified. Otherwise it is assumed to be rigid. The lateral dependence of the governing equations of motion, heat transfer, and continuity is resolved through spherical harmonic representations of field variables and the resulting radially dependent differential equations are solved numerically using the Green function method [4]. Among all parameters affecting the pattern of convection circulations, the free boundary condition at the surface and the secular decrease of temperature at the core/mantle boundary have by far the most dominant effects. These two factors result in fast cooling of the mantle and sharp reduction in its effective Rayleigh number, so that oscillatory vigorous convection circulations could become quasisteady and slow. A strong thermal boundary layer is developed near the surface, whereas that near the core/mantle boundary is relatively weak. Consequently, major lateral variations in temperature exist in the upper mantle, but they are subdued near the core/mantle boundary.

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SURFACE PROCESSES ON VENUS. R. E. Arvidson, McDonnell Center for the Space Sciences, Earth and Planetary Sciences, Washington University, St. Louis MO 63130, USA.

Magellan synthetic aperture radar (SAR) and altimetry data were analyzed to determine the nature and extent of surface modification for venusian plains in the Sedna Planitia, Alpha Regio, and western Ovda Regio areas. Specific cross sections derived from the SAR data were also compared to similar data for dry terrestrial basaltic lava flows (Lunar Crater and Cima volcanic fields) and playas (Lunar and Lavic Lakes) for which microtopographic profiles (i.e., quantitative roughness information) were available. In Sedna Planitia, where clear stratigraphic relations can be discerned among volcanic flow units, the youngest unit has planform and microwave characteristics indicative of pahoehoelike flows. The second youngest flow exhibits cross-section values similar to fresh a'a flows at the Lunar Crater and Cima fields. Older flows have the same planform shapes as the youngest a'a flow, but exhibit backscatter signatures similar to degraded terrestrial flows. We suggest that flows with a variety of surface textures have been emplaced at Sedna Planitia and elsewhere and that initial properties have been removed by surface processes for the older units. Degradational effects of ejecta are directly evident in deposits from the nearby impact crater Lind mantle sections of the Sedna flows. Differences in cross sections between mantled and unmantled flows are consistent with ejecta thicknesses of centimeters. Similar thicknesses are inferred for the extensive parabolic ejecta deposit from Stuart Crater, which is located on plains to the east of Alpha Regio. Ejecta deposits are inferred to accumulate during impact events and to be dispersed over geologic time by aeolian activity. The widespread distribution of thin ejecta deposits indicates that the rate of aeolian erosion is low, perhaps only a fraction of a micrometer per year. We thus conclude that most flow degradation in locations such as Sedna Planitia is due to *in situ* weathering. In addition, elevation-dependent weathering is inferred in western Ovda Regio, where plains above 6054 km radius have enhanced reflection coefficients (>0.20) as compared to adjacent plains at lower elevations. Furthermore, the presence of deposits with normal reflection coefficients blown in from lower elevation plains indicates that the conversion to high dielectric materials occurs at a slower rate than the rate of sediment accumulation by winds. Combined vertical rates of surface modification of meters over hundreds of millions of years are inferred from the extent of surface modification for plains and the impact crater abundance. This rate is orders of magnitude lower than the terrestrial value and suggests that it will be possible to constrain relative ages of surfaces on the basis of degree of preservation of volcanic landforms and microwave signatures.

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SHIELD FIELDS: CONCENTRATIONS OF SMALL VOLCANIC EDIFICES ON VENUS. J. C. Aubele and L. S. Crumpler, Department of Geological Sciences, Box 1846, Brown University, Providence RI 02912, USA.

Observations: Pre-Magellan analysis of the Venera 15/16 data indicated the existence of abundant small volcanic edifices, each ≤20 km diameter, interpreted to be predominantly shield volcanos [1,2] and occurring throughout the plains terrain, most common in equidimensional clusters. With the analysis of Magellan data, these clusters of greater than average concentration of small volcanic edifices have been called "shield fields" [3,4]. A typical shield field consists of volcanos numbering $\approx 10^2$ and ranging in density from 4 to 10 edifices per 10^3 km^2 within an area that covers $\geq 10^4$ km^2. Most of these fields are roughly equant in outline, but a small percentage are elongate or consist of diffuse concentrations of edifices over larger areas. Typical field diameters mostly range from 50 to 350 km, with a mode from 100 to 150 km (Fig. 1). The cumulative size distribution (Fig. 2) of shield fields more closely follows the trend of coronae/arachnoids/novae (features assumed to be dominantly intrusive) than features assumed to be dominantly extrusive (such as large or intermediate-sized volcanos); this similarity apparently reflects reservoir and source dimensions. The volcanic edifices within an individual shield field are generally ≤10 km in diameter, and are predominantly radar-bright and shield-shaped in profile with a single summit pit [5]. A small number of fields are composed predominantly of a less common edifice type such as radar-dark shields, edifices with radar-bright aureoles or halos, elongated small shields with bright radial flow patterns ("anemones"), or domical or conical profile edifices [5]. The radar-bright or radar-dark material locally surrounding shield field edifices, which sometimes covers local structural lineaments, is interpreted to represent associated volcanic material, probably thin lava flow units, although minor amounts of ash or cinder may produce a very thin local veneer in some areas [5]. If the visible flow fields associated with some shield fields are of average size, then the area of resurfacing associated with a shield field appears to be comparable to that of the area of a single large volcano. Shield formation did not apparently occur planetwide as a single event, as there appears to be a range of shield field ages in relation to the surrounding regional plains units based on stratigraphic relationships. A few vents within a shield field may be aligned along dominant structural trends, and summit pits frequently occur along dominant structural trends; however, the clustering characteristics of edifices within a shield field appear to be most similar to that of terrestrial cinder cone fields lacking in well-defined structural vent control.

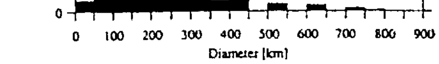

Fig. 1.

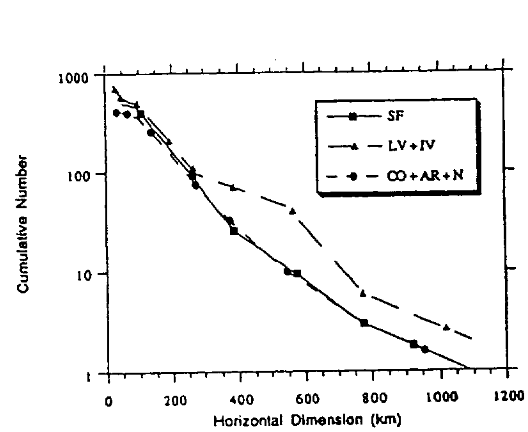

Fig. 2.

Distribution: At the conclusion of cycle 2 coverage, 556 shield fields (Fig. 3) have been identified in the catalog of volcanic features [3,6] prepared for the Magellan Science Analysis Team, Volcanism Working Group; shield fields are the most abundant single category type of volcanic or magmatic features. Approximately 70% of shield fields occur on 50% of the surface of Venus. Shield fields are somewhat more distributed over the surface than are large single magmatic or volcanic features such as coronae or large volcanos [3,6,7]; however, Magellan global analysis has confirmed the previous observation made from the Venera dataset [1] of at least one and possibly two dominant global concentrations. The region of greatest concentration, which also shows high concentrations of all other volcanic features [4,8,9], has been informally named the Beta-Atla-Themis or "BAT" region, centered at longitude 250°. Density of shield fields within this region ranges from 2 to 7 fields per 10^6 km^2 and high density of shield fields appears to define the margins of the BAT area. Magellan has also confirmed the previous observation based on Venera data [1] that small volcanos do not occur in large numbers in the areas dominated by ridge belts or in the very lowest or very highest elevations on the planet. Approximately 59% of shield fields occur in elevations between mean planetary radius and 2 km above MPR, 36% occur in regions below MPR in elevation, and only 5% occur in regions greater than 2 km above MPR. When normalized for percentage of surface area at these elevations, 76% of shield fields occur in regions 1 to 2 km above MPR. Fields are commonly spatially associated