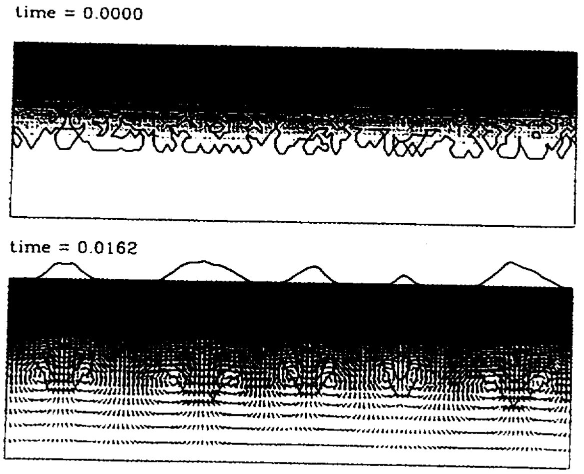

Fig. 1. Finite-element simulation showing the growth of melt-driven instabilities at the top of the mantle (depth of box ~160 km) from initially small (<0.1%) random partial melt perturbations. Temperature (shaded), velocity (arrows), partial melt distribution (contours, at 0 and intervals of 2.5%), melt production rate per unit area (on top). Time nondimensionalized to $D^2/\kappa$.

order as thermal anomalies driving mantle flow. Density anomalies equivalent to 100 K are obtained by only 1% partial melt or buoyant residuum, which is 3% depleted. These density effects are expected to have an effect on geoid and topography caused by one of these instabilities, and possibly the geoid and topography caused by thermal plumes.

Comparison of mantle geotherms for Venus (derived both from numerical simulations and from observations combined with theory) with an experimentally determined dry solidus for peridotite [3] indicate that the average geotherm passes close to or even exceeds the dry solidus at a depth of around 90 km. Thus, for any reasonable viscosity law, such as in [4], a region of lower viscosity is expected at shallow depth. This contradicts several geoid/topography studies based on simple mantle models, which require no low-viscosity zone. We investigate the possibility that the presence of buoyant residuum and partial melt at shallow depth may account for this discrepancy.

Global geoid modeling using the technique described in [5] indicates that a possible way to satisfy the long wavelength admittance data is with an Earth-like viscosity structure and a concentration of mass anomalies close to the surface, compatible with a shallow layer of buoyant residuum and/or partial melt. Geoid and topography signatures for local features, specifically Rayleigh-Taylor instabilities and thermal plumes with partial melting, are currently being evaluated and compared to data.

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N93-14388 464393

## CAN A TIME-STRATIGRAPHIC CLASSIFICATION SYSTEM BE DEVELOPED FOR VENUS?

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Magellan radar images reveal that Venus' exposed geologic record covers a relatively short and recent time span, as indicated by the low density of impact craters across the planet [1]. Therefore, because impact cratering in itself will not be a useful tool to define geologic ages on Venus, it has been questioned whether a useful stratigraphic scheme can be developed for the planet. We believe that a venusian stratigraphy is possible and that it can be based on (1) an examination of the rationale and methods that have been used to develop such schemes for the other planets, and (2) what can be gleaned from Magellan and other datasets of Venus.

Time-stratigraphic classification systems or schemes have been derived for all other terrestrial planetary bodies (Earth, Moon, Mars, Mercury) [2–5] because the schemes are useful in determining geologic history and in correlating geologic events across the entire surface of a planet. Such schemes consist of a succession of time-stratigraphic units (such as systems and series) that include all geologic units formed during specified intervals of time. Our terrestrial stratigraphy is largely based on successions of fossil assemblages contained in rock units and the relations of such units with others as determined by their lateral continuity and superposition and intersection relations. To define geologic periods on the other planets, where fossil assemblages cannot be used, major geologic events have been employed (such as the formation of large impact basins on the Moon and Mercury [3,5] or the emplacement of widespread geologic terrains on Mars [4,6]). Furthermore, terrestrial schemes have been supplemented by absolute ages determined by radiometric techniques; on the Moon and Mars, relative ages of stratigraphic units have been defined according to impact cratering statistics [3,4].

Stratigraphies are by nature provisional, and they are commonly revised and refined according to new findings. Boundaries of stratigraphic units are difficult to define precisely on a global scale; refinements such as newly discovered marker beds may require changes in nomenclature or minor adjustments in absolute- or relative-age assignments. Although the martian stratigraphy has been revised only once [4], the lunar stratigraphy is in its fifth major version [3] and continues to be refined in detail [7]. Terrestrial stratigraphy has been revised many times in its development over the past century. Although the Galilean satellites of Jupiter are being mapped geologically, there has been insufficient basis or need for the development of formal stratigraphies for them [8].

Given the current state of stratigraphic methods and their application to the planets, what are the prospects for a stratigraphy for Venus? To address this question, we need to examine two related questions: (1) Has the planet experienced widespread geologic events or processes resulting in the broad distribution of coeval materials (which would form the basis for time-stratigraphic units)? (2) Can we unravel the complex stratigraphic-tectonic sequences apparent on Venus? (Or can superposition relations and relative age be reasonably well established from Magellan radar or other datasets?)

Already a variety of potential venusian stratigraphic markers based on widespread geologic events and activities are emerging (Table 1). First, the global distribution of impact craters indicates that Venus had a global resurfacing event or series of events that ended about 500 ± 300 m.y. ago [1]. Presumably, most of the plains material that covers about 80% of the planet formed during that resurfacing and can be included in a stratigraphic system. Underlying much of the plains material are complex ridged or tesselated terrain materials; they must be older than the plains material, but their structures may in part be contemporary with its emplacement [9]. Postdating the plains material are most of the impact craters, many of the largest volcanic shields, and regional fracture belts [1]. Most of the plains are cut by lineations, narrow grabens, and wrinkle ridges. Perhaps such widespread structures may provide a basis for defining regional or even nearly global stratigraphic markers to

TABLE 1. Potential venusian stratigraphic markers (from youngest to oldest).

| |
|---|
| • Relatively pristine lava-flow surfaces as indicated by radar backscatter characteristics |
| • Preserved crater halos and surface splotches |
| • Widespread fractures, grabens, and ridges |
| • Plains material |
| • Complex ridged terrain (tesserae) |

which local volcanic and tectonic features and units may be correlated. Finally, very young time markers may be defined by the degree of weathering or eolian modification of a surface. For example, lavas flows at Maat Mons show a decrease in radar contrast and brightness with increasing age (based on superposition relations) [10]. Also, some impact craters retain radar-dark (less commonly radar-bright) halos perhaps consisting of impact debris; apparently related to the halos are dark and light surface "splotches" that may represent relatively young debris and shock-induced surface roughness produced by impacting bolides of a narrow size range that disintegrated deep down in the dense venusian atmosphere [1]. As these features age, they may become less distinct relative to surrounding terrains.

Initially, superposition relations were difficult to ascertain among various geologic units on Venus because of the general difficulty in perceiving topography on the radar images. (Exceptions, such as thick lava flows or domes, were relatively rare). Still, many stratigraphic relations can be determined in plan view, because overlying materials tend to mute or embay the texture and structure of underlying surfaces. More recently, Magellan has produced repeated radar images of selected areas, which permits stereoradargrammetry [11]. In addition, synthetic-parallax stereo-images (produced from merged Magellan images and altimetry) commonly show the association between geologic/tectonic-terrain units and regional topography.

Magellan radar mapping shows that Venus has had a complex geologic history that can be unraveled to a large extent from available data. Even though exposed rocks apparently record only a small portion of the planet's history, stratigraphic markers are sufficient to permit the development of a useful scheme of time-stratigraphic units. Such a scheme should result from NASA's new Venus Geologic Mapping (VGM) Program, which will cover the entire planet.

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**N93-14389**

## STRUCTURAL CHARACTERISTICS AND TECTONICS OF NORTHEASTERN TELLUS REGIO AND MENI TESSERA.

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**Introduction:** Tellus Regio-Meni Tessera region is an interesting highland area characterized by large areas of complex ridged terrain (CRT [1]) or tessera terrain [2]: Tellus Regio and Meni Tessera areas and deformed plains areas between the highland tesserae. The area was previously studied from the Venera 15/16 data and typical characteristics of complex tessera terrain of Tellus Regio were analyzed and a formation mechanism proposed [3]. Apparent depths of compensation of ~30–50 km were calculated from Pioneer Venus gravity and topography data. These values indicate predominant Airy compensation for the area [4,5]. Regional stresses and lithospheric structures were defined from analysis of surface structures, topography, and gravity data [6]. In this work we concentrate on northeastern Tellus Regio and Meni Tessera, which are situated north and west of Tellus Regio. Structural features and relationships are analyzed in order to interpret tectonic history of the area. Study area was divided into three subareas: northeastern Tellus Regio, Meni Tessera, and the deformed plain between them.

**Description of Areas and Interpretations of Structures:** *Northeastern Tellus Regio.* Northeastern Tellus Regio is defined here as a roughly triangle-shaped area between longitudes 84° and 92°E and latitudes 46° and 53°N. The ridgelike northern end of northeastern Tellus Regio is cut by a fracture belt at 53°N, 85°E, but the overall trend of the CRT is continued by CRT of Dekla Tessera. Together these areas form a >2000-km-long south-concave arc of tesserae, which extends to Kamari Dorsa south of Audra Planitia and west of Laima Tessera.

The northernmost area of northeastern Tellus Regio is characterized by wide, arcuate ridgelike features, which form the major structural element of the CRT in this area. The longest one of these ridgelike features is oriented in a northwest-southeast direction and it forms the curving northeastern edge of the CRT of Tellus Regio ("A" in Fig. 1). It is ~660 km long, 4–40 km wide, and has gentle slopes. The east-facing slope is steeper and more pronounced. The other two ridgelike structures of the CRT are situated southwest of the first one ("B" and "C" in Fig. 1). They are less distinct and shorter: ~40 km wide and 280 km long ("B") and ~30–85 km wide and 230 km long ("C"). Their general orientation is west-northwest/east-southeast. These ridgelike features end abruptly in the northwest, but in the south and southeast they merge to more topographically flat-looking tessera surface. The large ridgelike features of northeastern Tellus Regio are composed of narrower (widths 1–2.5 km), closely spaced, linear, and generally ridges tens of kilometers in length.

The narrow ridges and the larger-scale ridgelike features comprising them appear to be the oldest structural elements of the CRT. In the topography data the widest ridgelike patterns can be distinguished. Their heights are typically several hundred meters below or about the mean planetary radius of 6052 km. The topography and morphology of ridges support compressional origin. There are oval-shaped intratessera plains depressions and troughlike features in between the major ridgelike structures of the CRT in several places (e.g., 49° N, 87°E, "D"). These postdate the ridgelike features of the CRT. The oval plains areas have smooth radar-dark surfaces and are obviously covered by lavas. There are narrow (1–3 km wide) ridges on the edges of the oval-shaped plains, which follow the curvature of the edges of the plains. These ridges appear to have formed in a later episode of compression in the area.

There is a 30-km-wide belt of narrow linear ridges adjacent to the northeastern tessera border. The widths of these ridges are 1–2 km and are several tens of kilometers in length. These ridges apparently formed due to compressional stresses oriented perpendicular to the border of CRT (approx. northeast-southwest). These ridges are not