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DISTRIBUTION OF TESSERA TERRAIN ON VENUS: PREDICTION FOR MAGELLAN

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Abstract. Tessera terrain is the dominant tectonic unit in the northern hemisphere of Venus and is characterized by complex sets of intersecting structural trends and distinctive radar properties due to a high degree of meter and sub-meter scale (5 cm to 10 m) roughness. Based on these distinctive radar properties, a prediction of the global distribution of tessera can be made using Pioneer Venus (PV) reflectivity and roughness data. Where available, Venera 15/16 and Arecibo images and PV diffuse scattering data were used to evaluate the prediction. From this assessment, we conclude that most of the regions with prediction values greater than 0.6 (out of 1) are likely to be tessera, and are almost certain to be tectonically deformed. Lada Terra and Phoebe Regio are very likely to contain tessera terrain, while much of Aphrodite Terra is most likely to be either tessera or a landform which has not yet been recognized on Venus. This prediction map will assist in targeting Magellan investigations of Venus tectonics.

Introduction

Tessera terrain is one of the most complex landforms on the surface of Venus [Barsukov et al., 1986; Basilevsky et al. 1986]. It is characterized by complex patterns of intersecting structural trends in Venera 15/16 images of the surface [Basilevsky et al., 1986]. Tessera covers more area than any other tectonic unit mapped by Venera 15/16, between 10% and 15% of the surface north of 30°N [Sukhanov, 1986; Bindschadler and Head, 1989], and is concentrated in the region between Aphrodite Terra and the mountains of western Ishtar Terra. Because of its unusual structure, location, and widespread distribution, study of the tessera is likely to yield important information about the global tectonics of Venus.

Pioneer Venus (PV) reflectivity and rms slope data [Pettengill et al., 1980, 1982] reveal that tessera terrain also possesses distinctive radar properties: high values of rms slopes (θ) and low values of uncorrected Fresnel reflectivity (ρ) as compared to most of the surface of Venus [Bindschadler and Head, 1988, 1989]. Comparison of these PV data with reflectivity data corrected for diffuse scattering effects [Ford and Pettengill, 1984; Pettengill et al., 1988] shows that the distinctive radar properties of tessera are due to a high degree of roughness of the surface at scales of approximately 5 cm to 10 m [Bindschadler and Head, 1988; 1989]. Sub-meter scale roughness within the tessera causes diffuse scattering of radar at the PV wavelength (17 cm) and results in low values of uncorrected reflectivity [Bindschadler and Head, 1988; Pettengill et al. 1988]. Meter scale roughness is responsible for high values of rms slope. Thus, the radar properties of tessera are primarily related to surface roughness and do not correspond to the intrinsic dielectric properties of surface materials. High values of rms slope (0.5 to 10 m roughness) are characteristic of all tectonic units on Venus [Bindschadler and Head, 1989].

The distinctive radar characteristics of tessera allowed Kreslavsky et al. [1988] to predict the distribution of tessera over the entire PV data set. This was done by defining "predicted tessera" as any area on the surface with θ and ρ values within a range determined by eye from histograms of radar properties of tessera [Bindschadler, 1986; Bindschadler and Head 1989]. Within Venera coverage, the resulting map correctly predicted approximately 50% of mapped tessera terrain.

In this paper we present an improved prediction of the distribution of tessera and assess the prediction south of Venera coverage using Arecibo and PV-derived data on diffuse scattering. We find a number of regions are very likely to be tessera, including the Nokomis Montes region, Phoebe Regio, and parts of Lada Terra. Other regions, such as Aphrodite Terra and the Parga Chasma region, are likely to be tectonically deformed even if they are not found to be characterized by the distinctive structures of tessera terrain. This prediction can assist in targeting investigations of Venus tectonics using Magellan data.

Prediction

PV reflectivity (ρ) and rms slope (θ) values from the 1985 NSSDC data set were placed in an azimuthal equidistant projection to match the geomorphic map of northern Venus made by the USSR Academy of Science Working Group [Barsukov and Basilevsky, 1986]. PV data were spatially filtered using a gaussian weighting scheme (standard deviation = 100 km). For each pair of values ρ and θ, the surface area within the Venera map and the surface area within the tessera were calculated. To obtain a predictive measure (Π_{ts}), the two areas were divided for each pair of values (ρ,θ). For a given pair (ρ_i,θ_i), $\Pi_{ts} = 1$ indicates that surfaces characterized by (ρ_i,θ_i) are found only within the tessera; zero indicates that these data values are never found within the tessera. The resultant matrix of Π_{ts} values was used to create a tessera prediction map (Figure 1) by matching the Π_{ts} value to each pixel in a mercator projection map according to the reflectivity and rms slope of that region. Values of Π_{ts} were then color coded and overlain onto a shaded relief map of PV topography to create Figure 1.

The tessera prediction map (Figure 1) has an effective resolution of ~250 km. Resolution is lower than that of PV data because filtering is required to suppress noise in the prediction map. Areas of tessera smaller than 250 km are likely to be undersampled, and therefore prediction values for such areas can be considered as lower bounds on the actual values. The total area of predicted tessera within Venera coverage is equal to that of the mapped tessera for $\Pi_{ts} \geq 0.34$. At this threshold, predicted tessera matches mapped tessera 54% of the time. Mismatches are due to (1) the disparate resolutions of the Venera images (1-3 km) and the prediction map and (2)

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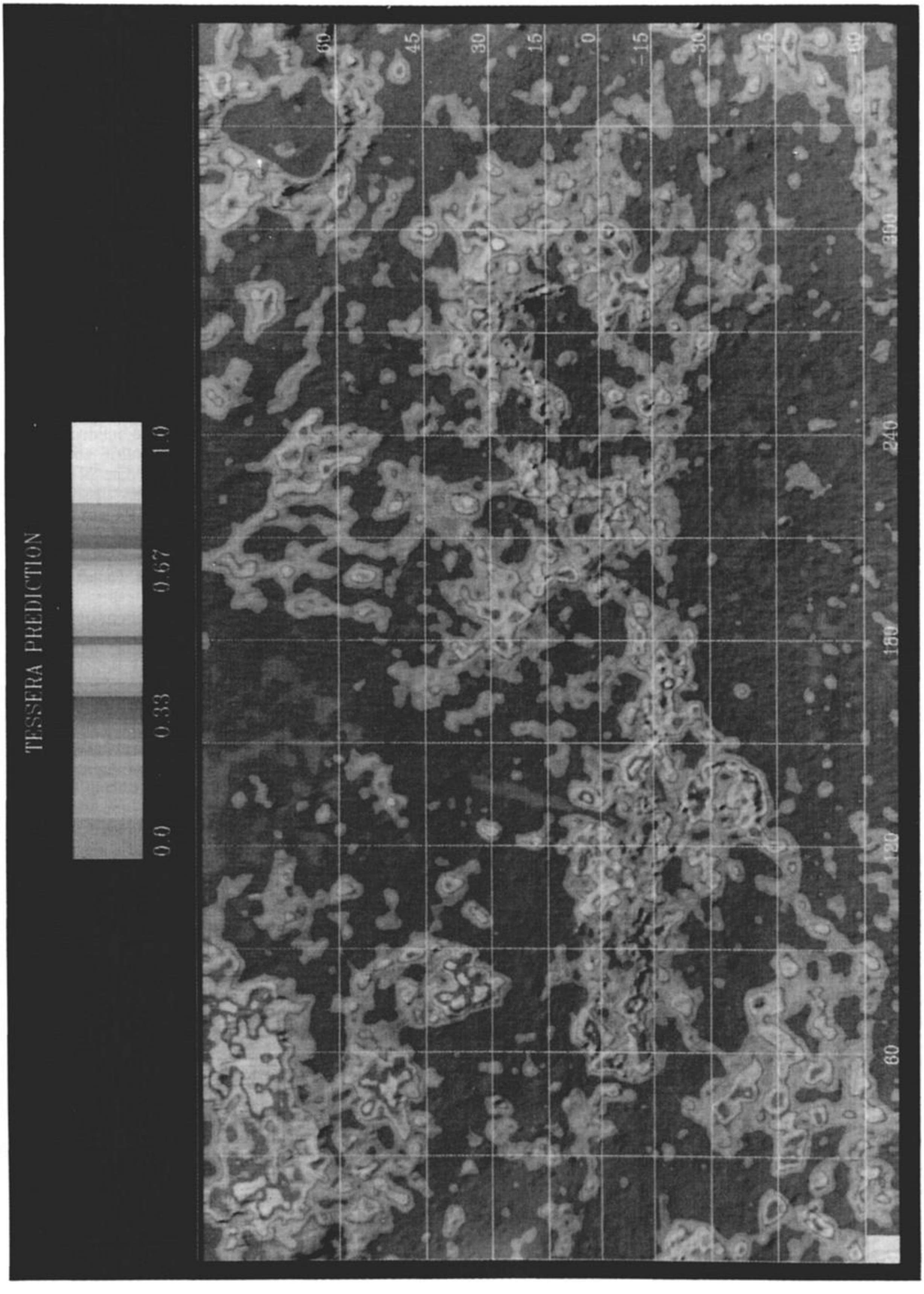

Fig. 1. Tessera prediction map. Prediction values (Π_{ts}) are coded and overlain onto a shaded relief image of PV topography. Effective resolution of the prediction map is approximately 250 km. Areas most likely to be tessera are characterized by $\Pi_{ts} \geq 0.6$, or yellow, red, and white tones. Color saturation has been subdued to emphasize topographic relief.

"false positives:" regions predicted to be tessera, but containing other landforms. Most of the latter mismatches are ridge belts. For example, the dendritic pattern of relatively high Π_{ts} values north of 45°N and between 180°E and 240°E (Figure 1) matches the distribution of ridge belts in this region. To minimize the effects of the former type of mismatch on our evaluation, the Venera 15/16 map of tessera was degraded by calculating the regional density of tessera at a resolution of ~250 km and then compared to the prediction map. Regional tessera density was calculated as the percent area of tessera within a circular window 250 km in diameter. Comparison of the prediction to mapped tessera at the same resolution yields a correlation coefficient of 0.72.

A detailed comparison of predicted and mapped tessera within Venera coverage was performed in order to more clearly understand the limitations of the prediction. This comparison showed that the best balance between excluding non-tessera and including mapped tessera was achieved for $\Pi_{ts} \geq 0.6$. These values correspond to yellow, red, and white tones in Figure 1. Accordingly, we consider the best candidate tessera south of Venera coverage as those characterized by $\Pi_{ts} \geq 0.6$. Although our discussion will focus on tessera terrain, some areas are likely to represent other tectonic landforms, such as chasmata or ridge belts.

Candidate tessera (Figure 1) are found in five distinct clusters and a number of smaller, more isolated regions. Cluster I is associated with Ishtar Terra, and consists primarily of Fortuna and Laima Tessera and Tellus Regio. Several smaller regions of tessera can be seen to the north and west of Tellus as distinct local highs in both topography and Π_{ts}. Cluster II is centered around Beta Regio and includes Phoebe Regio. High Π_{ts} values are found in parts of Devana Chasma despite the fact that it is narrow compared to the prediction map's resolution. The very high Π_{ts} values in eastern Beta correspond to local topographic highs which display complex structural patterns in new Arecibo data [Campbell et al., 1989] and appear to be heavily embayed tesserae. Cluster III stretches along Ganis and Parga Chasmata from northern Atla Regio to Themis Regio and also corresponds to a global-scale linear trend in regional slope [Sharpton and Head, 1986] and topography [Schaber, 1982]. Most regions of high Π_{ts} values near Atla are not associated with Maat or Ozza Mons (thought to be large shield volcanoes), but rather with either distinct troughs and chasmata or irregularly shaped topographic highs (e.g., Nokomis Montes). Cluster IV consists of a number of isolated, irregular topographic highs that make up Lada Terra. Alpha Regio, which lies to the northwest of Cluster IV, is known to be tessera from recent Arecibo data [Campbell et al., 1989]. Cluster V is associated with Aphrodite Terra. High Π_{ts} values are found around the margins of Ovda and Thetis Regiones, in western Aphrodite, and near Artemis Chasma.

Diffuse scattering data [Ford and Pettengill, 1984; Pettengill et al., 1988] can be used to evaluate the prediction in the region from 20°S to 45°N Lat. These data demonstrated that the low values of uncorrected reflectivity observed in the tessera were primarily the result of sub-meter scale (5-50 cm) roughness [Bindschadler, 1986; Bindschadler and Head, 1988]. Figure 2 is a map of the percent diffusely scattering material on the surface, color coded and overlain onto shaded relief PV topography. The highest percentages of diffuse scatterers (Figure 2) are found in known tessera, predicted tessera, and in chasmata [Bindschadler and Head, 1988]. Diffuse scattering is strongly correlated with the prediction map (Figure 1), except in central and western Aphrodite Terra, particularly at high elevations. This area is characterized by a high percentage of diffuse scatterers but Π_{ts} values are relatively low. This indicates that the surface of these regions is quite rough at meter and sub-meter scales, but the surface materials are unlike those in the mapped regions of tessera in terms of intrinsic dielectric properties. The high reflectivity values in this region appear to depend strongly on elevation, and are likely to have little to do with surface morphology. Therefore, despite low Π_{ts} values, most of Aphrodite is almost certain to be tectonically deformed, and is likely to be tessera. The styles of deformation in Aphrodite have significant implications for models of Venus tectonics [e.g., Head and Crumpler, 1987; Kiefer and Hager, 1988; Bindschadler and Parmentier, 1989]

Conclusions

Using the distinctive radar properties of tessera, we have produced a map which predicts the distribution of tessera and other tectonic units within the PV data set. Predicted tessera appear to cover on the order of 10-20% of the surface, largely dependent upon inclusion or exclusion of portions of Aphrodite. This suggests that the geology of equatorial and southern Venus may be quite similar to the area imaged by Venera 15/16. Five distinct clusters of tessera are identified, four of which lie partly to completely outside of Venera 15/16

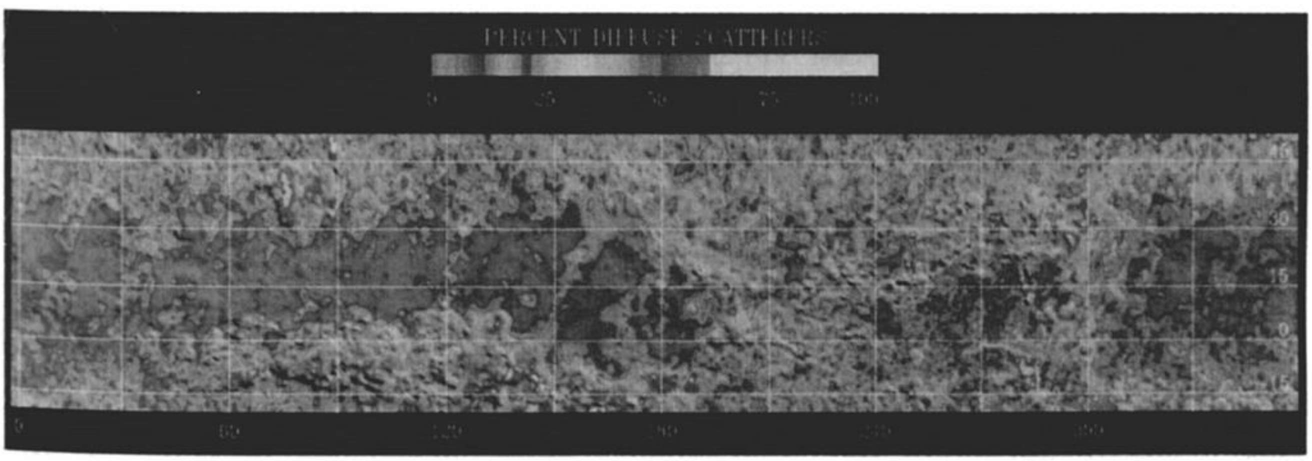

Fig. 2. Diffuse scattering map, color coded and overlain onto PV topography in the same manner as Fig. 1. High percentage of diffuse scatterers usually correspond to known or predicted tessera. High values in Aphrodite suggest that much of that region may be tessera. Color saturation has been subdued as in Fig. 1.

Table 1. Tessera Prediction Assessment

Name	Location		Assessment
Alpha Regio	17°S - 30°S	0° - 10°E	tessera*
Lada Terra	30°S - 65°S	15° - 75°E	tessera, ridge belts
E. Aphrodite	5°N - 20°S	55° - 140°E	tessera, ?
Artemis Chasma region	20°S - 45°S	120° - 145°E	chasmata, tessera
W. Aphrodite	10°S - 20°S	140° - 190°E	chasmata, tessera
NW Atla Regio (Nokomis Montes region)	10°N - 40°N	175° - 210°E	tessera, chasmata
Parga Chasma region	0°S - 40°S	210° - 300°E	chasmata, tessera
NW Beta Regio	30°N - 40°N	255° - 280°E	tessera
Phoebe Regio	0°N - 20°S	270° - 300°E	tessera, ?
E. Beta Regio	15°N - 40°N	295° - 310°E	tessera*

* Known to be tessera from recent Arecibo data [Campbell et al. 1989]

coverage. In addition, a number of distinct, smaller predicted tesserae are identified. Considering the prediction values, elevations and topographic shapes of regions, and any available diffuse scattering data and Arecibo images, we have evaluated the prediction and predict what landforms will be found in these regions by Magellan. This assessment is summarized in Table 1, which gives names, approximate locations, and expected landforms for each cluster or significant region of tessera. Because the prediction map is based upon surface roughness characteristics not uniquely associated with tessera, both ridge belts, chasmata, or as yet undiscovered landforms could also be present in some cases. For example, several topographic troughs in Aphrodite are characterized by high Π_{ts} values and may be extensional features. The tessera prediction map (Figure 1) and our evaluations can assist Magellan investigators in identifying regions of particular interest to studies of Venus tectonics

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