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VEGA LANDING SITES: VENERA 15/16 UNIT ANALOGS FROM PIONEER VENUS REFLECTIVITY AND RMS SLOPE DATA

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Abstract. Pioneer Venus radar data on surface properties have been used to compare the Vega spacecraft landing sites with the northern 1/4 of Venus mapped by the orbiters Venera 15 and 16. The regions surrounding both landing sites possess surface reflectivity and small-scale roughness properties most similar to those of mapped volcanoes and volcanic plains regions and different surface properties than those of mapped tectonic units. Regions analogous to the Vega 1 site are relatively rare, covering 2.8% of the mapped surface. Vega 2 analogs are much more common and cover 22.6% of the surface. Neither landing site is representative of the nearby highlands of Aphrodite, but the Vega 2 landing site is similar to much of the northern plains of Venus.

Introduction

The Vega 1 and 2 spacecraft landed on Venus in June of 1985. Both landing sites are located in Rusalka Planitia, near the northern flanks of Aphrodite Terra. Vega 1 landed at 8.05°± 1.0° N, 176.89°±1.0° E, Vega 2 at 7.51°± 1.5° S, 179.8°± 1.5° E [V.L. Barsukov, personal communication 1985]. Gamma-ray spectrometry at the Vega 1 site and gamma- and X-ray fluorescence (XRF) spectrometry at the Vega 2 site have been interpreted to indicate gabbroic rock compositions [Surkov et al., 1986a,b]. Basaltic compositions of surface materials were measured by XRF and gamma-ray spectrometery in the Beta-Phoebe region by the Venera 9,10 [Surkov et al., 1976; Surkov, 1977], 13, and 14 landers [Surkov et al., 1982; Moroz, 1983]. Synthetic aperture radar (SAR) images of the northern 1/4 of Venus have also been obtained by the Venera 15 and 16 orbiters [Kotelnikov et al., 1984]. On the basis of surface morphology, much of the surface of northern Venus has been inferred to consist of volcanic plains, likely to be basaltic in nature [Barsukov et al., 1986]. In addition, the close proximity of the landing sites to the highlands of Aphrodite makes it important to see whether these sites possess surface properties similar to Aphrodite. Thus a comparison of the Vega landing sites and the geologic units mapped by Venera 15 and 16 would add to our understanding of how representative the landing sites are of the rest of Venus.

Method

The Pioneer Venus (PV) reflectivity and rms slope data [Pettengill et al., 1980, 1982] provide a method for comparison of the Vega landing sites and the portion of the northern high latitudes covered by Venera 15 and 16. Reflectivity and rms slope data yield information on the material properties (dielectric constant, porosity, etc.) and the 0.5 to 10 meter scale roughness of the surface, respectively [Pettengill et al., 1980, 1982; Head et al., 1985, Garvin et al., 1985]. The estimated landing error noted above for each of the landers was used to determine the area over which surface properties would be analyzed. Thus all PV reflectivity and rms slope data within 1.0° of the Vega 1 site and within 1.5° of the Vega 2 site were averaged to obtain a measure of the surface properties of the landing sites. Both the original reflectivity data set [Pettengill et al., 1982] and a version corrected for the effects of diffuse scattering [Ford and Pettengill, 1984] were used as part of the characterization of the landing sites. Only the uncorrected data were used in analysis and comparison of the Venera 15/16 unit map because the corrected data is limited by the latitudinal extent of Pioneer Venus SAR coverage: from 15° S to 45° N [Pettengill et al., 1980]. Venera 15/16 data extends southward from 90° N only as far as 30° N [Kotelnikov et al., 1984].

The Venera 15/16 geologic unit map [Barsukov et al., 1986] has been digitized and placed into an equal area map projection along with the PV data [Bindschadler, 1986]. The geologic unit map consists of six plains units, six tectonic units, and a volcanoes unit. [Barsukov et al., 1986; Basilevsky et al., 1986; Bindschadler, 1986]; unit names are given in Table 1. Locations of regions with reflectivity and rms slope within 1 standard deviation of values for the Vega landing site regions have been noted. These analogous regions are shown in Figures 1a and 1b on a simplified version of the Venera unit map. To find the Venera unit most analogous in surface properties to the Vega sites, the percent area covered by analogous regions was measured for each of the Venera units (Table 1). Because of the large difference in the total area covered by Vega 1 and Vega 2 analogous regions, a normalized residual percent was also calculated (Table 1) to allow a direct comparison of similarity or dissimilarity of units to landing sites. This residual is calculated by taking the difference between the percent Vega 1 or 2 analogs within a given unit and the percent area expected if the analogs were randomly distributed. This difference is then normalized to the random distribution percentage. A residual of zero thus indicates no more than the expected percent area covered by landing site analogs, while a positive value indicates more than expected coverage.

Discussion

The 2° by 2° region surrounding the Vega 1 site contains 3 PV measurements of rms slope and reflectivity.

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Table 1. Similarity of Venera Units to Vega Sites.

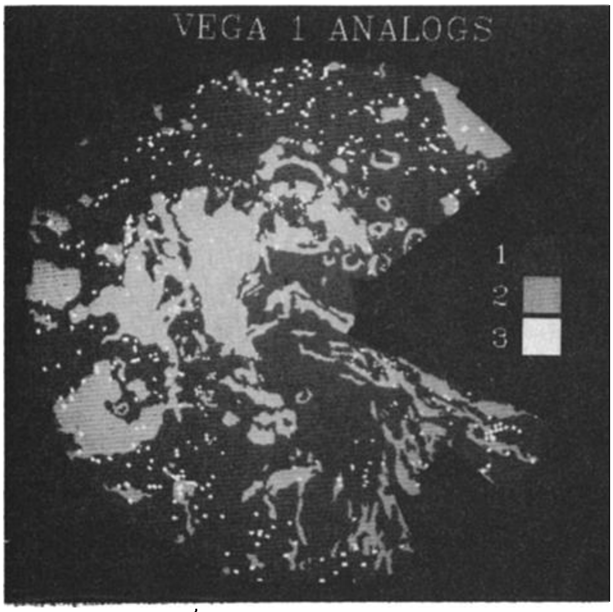
Unit[1]	Vega 1		Vega 2	
	%Area[2]	Residual	%Area	Residual
smooth plains	3.7	+0.33	28.8	+0.27
highland smooth plains	4.1	+0.47	36.1	+0.60
patchy rolling plains	2.4	−0.14	27.4	+0.21
dome and butte plains	3.7	+0.33	22.2	−0.02
band and ring plains	2.5	−0.10	30.1	+0.33
ridge and band plains	0.9	−0.68	15.8	−0.30
volcanoes	4.6	+0.65	24.6	+0.09
domelike uplifts	1.7	−0.39	9.7	−0.57
ovoids	1.2	−0.57	9.4	−0.13
banded terrain	0.5	−0.82	2.4	−0.89
ridge belts	2.7	−0.03	17.3	−0.23
furrow belts	2.0	−0.28	13.7	−0.39
parquet terrain	1.9	−0.32	9.7	−0.57

[1] Unit names based on Barsukov et al. [1986], see [Bindschadler, 1986].
[2] Percent area of a unit covered by Vega 1 or 2 analogs.

It is characterized by an rms slope value of 2.5°±0.4°, an uncorrected reflectivity of 0.11±0.01, and a corrected reflectivity of 0.14±0.03. The region is thus smooth to transitional in roughness at the 0.5–10 meter scale, is dominated by rock surfaces of normal porosity [Head et al., 1985; Garvin et al., 1985], and is rough enough at the 5–50 cm scale of diffuse scattering [Bindschadler, 1986] to lower the apparent reflectivity by nearly 30%. Increasing the size of the landing site region to 3° by 3° (10 PV measurements) does not result in significant changes in the mean reflectivity or rms slope.

An unsupervised clustering analysis has been performed on the uncorrected reflectivity and rms slope data from the PV orbiter and used to create a radar unit map [Davis et al., 1986]. The mean values of rms slope and uncorrected reflectivity for Vega 1 lie outside any of these clusters by more than one standard deviation, although including the standard deviation of values at the landing site leads to overlap with both units number 8 and 10. The Vega 1 site is thus transistional between these units, which have been interpreted as somewhat weathered basaltic surfaces [Davis et al., 1986].

For the Vega 1 site, all tectonic units possess negative residuals (Table 1). Of these, only the ridge belt residual is near to zero. Thus, the Vega 1 landing site is characterized by surface properties unlike those that typify the tectonic units. Of the plains units, two display slight anticorrelations with the Vega 1 site, while one unit, the ridge and band plains, is strongly anticorrelated with the site. Only four units display positive residuals (Table 1). These are the



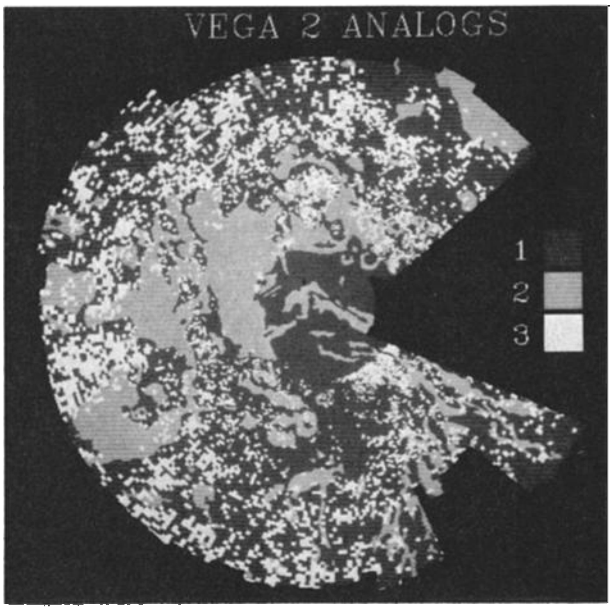


Fig. 1. Location of regions with surface properties analogous to the Vega landing sites. 1a) Vega 1 landing site analogs. 1b) Vega 2 landing site analogs. Key: 1 — plains units, 2 — tectonic units, 3 — landing site analogs

smooth plains, highland smooth plains, dome and butte plains, and volcanoes units. A detailed examination of the these units and correlations with the Vega 1 site shows no strong tendency for analogous regions to be grouped spatially within any of these units (Figure 1a). It is interesting to note that all these units are associated with volcanic landforms [Barsukov et al., 1986; Bindschadler, 1986] and that the combined PV data on surface properties and Venera 15/16 map suggest that the Vega 1 site is most similar to mapped volcanoes.

The 3° by 3° region surrounding Vega 2 contains 14 PV measurements and is smoother and slightly less radar reflective than the Vega 1 region. It is characterized by an rms slope value of 1.6°±0.5°, an uncorrected reflectivity of 0.12±0.03, and a corrected reflectivity of 0.13±0.02. The close match between the corrected and uncorrected reflectivity data indicates that the site is smoother than the Vega 1 site at the 5–50 cm scale, while the rms slope value indicates it is also smoother at the 0.5–10 meter scale. A comparison with statistically-derived surface units [Davis et al., 1986] places the Vega 2 site within unit 5, interpreted as somewhat weathered basalt and slightly smoother than units 8 and 10 noted above [Davis et al., 1986]. Both landing sites are characterized by values of reflectivity that indicate surfaces dominated by normal porosity rocks composed of ordinary silicate minerals with little or no metal enrichment [Garvin et al., 1985; Head et al., 1985].

Regions analogous to the Vega 2 site cover approximately eight times the area covered by Vega 1 analogs. Vega 2 analogs also display a tendency to clump together within plains regions; for example, within Sedna Planitia, Leda Planitia, and Lakshmi Planum (Figure 1b). As with the Vega 1 site, all tectonic units display an anticorrelation with the surface properties of the Vega 2 site. The volcano, ovoid, and dome and butte plains units all display residuals near zero and the ridge and band plains are again anticorrelated with the landing site. Only four units display clearly positive residuals (Table 1): the smooth, highland smooth, patchy rolling, and band and ring plains. In terms of PV reflectivity and rms slope data, however, the highland smooth plains, restricted to Lakshmi Planum, are the most similar to the region surrounding the Vega 2 landing site.

Figures 1a and 1b are most clearly contrasted by the difference in the percent area covered by landing site analogs: 2.8% for Vega 1, 22.6% for Vega 2. This difference appears to be due to 1) the larger range of reflectivity values within the regions surrounding the Vega 2 site and 2) the lower values of rms slope within the Vega 2 region. Most plains units contain large areas with rms slope near 1.6° but only small regions with roughness near 2.5° [Bindschadler, 1986]. Both Vega 1 and Vega 2 analogs are lacking within the tectonic units as compared to the plains (Figures 1a, 1b). Vega 2 analogs in particular appear to cluster strongly within the plains units (Figure 1b). We also note that neither the Vega 1 nor Vega 2 landing region is representative of the surface properties of the highlands (elevation > 6053.0 km [Masursky et al., 1980]) of Aphrodite [Head et al., 1985].

Conclusions

In terms of surface properties measured by the PV orbiter, the Vega 1 and 2 landing site regions are most like the plains units and the volcanoes unit mapped from Venera 15/16 radar images. They differ substantially from tectonic units such as the banded terrain, parquet terrain, and ovoids. Regions with surface properties analogous to those of the Vega 1 site cover only 2.8% of the surface and are most strongly corrleted with mapped volcanoes. Vega 2 analogs are found over 22.6% of the surface and correlate best with the plains of Lakshmi Planum. In terms of average surface roughness and material properties, neither landing site is representative of the Aphrodite highlands, while the Vega 2 region is quite similar to much of the northern plains seen in Venera 15/16 images and is quite likely to be volcanic in origin.

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