REGIONAL GEOLOGY OF THE BETA-PHOEBE REGION ON VENUS. J. B. Garvin and J. W. Head,
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The planet Venus is dominated by extensive rolling plains (65% of surface area) which serve
to separate and isolate the highlands and lowlands. Of the three major highland regions on Venus,
the Beta-Phoebe region is the most fully characterized, on the basis of the wealth and variety of
data available -- Earth-based radar images (Arecibo, Goldstone), Venera lander panoramas (Veneras
8-14 landed east of these highlands), and complete Pioneer-Venus orbiter radar coverage. Neither
Aphrodite nor Ishtar Terrae are covered as well as the Beta-Phoebe region; there has yet to be a
lander mission to either of these highlands, though the Vega landers are targeted for an area
near Aphrodite. The data available for Beta-Phoebe and the surrounding plains spans several or-
ders of magnitude in resolution, from cm-scale in the Venera panoramas to several km-scale in
Earth-based radar backscatter images, to 30-100 km in Pioneer-Venus maps of radar roughness (a0),
reflectivity (p), and altimetry (z). This affords us an opportunity to analyze the geology of the
region from the surface (Venera panoramas) and from afar (radar), and allows us to assess how re-
presentative the Venera lander sites are of the high plains and low highlands for this part of
Venus. In addition, the entire Beta-Phoebe area can be compared with planet-wide radar proper-
ties. This type of study is similar to that performed for regions on the Moon; radar, high- and
low-resolution orbital images, and surface photos were correlated for several areas near the
Apollo landing sites by Moore et al. [1,2].

Earth-based radar observations of Venus identified the Beta highlands, even in low-resolution
backscatter images, because of the extremely high backscatter of its elevated (~9 km) summit re-
gions. The reflectivity of such regions (e.g., Thetia Mons) is 0.28 ± 0.07 (3), which suggests the
occurrence of extremely dense materials (~3 g/cm³) likely to be enriched in high dielectrics (3, 4).
Recent high-resolution backscatter images from Arecibo show details at scales of 2-3 km.
Such images reveal structures which strikingly resemble vast lava flows, rift zones, and a pos-
tible summit caldera (Thetia Mons) (5). These discoveries are not surprising as the Venera 9 and 10
spacecraft acquired high-resolution spectroscopy data from the eastern flanks of Beta which indicated bas-
altic compositions (6,7). In addition, the Venera 10 panorama showed that there are semicontinuous,
platy exposures of bedrock at the surface of Venus which morphologically resemble eroded pahoehoe
lava flows (6,7,8,9). In order to interpret the regional geology of the Beta-Phoebe region and
the plains to the east, we have produced maps of the PV radar properties for the region (10,11)
and have statistically analyzed small (200 x 200 km) areas around the Venera 9-14 lander site coordi-
nates. Table I summarizes the averaged radar characteristics. While such averages (and standard
deviations) are useful, the spatial distribution of radar properties is especially useful in exami-
ning how extensive a type of surface is likely to be (10,11).

Since all of the Venera sites fall in an elevation interval from 0.9 to 2.1 km, we will focus
on the spatial distribution of roughness, reflectivity, and model density (8) in the region at
these elevations. The more elevated regions show the most distinctive radar backscatter patterns,
and are more extreme (higher α, p) in their PV radar properties. The high plains in the Beta-
Phoebe region are concentrated around the Beta and Phoebe highlands, and serve to connect the
smaller highland regions together. They are replaced by lower plains and lowlands to the east of
Beta, but continue to the southeast (where V11-14 landed). The roughness pattern in these plains
is variegated, but is dominated by surfaces with 3-4 RMS slopes. Isolated clusters of high
(>5 RMS) roughness occur predominantly around the most elevated highlands -- areas near
V9 and those containing V12 are examples. Frequently, the high roughness patches are low in p
(density <2g/cm³), perhaps reflecting an appreciable soil-cover or substrate, or possibly due to an
artificial lowering of the measured p because of a high degree of small-scale (cm) roughness.
Clusters of very smooth (1-2 RMS) terrain occur mostly south of Phoebe and are usually ringed
by increasing rougher terrain. A small region at 4ºN, 300ºE shows this pattern of gradational
roughness, and could represent an impact structure or small volcano -- this feature shows up as a
bright-haloed circular structure with a dark interior in Arecibo images (12). The terrain around
Beta Regio is typically 3-4º or more in roughness, with rougher areas occurring at higher eleva-
tions. The Venera 9 region is probably representative of locally blocky areas which have rough-
nesses above 4º (e.g., VL-1 on Mars and average lunar mare), but is not typical; the Venera 10
area (roughness 3-4º) is most typical of the entire region. There is a general increase in the
amount of smoother terrain south of Phoebe -- large clusters with roughness < 2.5º can be found.
Terrain with roughnesses between 2º and 3º is most common to the east and southeast of Phoebe:
Veneras 11, 13, and 14 all landed in areas such as this. V12 landed in a small, high-roughness
region amidst smooth terrain.

A different pattern emerges for reflectivity (or density). Most of the plains surrounding
Beta have p < 0.1 (density < 2g/cm³), but as one proceeds SE, small regions of isolated higher p
occur (p > 0.13 or density > 2.3 g/cm³). The p units appear to be more gradational than the
roughness ones, and larger continuous regions are most common. Isolated regions of high or low
p are uncommon except along the SE of Beta and far to the east on the plains. One vast region of low p
(p < 0.1) and V12 landed in a small, semicontinuous region of very low p, but with high roughness.
VII, 13, and 14 sampled a wide region with average p (0.13-0.16) typical of the plains east of Phoebe.
V10 landed at the edge of a unit with p like VII, V13 and V14;
this unit is adjacent to the continuous, low \( \rho \) (< 0.1) region surrounding Beta, and extending to the NE. The exact interpretation of geologic nature of these units must await VRM and future Venera landers.

In summary, the Beta-Phoebe region, and in particular the elevated plains in this area, appear to be atypical of the more common lower plains (0-1 km) on Venus. They are low to average in \( \rho \), variable in roughness, but rougher than average, and more elevated than average. Most of the Venera landers sampled typical plains for this area. The exceptions are V9 (blocky, low \( \rho \), more elevated) and V12 (lowest \( \rho \), highest roughness), both of which sampled "locally" anomalous areas in the region, perhaps related to small volcanic or impact structures. Evidence for volcanism and meteor impact (12) can be found in the Beta-Phoebe region. VRM and further high-resolution Arecibo coverage of the region will greatly clarify these findings.

Table I: Radar properties from PV data (V9-V14 are Venera lander regions, 200 x 200 km).

<table>
<thead>
<tr>
<th></th>
<th>Beta-Phoebe</th>
<th>Venus</th>
<th>V9</th>
<th>V10</th>
<th>V11</th>
<th>V12</th>
<th>V13</th>
<th>V14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg. elev. (km&lt;0.50)</td>
<td>0.83±0.79</td>
<td>0.92±0.55</td>
<td>2.1±0.4</td>
<td>1.5±0.6</td>
<td>1.2±0.2</td>
<td>1.3±0.5</td>
<td>1.4±0.3</td>
<td>1.0±0.3</td>
</tr>
<tr>
<td>Avg. RMS slope</td>
<td>2.79±0.97</td>
<td>2.64±0.75</td>
<td>4.0±1.3</td>
<td>3.1±0.8</td>
<td>2.9±0.8</td>
<td>5.1±1.8</td>
<td>3.0±0.3</td>
<td>2.9±0.7</td>
</tr>
<tr>
<td>Avg. Reflectivity</td>
<td>0.126±0.04</td>
<td>0.130±0.03</td>
<td>0.10±0.02</td>
<td>0.10±0.03</td>
<td>0.15±0.04</td>
<td>0.08±0.04</td>
<td>0.15±0.08</td>
<td>0.14±0.04</td>
</tr>
<tr>
<td>Avg. &quot;Density&quot;</td>
<td>2.20 (1.67-2.75)</td>
<td>2.26 (1.84-2.7)</td>
<td>&lt;1.9</td>
<td>1.9</td>
<td>2.5</td>
<td>1.6</td>
<td>2.6</td>
<td>2.4</td>
</tr>
</tbody>
</table>

† From Krotikov (4) model where density = 4 \( \sqrt{\rho} \) (1-\( \rho \)) g/cm³ for a given reflectivity \( \rho \).