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Venus: The Nature of the Surface from Venera Panoramas

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Images of the surface of Venus obtained by the Soviet Venera 9, 10, 13, and 14 landers have been analyzed to provide a basis for understanding the nature of geologic processes operating there. The four spacecraft landed in the Beta-Phoebe region at median elevations in the upland rolling plains province. The landing points are each separated by distances of more than a thousand kilometers. The Venera panoramas were digitized and transformed into various perspectives in order to facilitate analysis and comparison with other planetary surfaces. Bedrock is exposed at the Venera 10, 13, and 14 sites and is characterized by semicontinuous, flat polygonal to subrounded patches up to several meters in width. The bedrock surface is often dominated by subhorizontal to horizontal layered plates with thicknesses of several centimeters and abundant linear and polygonal vertical fractures. Angular to subangular layered to platy blocks in the 5- to 70-cm range dominate the Venera 9 site and occur much less frequently at the other sites. Blocks appear to share many characteristics with the exposed bedrock and are interpreted to be largely derived from it. Soils (particles <1 cm) are abundant at the Venera 9, 10, and 13 sites but are uncommon at Venera 14. Features indicative of a strong eolian influence (moats, dunes, wind tails) are not observed. A striking aspect of the Venera landing sites is their extreme similarity despite separation distances of thousands of kilometers. Several hypotheses are considered for the origin of the bedrock surfaces, and we investigate in detail the hypothesis that bedrock originated from surface lava flows. In this interpretation, the broadly platy nature of the surface is analogous to the rolling and undulating nature of terrestrial pahoehoe flows caused by the formation and deformation of a semisolid crust. The layering is interpreted to be formed by a combination of upper thermal boundary layer formation and horizontal sheets formed by cooling and shearing during flow emplacement. Vertical fractures are attributed largely to joint patterns formed during cooling. This interpretation made on the basis of surface morphology is consistent with Venera 13 and 14 geochemical results which reported high potassium basalt and tholeiitic basalt compositions, respectively. If this interpretation is correct, large regions of the Beta-Phoebe area are likely to be characterized by lava flows. The relative freshness of features observed by Venera 14 suggests that some bedrock surfaces are geologically young or that erosion rates are low.

1. INTRODUCTION

Images obtained by landed spacecraft and astronauts on the moon [*Surveyor Investigation Team*, 1969; *Vinogradov*, 1971; *USSR Academy of Sciences*, 1966, 1969; *Swann et al.*, 1972; *Muehlberger et al.*, 1972], Mars [*Mutch et al.*, 1976*a*, *b*; *Garvin et al.*, 1981*a*, *b*], and Venus [*Florensky et al.*, 1977*a*, *b*, 1982*a*, *b*] have provided fundamental information about planetary surfaces at scales from millimeters to decameters. This information provides a means of (1) documenting the types of geologic materials on the surface, (2) understanding the geologic processes operating to form and modify planetary surfaces, (3) clarifying the nature of geologic features and processes interpreted from orbital spacecraft images obtained at lower resolution, and (4) establishing a physical basis for the understanding of the behavior of incident electromagnetic radiation (e.g., radar) utilized in remote sensing of planetary surfaces. The purpose of this paper is to analyze the information collected by the Soviet Venera 9, 10, 13, and 14 lander spacecraft imaging systems in order to allow a systematic comparison with other planetary surfaces and to provide an improved understanding of the surface of Venus. Plate 1 displays the locations of the Venera sites on a map of the topography of the Beta-Phoebe region on Venus. Table 1 summarizes details of the Venera lander missions. In order to facilitate morphologic and morphometric analysis of surface features, the Venera images were transformed into various perspectives, including those utilized in the analysis of the martian surface by the Viking landers [*Garvin et al.*, 1983*a*]. The array of images is described in terms of three basic characteristics: bedrock, fragments, and soil. Comparisons are then made with the surfaces of the moon, earth, and Mars to provide a basis for the interpretation of the surface of Venus.

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2. IMAGING SYSTEMS AND TRANSFORMATION METHODS

The cameras aboard the Venera spacecraft were digital facsimile scanning telephotometers [*Florensky et al.*, 1977*b*; *Keldysh*, 1979; *Moroz*, 1983; *Bokshteyn et al.*, 1983]. The cameras were located about 90 cm above the base of the spacecraft and were pointed 50° downward from the horizontal plane of the spacecraft. The imaging system scans in vertical sweeps of 40° and views 90° to the left and right of the subcamera point on the surface in front of the spacecraft. The camera rotates about a fixed axis producing an inclined cylindrical projection. This particular camera orientation was used in order to allow both the near-field and the far horizon to be imaged using a single, fixed viewing geometry. This viewing geometry results in the apparently inclined horizon visible at the far left and right of the unrectified panoramas (Figures 1–3). Objects in the near field directly in front of the lander impact ring are relatively undistorted, while objects nearest the horizon are stretched by a factor of 2–3 in the horizontal direction. Veneras 9 and 10 were each equipped with cameras on one side of the spacecraft, while Veneras 13 and 14 were each equipped with two similar imaging systems, located 180° apart. For Veneras 13 and 14 the 180° azimuthal coverage for each camera system allowed small regions of overlap in the lower corners of the panoramas so that, when rectified, a continuous 360° view of a narrow portion of the surface of Venus can be produced. Veneras 9 and 10 obtained black and white images only, while Veneras 13 and 14 obtained black and white and color images [*Florensky et al.*, 1982*a*, *b*]. The dimensions of various spacecraft parts are listed for scale in Table 2.