Venus: Detailed Mapping of Maxwell Montes Region

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From October 1983 to July 1984, the north hemisphere of Venus, from latitude 30° to latitude 90°, was mapped by means of the radar imagers and altimeters of the spacecraft Venera 15 and Venera 16. This report presents the results of the radar mapping of the Maxwell Montes region, one of the most interesting features of Venus' surface. A radar mosaic map and contour map have been compiled.

The main purpose of the spacecraft Venera 15 and Venera 16 was to map the north hemisphere of Venus. For a period of 8 months, an area of 115×10^6 km^2 was mapped. As an example, this report gives the results of the mapping of Maxwell Montes.

The spacecraft were launched in elliptical, approximately polar orbits with periods of rotation of 24 hours. Their distance above Venus' surface was from 1,000 km at periapsis (about 62° latitude) to 65,000 km at apoapsis.

The spacecraft were equipped with an 8-cm wavelength radar system comprising the synthetic aperture side-looking radar and radar altimeter. In the course of the radar survey, the electrical axis of the radar altimeter antenna was directed along the local vertical to the center of the planet using the spacecraft's astro-orientation system. The angle between the electrical axis of the side-looking radar antenna and the local vertical was 10°.

Because the elements of the planet's surface were spaced at different intervals and had different radial velocities relative to the spacecraft, reflected and received signals had a different time delay and frequency because of the Doppler effect. This was used to separate waves reflected from particular elements and to create an image. The reflected signal readings were stored on board the spacecraft and then transmitted to Earth for processing. Separation of the reflected signals according to the time delay and the Doppler frequency shifts and construction of the radar images and the height profiles were subsequently accomplished by a special digital device—an electronic Fourier processor.

In each passage of the spacecraft near Venus' surface, a swath 120 km in width and 7500 km in length extending along the ground track was surveyed. Part of a swath 1100 km in length, surveyed by Venera 16 on 20 January 1984, is shown on the bottom of Fig. 1 (*1*). This is a picture of the Maxwell Montes region showing a large crater, previously named Cleopatra Patera. The spacecraft was moving from left to right, its track being above the swath (corresponding to 0° in vertical scale). The stronger the power of the reflected signals, the brighter the detail on the image. The slopes facing the incident ray look bright, and the slopes facing away from the incident ray look dark.

The radar image is matched with the height profile (top of Fig. 1) (*2*) obtained 3 days earlier; the white line shows the ground track (offsets are due to altitude differences). The maximum elevation for a given track is 11 km above the mean radius of Venus (6051 km according to the International Astronomical Union). The crater crossed by the track of the survey is situated on a mountain slope and is of complex shape. Comparison of the image with the profile shows that, inside the larger crater (1.5 km deep), there is another crater of smaller diameter whose bottom is 1 km deeper. The bottom of the inner crater is flat, and the walls are steep.

At present, mosaic and topographic maps of Venus are drawn by combining individual swaths and height profiles in a definite map projection. Figure 2 shows a mosaic map of Maxwell Montes and the surrounding region and Fig. 3 shows a topographic map. Both were compiled from the radar survey of Venera 15 and Venera 16 from 30 December 1983 to 1 February 1984 (*3*).

The territory as shown in Fig. 2 (total area, 3.75×10^6 km^2) is the most detailed image of Maxwell Montes available (*4*). Lakshmi Planum, a large plateau 5 km in height, is slightly west of the two craters in the Cleopatra Patera region. Both craters are circular in shape (*5*). The center of the inner crater (55 km in diameter) is slightly north-

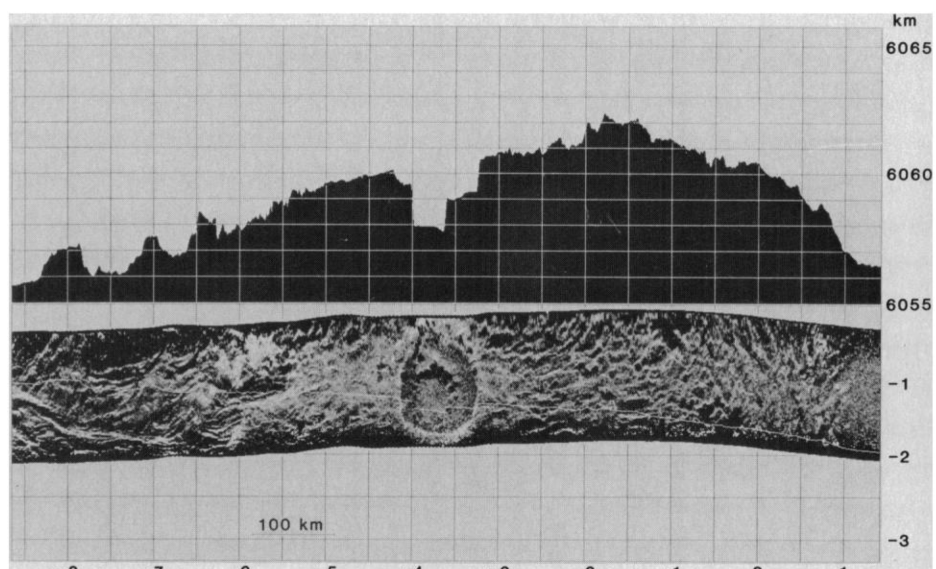

Fig. 1. (Bottom) Radar image of Maxwell Montes from Venera 16 on 20 January 1984. The angular distance relative to periapsis (~62° latitude), measured in degrees from the planet's center of mass (1° on the Venus surface covers 105.6 km), is plotted along the horizontal axis. This value is negative at latitudes higher than 62°. The angular distance relative to the orbit plane is plotted along the vertical axis. (Top) The surface height profile calculated along the spacecraft track on 17 January 1984, which is depicted by the white line in the image. The vertical axis for the height profile gives the surface radius value at each point (in kilometers). This value is calculated as the difference between the distance from the planet's center of mass to the spacecraft and the measured height (*2*). The vertical scale is enlarged 32 times compared to the horizontal scale.

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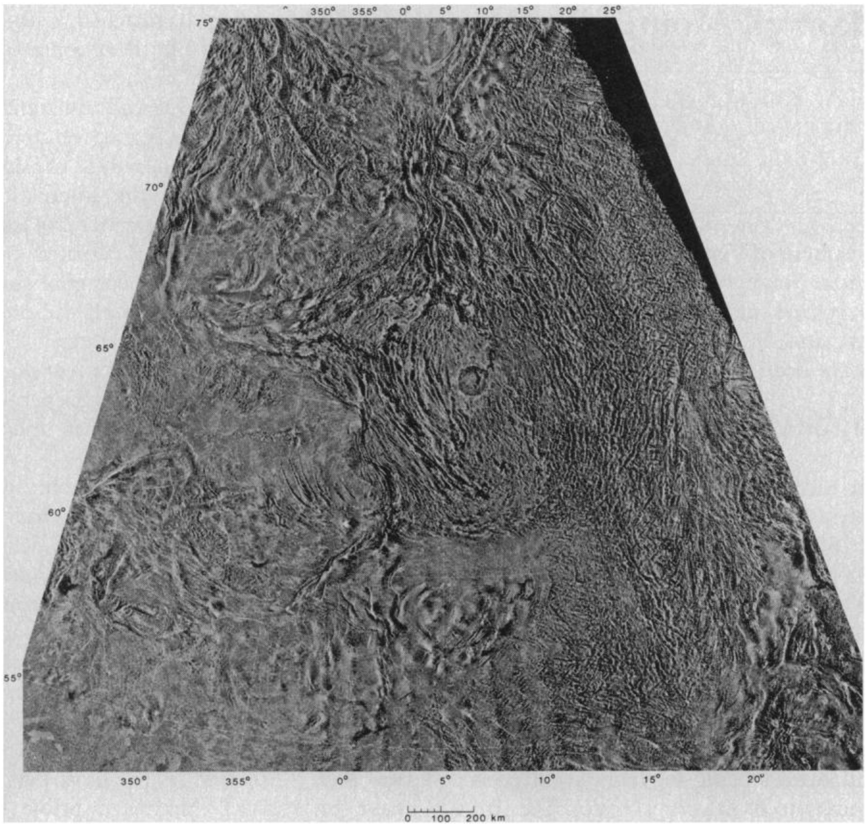

Fig. 2. Mosaic map of the Maxwell Montes and surrounding region taken from Venera 15 and Venera 16 radar observation data from 30 December 1983 to 1 February 1984. Projection, Lambert-Gauss normal equiangular conic. Standard parallels, 58.3° and 72.4°. Radiowaves are incident from the east at an angle of about 10° to the local vertical.

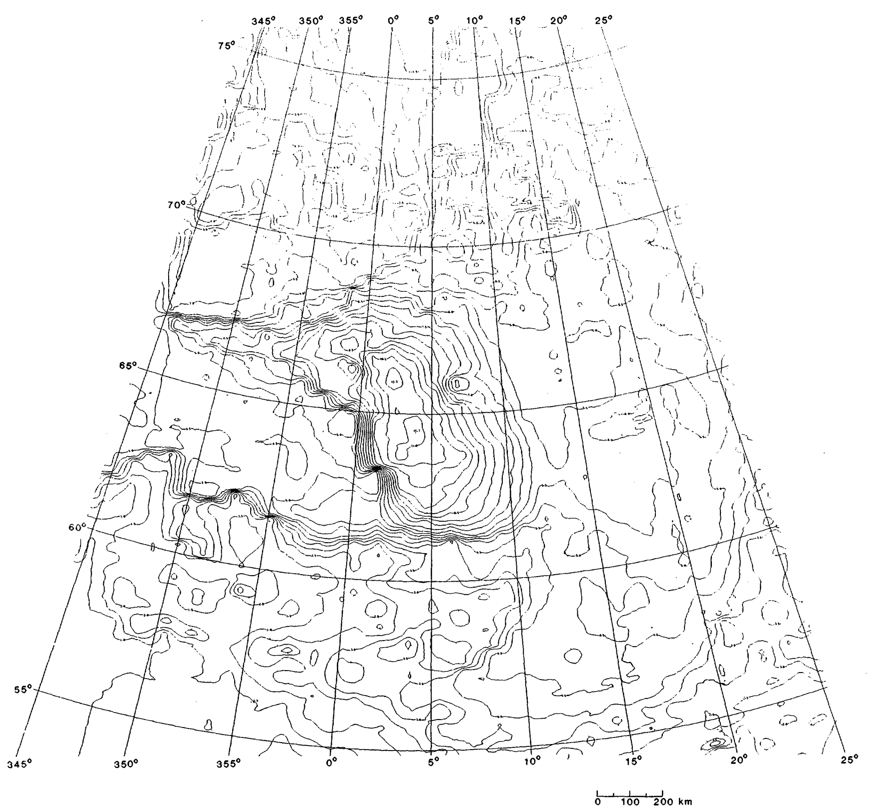

Fig. 3. The Maxwell Montes and surrounding region contour map (coordinates given in Fig. 2). Horizontals with 500-m steps are plotted relative to the level of the mean sphere of radius 6051.

west of the center of the outer crater (95 km in diameter). The eastern wall of the outer crater is low, and the bottom merges with the eastern slope of the mountain range (*6*).

To the west the Cleopatra Patera region is fringed with almost parallel ridges extending hundreds of kilometers and spaced 5 to 15 km apart. In this oval-shaped region (400 km from north to south, 200 km from east to west), the highest altitudes exceed 10 km (above the sphere radius of 6051 km), making it the most elevated region of Venus. In the northern part of the oval, 200 km from the center of Cleopatra Patera (2.3° longitude, 65.9° latitude) the highest point (elevation, 11.5 km) is located, as fixed by the radar altimeter of Venera 16 on 14 January 1984 (Fig. 4)(*7*). South-southeast of this point (3.9° longitude, 64.4° latitude) is the second highest point (elevation, 11.3 km). As shown by horizontals (Fig. 4), the northern part of this mountain region extends westward, where the heights are still greater than 9 km.

The height decreases sharply toward the southwest. Over a distance of 20 km the slope descends by 4 km, and the average slope angle exceeds 10°. From this side the Maxwell Montes region is pressed by Lakshmi Planum, and parallel folds are frequent. The folds fringing Cleopatra Patera are also seen from the east (Fig. 2), but here their structure is destroyed by transverse shifts. The region surrounding Cleopatra Patera thus appears to be flatter than the Maxwell Montes region. The relief folds seem to be covered by material from volcanic activity or meteorite impacts. Another

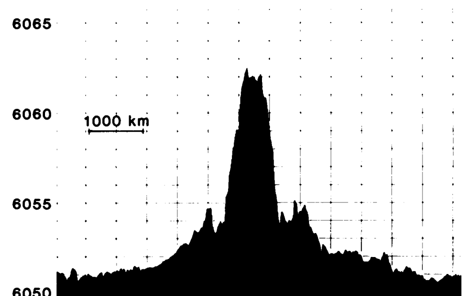

Fig. 4. The height profile of the Venus surface in the Maxwell Montes region, obtained from Venera 16 on 14 January 1984, showing the location of the highest point of the Venus surface (−3.7° relative to periapsis). The symbols are the same as in Fig. 1. The vertical scale is enlarged 320 times compared to the horizontal scale. The total track length is 7100 km. The north pole lies at approximately −30°. In contrast to the data for Fig. 1, reflected signal processing represents the altitude of the spacecraft above the mean surface of a region 40 to 50 km in diameter.

possible impact crater (25 km in diameter) is situated slightly below the middle of Fig. 2 (6.5° longitude, 56.9° latitude).

Toward the south, the Maxwell Montes region and Lakshmi Planum merge into Sedna Planitia. The steepness of the slope in the southern portion of Lakshmi Planum (Vesta Rupes) is greater than 10°. In the northern portion the folds come together in a winding "plait," which descends to an altitude of 2 km over a distance of more than 500 km in the meridional direction and then merges into the plain. This is a southern part of the vast plain close to the pole that was discovered by Venera 15 and Venera 16. In the northern and southern parts of this region (Fig. 2) are numerous cone-shaped features standing out especially clearly on the background of smooth surface relief. These cones are most likely of volcanic origin.

REFERENCES AND NOTES

1. The image contains 1350 vertical lines, each having 195 points. The slant range and radial velocity relative to the spacecraft were calculated for each point of the image; for this purpose the data for distance and velocity with respect to the Venus center of mass were used. The lines and points are separated from each other by 800 m, which is slightly less than the radar spatial resolution (~1 km). For obtaining the same contrast of surface features in the regions of high and low reflectivity, the power of the reflected signal was normalized to the mean value in the window (160 km) running along the swath.
2. The processing of the radar altimeter reflected signals yielded the spacecraft altitude over the mean surface of the strip (40 km long, 7 km wide) with a root-mean-square error of about 50 m, the step along the ground track being 3 km. This error characterizes the relative accuracy of the relief height determination at over a distance of 500 to 1000 km along the track. At the ends of a track, as well as between tracks, the error may be 10 times larger. Considerable deviations of the local radius from the value of 6051 km, which is considered the radius of the sphere on which the image is plotted, resulted in appreciable perspective distortions in the crater configuration that were also taken into account while plotting the radar altimeter track on the image.
3. The radar image bands for each day of the survey were plotted on the sphere of 6051 km radius (venusian coordinate system) and then projected onto the cone surface drawn between two standard parallels. In accordance with the International Astronomical Union, the right ascension of the Venus rotation north pole is taken as 273.8°, the declination as 67.2°, and the period of rotation as 243.01 days. Zero meridian position of the venusian coordinate system is defined from the observation that, on 20 June 1964 at 0 hours ephemeric time, the longitude of Venus' central meridian was 320°. On a contour map the measured height values were reproduced directly on the altimeter track, whereas between the tracks they were interpolated.
4. Radar surveys by the spacecraft Pioneer Venus [H. Masursky *et al.*, *J. Geophys. Res.* **85**, 8332 (1980)] showed that Maxwell Montes is the most elevated region on Venus, although low spatial resolution made the analysis of their nature difficult. The general structure of the central part of the mountainous region together with Cleopatra Patera was visible on the radar images obtained recently from Earth at the Arecibo facility [D. B. Campbell, in *Abstracts of the Twenty-fifth Plenary Meeting of COSPAR* (Graz, Austria, 1984), p. 69]. However, the surrounding areas having smoother surfaces were less visible because of the low level of reflected signal. When Venus is observed from Earth (taking into account the large distance), the angle between the incident ray and the local vertical is equal to the venusian latitude, which is 60° to 70° for Maxwell Montes. From the Venera 15 and Venera 16 radar survey, the incident angle is from 9° to 15°. Therefore backscattering has a high intensity, and the surface features are observed fairly well throughout the map (Fig. 2). As a rule, the reflected signal does not drop below the level that exceeds the noise power of the receiving equipment by 10 decibels. This gives a uniform quality of radar images in regions with both high and low reflectivity.
5. The height of the local relief and corrections to the spacecraft coordinates were taken into consideration. The spacecraft coordinates were specified in accordance with the procedure that considers disturbances in the parameters at the time when the astro-orientation system is being switched on. Comparison with Fig. 1, where the image was constructed on the sphere of 6051 km radius, shows that taking into account the height of the local relief leads to cancellations of the image distortions that are particularly observable in the Cleopatra Patera region.
6. In the initial construction of the contour map, the measurements were averaged in a running window with a 100-km effective diameter, which caused smoothing of the relief [V. A. Kotelnikov *et al.*, *Pis'ma Astron. Zh.* (*U.S.S.R.*) **10**, 883 (1984)].
7. According to the Pioneer Venus altimeter data, the highest point of Maxwell Montes lies 220 km farther south (longitude 2.2°, latitude 63.8°), its height being 11.1 km (also above the level of the mean sphere of radius 6051 km)[H. Masursky *et al.*, *J. Geophys. Res.* **85**, 8332 (1980)].

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X-ray Diffraction from Magnetically Oriented Solutions of Macromolecular Assemblies

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A simple system was developed for obtaining x-ray diffraction patterns from magnetically oriented solutions of macromolecular assemblies. A small permanent magnet was designed that produces a magnetic field of 16 kilogauss in a volume of 1 cubic millimeter and is mountable on most x-ray cameras. Many subcellular structures have sufficient diamagnetic anisotropy that they exhibit orientation in dilute solution when placed between the poles of the magnet. Diffraction from solutions oriented in this magnet can provide substantially more structural information than small-angle scattering from isotropic solutions. In favorable cases, such as dilute solutions of filamentous bacteriophages, it is possible to produce oriented fiber diffraction patterns from which intensities along layer lines can be measured to 7-angstrom resolution. The magnetically induced birefringence observed in solutions of other macromolecular assemblies suggests that this technique may have broad applicability to subcellular structures.

MOST MACROMOLECULAR ASSEMblies exhibit sufficient diamagnetic anisotropy (*1*) that they become oriented in a magnetic field of moderate strength (10 to 20 kG). These include such widely diverse structures as the filamentous bacteriophages (*2–4*), whole retinal rods (*5*), fibrin (*6*), purple membrane (*7*), nucleic acids (*8*), and sickle cell hemoglobin fibers (*9*). Orientation of these assemblies in solution has usually been characterized by measurement of magnetically induced birefringence or neutron diffraction. Whereas small-angle diffraction from isotropic solutions produces a one-dimensional data set containing limited information, diffraction from an oriented solution produces a two-dimensional data set that can provide detailed information about molecular structure (*10*). Consequently, x-ray diffraction from magnetically oriented solutions has the potential to produce more structural information than conventional solution scattering.

Technical problems have made x-ray diffraction studies of solutions in a magnetic field difficult. For example, the magnet geometry is usually incompatible with the geometric requirements of x-ray cameras. High-quality x-ray diffraction patterns require the x-ray source, focusing optics, specimen, and film (or detector) to be within a few centimeters of each other. This is difficult to achieve when the specimen is between the poles of a large electromagnet or surrounded by the Dewar of a superconducting magnet. Furthermore, a weak fringe magnetic field will deflect the electron beam used in the production of x-rays in a conventional x-ray source (*11*). An alternative approach is to orient a specimen in a magnetic field and then remove it for study. For dilute solutions this approach is impractical because, once the solution is removed from the field, orientation of the particles decays. X-ray exposure appears to hasten this decay.

Orientation of the specimen can be maintained on removal from a magnetic field if its viscosity is substantially increased while in the field. Stable, highly oriented fibers of filamentous bacteriophages have been produced by partial drying of relatively dilute solutions (30 to 50 mg/ml) (*3, 4, 12*) to

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