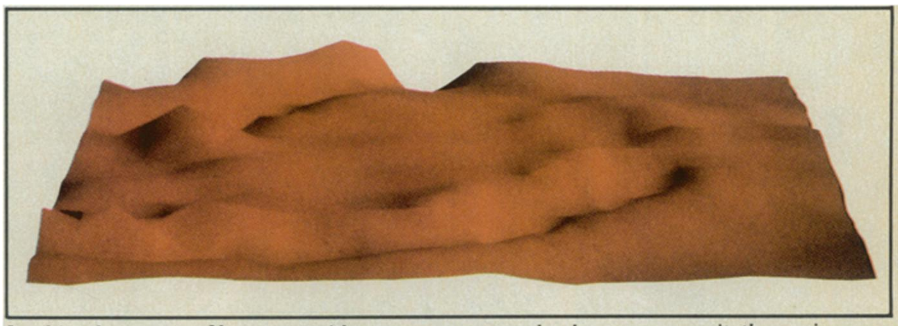
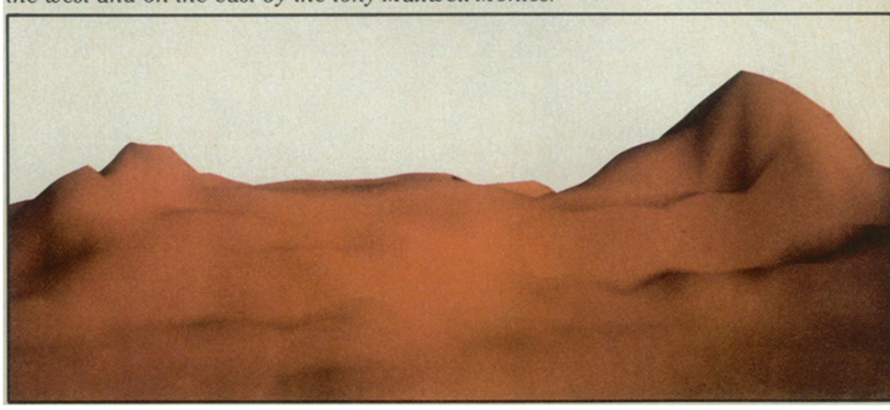
ONE EYE–MANY VISIONS

The only global look at the surface of Venus has come from the Pioneer Venus orbiter's radar, and computer-armed researchers are making the most of it

BY JONATHAN EBERHART



Looking low across Venus as neither camera nor radar has ever seen it, these views are nonetheless "real," showing the planet's ups and downs as slopes in a synthetic surface created from the Pioneer Venus orbiter's radar altimetry data by a computer whose "viewpoint" can be moved to different altitudes, angles and locations. Slopes are computer-"smoothed" between data points, and vertical scale is highly exaggerated. Above: Looking north across Artemis Chasma, the ring-shaped canyon, some 2,200 km across, south of Aphrodite Terra. Below: Vast Lakshmi Planum, bounded by the Akna Montes on the west and on the east by the lofty Maxwell Montes.



J. Gomez, J. Blinn/JPL Computer Graphics Lab

Haze-shrouded Venus has been probed by radar from earth for two decades, at the beginning of which time the existing equipment could barely even detect the planet's presence. Today the field is vastly more sophisticated, but earth-based observers can still "see" only a small portion of the surface. A sufficiently strong radar echo requires the two planets to be close — with Venus at inferior conjunction, between earth and the sun — and Venus's rotation rate is such that the side facing earth shifts only a few degrees between successive conjunctions. It would take more than a century to cover all 360° of longitude, and high latitudes are virtually off limits due to the weak echo that results from the long atmospheric path-length and high surface scattering confronting the incoming signal. Elevation measurements in particular are confined to a narrow band near the equator.

On Dec. 4, 1978, however, the Pioneer Venus orbiter carried a radar into a Venus-circling path that would give it the first-ever global view of the planet's long-hidden surface. It is not completely all-encompassing — the spacecraft's 74° orbital inclination and 17°N periapsis latitude, plus the instrument's "look-angle" and 4,700-kilometer maximum operating altitude, confine its data to between 74°N and 63°S. But that's about 93 percent of the planet, most of which had never before been "seen" at all. Furthermore, the surface of Venus affects the reflected radar signal in a variety of revealing ways, and the radar itself operates in different modes. To get the most from the new treasure trove of data, researchers have developed several ingenious ways of looking at the results.

The most straightforward of the radar's capabilities is measuring the heights of conspicuous ups and downs such as mountains, canyons and plateaus, by simply timing the echo as an indicator of the spacecraft's distance from its target point to within 200 meters. One way of displaying the relative elevations has been as a "shaded relief map" (SN: 6/7/80, p. 359) whose peaks and valleys are made visible by using computer-added "sunshine" (of which there would be none, of course, in a radar map) to cast synthetic shadows. Applied by Eric Eliason of the U.S. Geological Survey in Flagstaff, Ariz., together with colleagues including principal investigator Gordon Pettengill of MIT, this technique best shows the surface's "high-frequency variations" — steep slopes — though it may completely overlook gently sloping features even of tremendous size.

An alternative is the color altimetry map on the next two pages. Here, the radar data are displayed not as relative elevations, but as altitudes—distances from the planet's center. The measurements have been "binned," or grouped together, into half- and one-kilometer intervals, with different colors assigned to the different altitudes. An example of what the black-and-white shaded relief map misses is Atalanta Planitia, a vast, roughly circular feature some 1,300 km across, centered at about 65°N by 165°. The colors clearly bring out its basin-like shape, but because it descends so gradually from its rim to its central depth, the shadowing of the shaded-relief method shows nothing there at all. Shadowing has also been applied to the color altimetry map, in fact, and emphasizes such steep-sided features as the two great "continents," Ishtar Terra and Aphrodite Terra. But it remains for the false-color scheme to reveal details of the much gentler, rolling plain that comprises 60 percent of the surface, varying by no more than a kilometer from the planet's average radius of 6,051.4 km.

Besides looking at the surface's large-scale features, another use of the radar is to measure its roughness on a scale of a meter or so, giving an idea of the general nature of the terrain that researchers can compare with, for example, typical volcanic basalt fields on earth. The idea here is to measure the "scatter" in the timing of the radar echo, which happens because parts of the beam follow paths of different lengths as they bounce around among boulders, pits and rock facets before they head back toward the antenna. Over much of Venus, the roughness pattern seems to correspond in general with the larger-scale features, but there are some large, rough markings (see top right photo p. 170) that match nothing known from the present altimetry data. Also, roughness data alone can be misleading. Researchers once thought lofty Lakshmi Planum to be a basin, when they had only roughness measurements to show its smooth center

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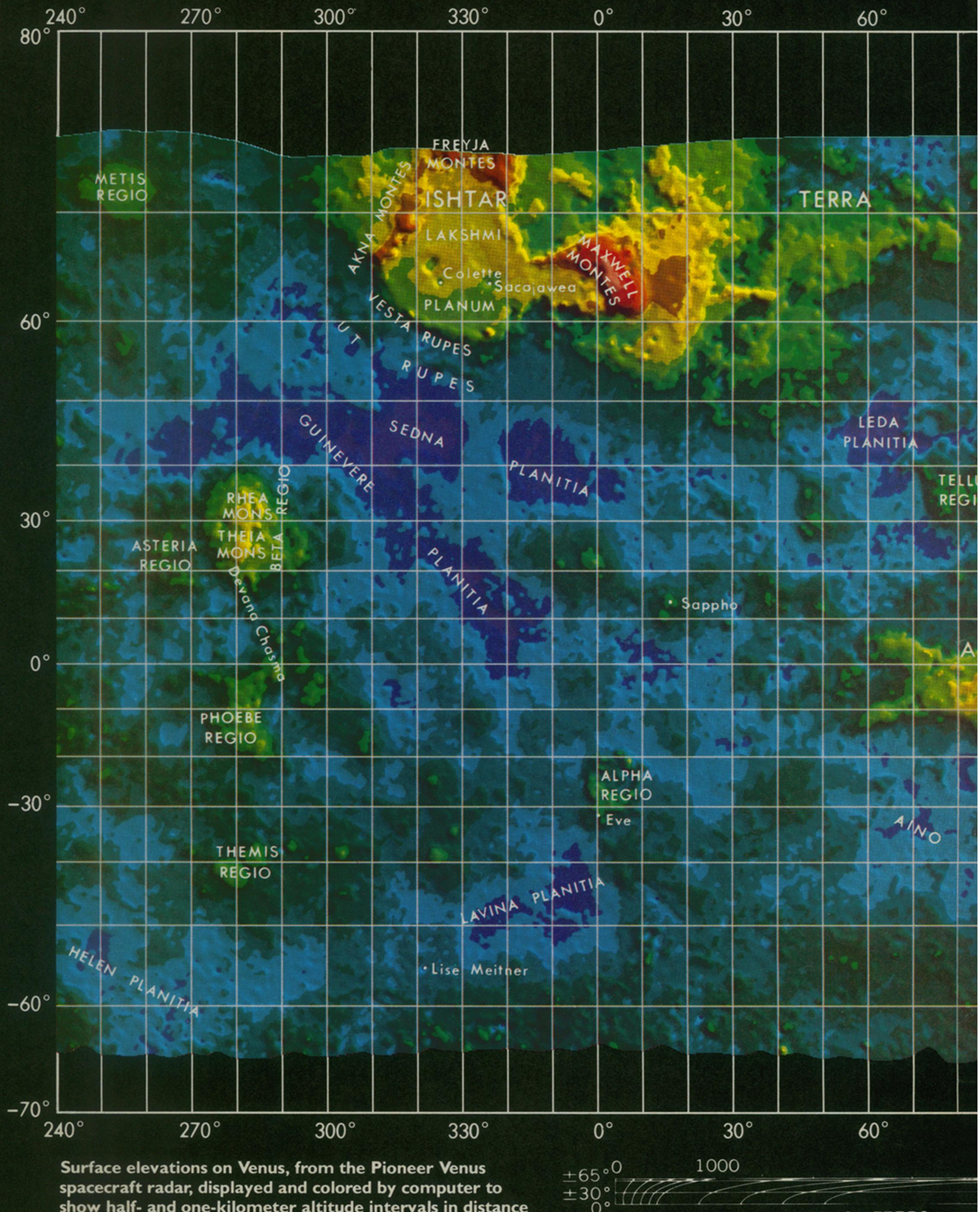
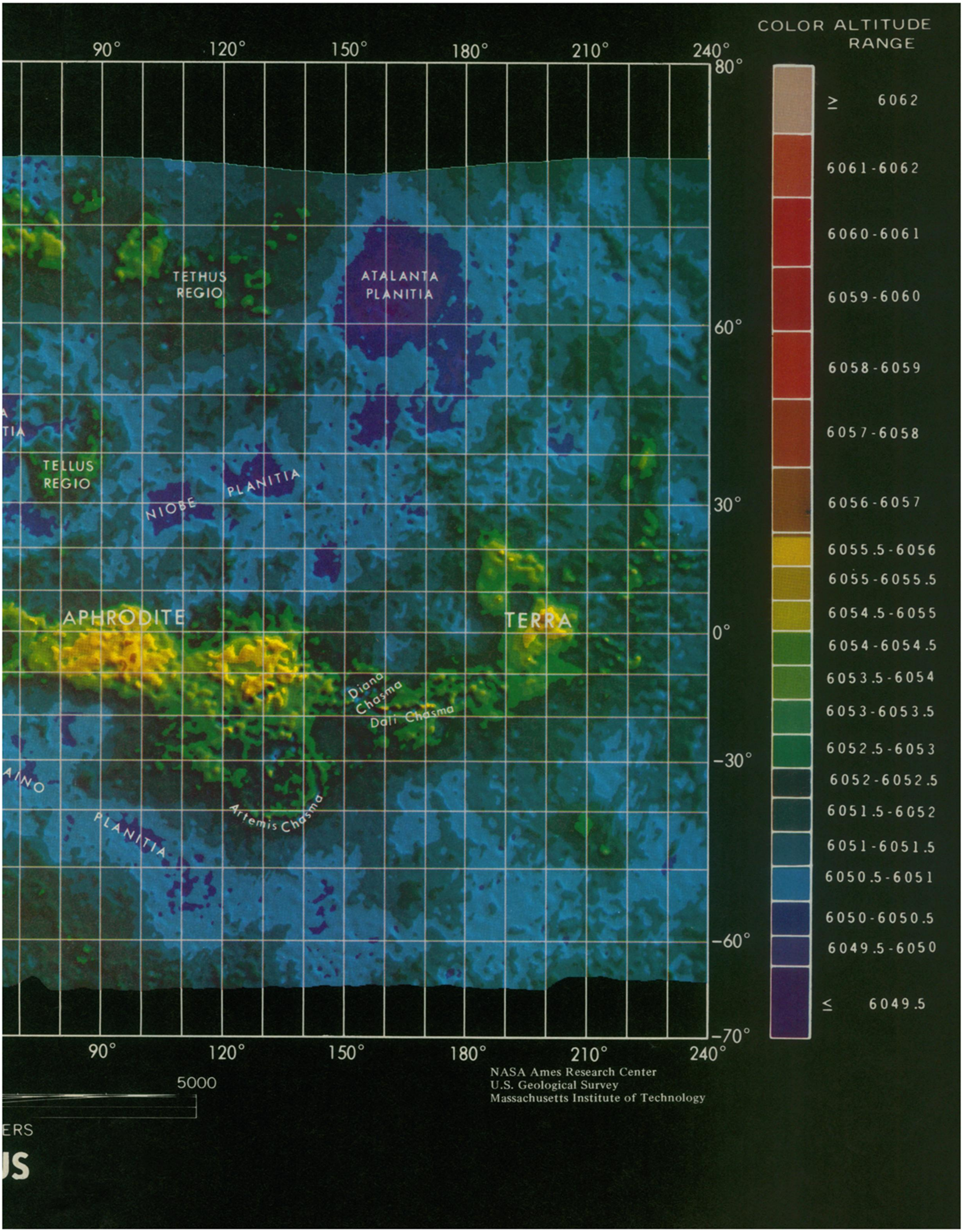


Surface elevations on Venus, from the Pioneer Venus spacecraft radar, displayed and colored by computer to show half- and one-kilometer altitude intervals in distance from the planet's center. Relief effect is enhanced by computer-generated "shadowing," as though the sun were shining from upper right.

VENUS


COLOR ALTITUDE RANGE
≥ 6062
6061-6062
6060-6061
6059-6060
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180°
210°
240°
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60°
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TETHUS REGIO
ATALANTA PLANITIA
TELLUS REGIO
NIOBE PLANITIA
APHRODITE TERRA
Diana Chasma
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Artemis Chasma
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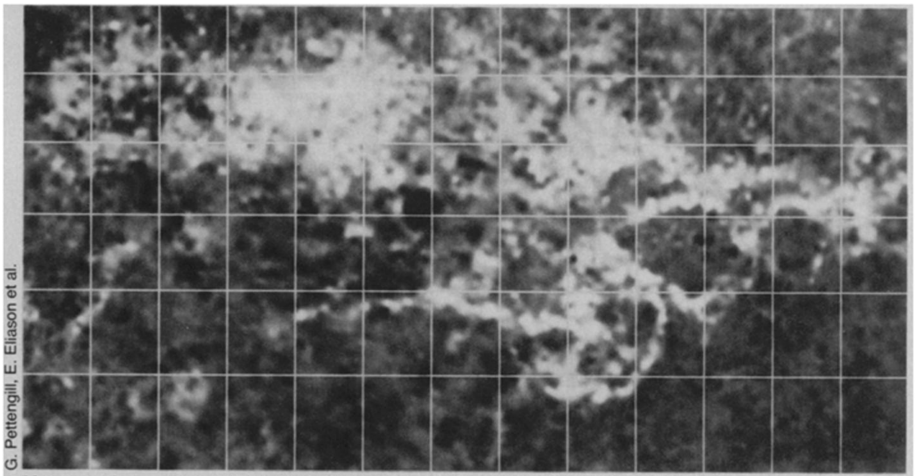
NASA Ames Research Center
U.S. Geological Survey
Massachusetts Institute of Technology

... Venus

and rough rim. It was a puzzlement when altimetry data showed Lakshmi to be a high plateau, says Harold Masursky of the USGS, until it was realized that the radar-bright (rough) edge could owe its appearance to debris that had simply rolled down



Using only a single kind of radar analysis can be perplexing. Earth-based radar image from Arecibo in 1976 showed Lakshmi Planum on Venus (left) to have a smooth (dark) center with a rough (bright) border, prompting researchers to think it was a vast basin — until altimetry data (previous page) showed it to be a 3.3-kilometer-high plateau. Meter-scale roughness measurements from Pioneer Venus orbiter show a rough linear feature some 3,000 km long extending westward from the circular canyon Artemis Chasma south of Aphrodite Terra (above), yet it hardly shows on the altimetry map, suggesting that the streak may be less than 200 meters high (or deep).

onto the slope from the flatland above.

The spacecraft's instrument also doubles as a side-looking, "imaging" radar, whose results (not shown) combine both slope and roughness measurements. Constrained to between about 50°N and 10°S, its import is still being studied, but its images, Eliason notes, have already been used to create spectacular stereoscopic views.

The diverse data and their varied presentations are not confined to flat maps such as Mercator projections. At the computer graphics laboratory of Jet Propulsion Laboratory in Pasadena, James Blinn has computer-manipulated the data into a "movie" of a rotating globe that can be viewed from any distance and direction. Eliminating the distortions of flat maps, it shows, for example, that the northern highland Ishtar Terra is far smaller than near-equatorial Aphrodite Terra, though the two appear similar on Mercator projections. Also at the JPL facility, Julian Gomez has been able to display portions of the surface from low angles and altitudes that were inaccessible to the spacecraft. (The October JOURNAL OF GEOPHYSICAL RESEARCH will be devoted to the Pioneer Venus mission, including a detailed description of the planet's geology and surface properties by Pettengill, Masursky, Eliason, Peter Ford, George Loriot and George McGill.)

And, with the all-concealing atmosphere still in the way, radar still has more to offer. The limited spatial resolution of the Pioneer Venus instrument keeps it from seeing craters smaller than about 20 km across, and the roughness data are insufficient to enable such key judgments as whether a given near-circular feature represents a meteorite impact or a lava-filled mare. Long sought by researchers, and hoped for a start in NASA's upcoming budget, is the Venus Orbiting Imaging Radar spacecraft, which would yield a vast improvement in resolution including spot-mapping with an advantage over Pioneer Venus of more than 100-fold. With orbiting cameras made useless by the hazes and clouds, radar is proving to be a remarkable substitute — and in some ways, even preferable. □

Radar image of northeast Tennessee from the earth-orbiting Seasat illustrates potential of proposed Venus Orbiting Imaging Radar spacecraft (VOIR). *Left: Image processed to simulate best earth-based resolution of Venus, roughly equivalent to photographic resolution of 20,000 km per line pair. This is about 2.5 times the best from the Pioneer Venus orbiter, which would show this image only as a gray square. Center: Same image reprocessed to the 600-meter resolution at which* VOIR *would map most of the planet, revealing major ridge patterns and other details invisible in existing Venus data. Right: 1 or 2 percent of surface would be scanned at 150-meter resolution, showing finer-scale features that could help determine terrain-modifying processes.*