
Spacecraft and ground-based radar altimetry and images have now permitted a first look at the global distribution of geologic terrain units and a first approximation of a crustal evolutionary history of Venus. Pioneer-Venus radar observations have shown that about 20% of the planet (between 63° S and 75° N latitudes) consists of "lowland" plains characterized by low surface scattering efficiency (radar-dark areas with few rocks or radar-absorbing materials), 1° to 2° meter-scale root mean square (rms) slopes, and elevations between 0 km and -2.9 km (from the mean radius of 6051.4 km). These areas may be covered by basaltic lava flows like the basins of the Earth and Moon. Seventy percent of the surface is "rolling uplands" with slightly higher scattering efficiency, 1.5° to 3° rms slopes, and elevations between 0 km and 3 km. A "granitic" composition is inferred from Venera 8 data. The upland's are characterized by many shallow dark-floored very shallow "craters", many smaller ringlet "craters", and wispy linear features that are radar bright and rough but with little relief that may be fault zones. Alpha Regio (25° S 5° E) is a low plateau (1.5 km above the mean radius) in the rolling "cratered" uplands. It is transected by multiple complex anastamosing linear features. It resembles the terrestrial Basin and Range structures and apparently has been complexly ruptured by faulting. It is surrounded by "cratered" plains with minor faulting that may represent exposed ancient crust. Crater densities of the "upland" region from the Arecibo images lie along the curves for cratered uplands of Mars and the Moon. Densities from Pioneer Venus and Goldstone images are bias low because of low resolution and restricted area. Tectonic trend rosettes closely resemble some terrestrial and martian rosettes and strongly differ from the "lunar grid" patterns that characterize the Moon and Mercury. The remaining 10% of Venus is "highlands" characterized by high surface scattering efficiency (radar bright due to rocky surfaces), rms slopes between 3° and 10°, and elevations to 11.2 km (the top of Maxwell Montes at lat 65° N long 0°). The "highlands" observed thus far consist of two continental-size masses--Ishtar Terra and Aphrodite Terra--and a group of "islands" (e.g. Beta Regio) that are highlands of small extent. A fourth elevated feature about 3 km high not observed by Pioneer-Venus has been described from Earth-based observations (Campbell et al., 1972) as lying on the equator (Long 190° to 200°).

The northern continent (Ishtar Terra) is as large as Australia and consists of a high plateau, Lakshmi Planum, with mountain ranges (Akna Montes and Freyja Montes) lying on the west and north, respectively. The plateau is a poor radar scatterer (radar dark) with 1° to 4.5° rms slopes and relatively low relief variations, although lying at about 5 km above the planet's mean ("oceanic") level. The annulus of greatly varying rms slopes, scattering efficiency, and topographic gradient marking the edge of Lakshmi Planum is probably associated with slumping and talus formation on the slopes of a boundary fault scarp about 2 km high. A parallel scarp about 1 km high steps down into the adjacent lowland. If the plateau were basaltic lavas it would produce a large gravity anomaly, which is not observed (Phillips et al., 1979). Therefore, it may consist of thin lavas on uplifted ancient crust, as in the Tharsis Montes on Mars.

Maxwell Montes, which sits atop this 5-km-high plateau of Ishtar Terra,
appears from Earth-based high-resolution images to be atectonically disrupted volcanic construct of relatively old age. Again the lack of a gravity anomaly indicates that it may not be basaltic, but rather intermediate to silicic in composition. Farther to the east of Maxwell Montes, an extended area of complex ridges and troughs and high 4.5° to 10° RMS slopes may represent additional evidence of tectonically disrupted crust. The extreme brightness of just the Maxwell Montes feature on Ishtar Terra indicates that the steep slopes of this Mt. Everest of Venus are covered with rocks larger than 10 cm. The remainder of the upland plateau east of Maxwell Montes has fewer rocks but similarly high RMS slopes at the meter scale. Earth-based depolarization studies predicted the blocky and topographically rough slopes of Maxwell Montes (Jurgens, 1970).

Aphrodite Terra, half the size of Africa, lies on the Venus equator. It may be older and more degraded than Ishtar Terra and does not appear to contain uplifted plateaus or obvious volcanic constructional mountains. The "continental" feature rises to 6 km above the planet's mean level and exhibits high scattering efficiency, large (4.5° to 7°+) RMS slopes, and strong depolarization capability (as determined from Earth-based observations). East of Aphrodite, a broad (60° x 60° of latitude and longitude) plateau rises an average of 2 km above the mean level and contains a complex of ridges and trenches of curvilinear shape. The trenches (Pettengill et al., 1979) have distinct raised rims, and the general region is characterized by high RMS slopes that on Mars are indicative of rugged canyon walls and chaotic terrain. A 1500-km-diameter, semicircular feature with two ridges and an intervening trough is an intriguing structure of possible volcano-tectonic origin located on the low plateau at lat 35° S, long 140°.

Beta Regio is the third recognized highland feature. It is a large region of complex scattering efficiency variations, elevation perturbations, and RMS slope diversity. The region is dominated topographically by the features Theia Mons and Rhea Mons, 5.4 km high above mean level. A large ridge of 2 km relief extending south of Theia Mons turns to the east and continues south to terminate at approximately 20° S. The southernmost portion of this ridge contains a large canyon-like structure first described in high-resolution Earth-based radar images by Malin and Saunders (1977) and Goldstein et al. (1976). A second linear structure 4500 km long extends S 50° W from Rhea Mons and is characterized, as is the south-trending structure, by high (4.5° to 10°) RMS slopes and high scattering efficiency (radar bright). Farther to the south two additional highland areas lie along the north-south tectonic trend. The Thea Mons feature is seen on high-resolution Earth-based images to have trends of high scattering efficiency radiating in all directions away from its central region. The presence of these features, in addition to a summit depression on Thea Mons, suggests a basaltic volcanic constructional origin of young age for these "islands" of highland terrain. Veneras 9 and 10 landed just east of these shields and determined that the rocks were "basaltic" from gamma ray spectrometry.

The distinctly unimodal distribution of relief on Venus and a low center of mass—center of figure of <400 m (Pettengill et al., 1980) could indicate that the 70% of the planet described above as "rolling uplands" could represent the ancient continental crustal material. If such a universal level of continental crust does exist, it could imply that the crust deforms easily and that the continents were widely distributed over much of the planet's surface at an early stage. On the other hand, if Ishtar Terra and Aphrodite Terra are geologically old, their height above mean "oceanic" level
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indicates that the continental crustal rocks must be relatively creep resistant and that water is scarce or absent in the crust (Weertman, 1979). Further analysis of the Pioneer-Venus data may provide some important clues as to the age of these geologically important highland terrains.

Geologic History: There was a widespread, highly differentiated, cratered, ancient crust. Two continental areas formed, possibly over mantle plumes, although clearcut uplift and volcanic construct are seen only in the northern area. East of the two continents lies a tectonically disrupted zone of ridges and trenches that descend into lowlands that may be floored by mare-type basalt flows that are young, that is, uncratered. Continued tectonism and volcanism occurred in the Beta Regio with construction of basaltic shield volcanoes.

References