
Among the unanswered questions concerning Venus are the age of its surface and the mechanisms of lithospheric heat transfer (conduction, plate recycling, and hot spot volcanism). The presence or absence of impact craters is germane to these questions. If there is a large population of impact craters, then the surface is ancient and Venus is characterized by conduction like the Moon, Mars, and Mercury, rather than plate recycling and hot spot volcanism. Alternatively, if there is a large population of volcanic craters, then the surface is younger and other mechanisms of heat transfer likely dominate (1). If there are both types of features then mechanisms of heat transfer may vary areally, and/or with time. Thus, development of criteria to distinguish the origin of circular features on Venus is an important task. This is made difficult by the relatively low-resolution radar images and lack of high-resolution global coverage available for Venus. Previous studies (2-9) have emphasized various aspects of the observational, theoretical, experimental, and comparative planetological studies of cratering on Venus, and several have reached divergent opinions concerning the age of the Venus surface. Masursky et al. (1980) conclude that the density of circular features of likely impact origin in the Venus rolling plains is comparable to the ancient cratered terrain of the Moon, Mars, and Mercury (9), while Campbell and Burns (2,3) suggest that the surface may be relatively young, in the range of 600 m.y. to 1000 m.y. A major source of uncertainty in both studies is the possible inclusion of circular features of non-impact (volcanic or tectonic) origin in the so-called impact crater population. The purpose of this study is to continue the development of a classification scheme of circular features on Venus in order to further distinguish their origin and distribution.

Previous studies (2,3) have described two major types of circular features: large, radar dark, quasi-circular regions with diameters 200-1300 km; and well-defined circular areas of low backscatter surrounded by an area of high-contrast rough terrain, less than 300 km diameter. These studies have concentrated on the nature and distribution of the second type because of their similarity to impact craters seen in lunar radar images. In our classification scheme, we build on previous studies but include the full range of circular features, including those with a very high likelihood of volcanic origin. By examining the full range of circular features, and incorporating new high-resolution radar data, we hope to clarify the origin of these features and the distribution of the associated geologic processes on Venus.

The range of radar characteristics associated with circular features is shown in Figure 1. Four basic classes have been delineated. Class I features are characterized by a bright patch with a dark center, with the dark-to-bright radius $r_p < 0.75 r_d$. The bright patch has a diffuse outer boundary and is generally quite circular (Fig. 1). The central dark area is less circular and has a somewhat diffuse boundary with its bright surround. The primary example of this class is Theia Mons (23°N, 281°), from which apparent flow-like patterns extend radially outward from its bright surround in high-resolution radar images (11). The feature corresponds to a topographic high; it is located in a region characterized by other bright areas with dark central patches which are thought to be of volcanic origin (e.g., Rhea Mons, 33°N, 283°). These factors have led to the interpretation that Theia is a volcanic feature (11), indicating a possible volcanic origin for other Class I features.

The circular features in Class II were described by Campbell and Burns (1980) as large, dark, quasi-circular regions of large diameter (> 200 km). This type of feature was also observed in Pioneer-Venus radar data (12). Two
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examples are located at 18°N, 325° and 29°N, 336°. Many Class II features contain a bright spot or spots, which are not necessarily centrally located. Features in this class were not included by Campbell and Burns in their crater counts. In general, the Class II features are considered enigmatic in origin.

We further define a subclass (IIA) characterized by a bright topographically high ring located in a large, dark, irregularly shaped area that is of relatively low topography compared to the surrounding area. An example is located at 74°N, 315°, directly west of Freyja Montes. The bright ring in this depression has an approximate diameter of 200 km, with the depression close to 500 km across. The large topographic depression suggests an origin at least partially influenced by tectonic processes.

Class III features contain a single bright ring with a dark interior, where \( r_D > 0.75 \ r_p \). Class III approximately corresponds to the second group described by Campbell and Burns (1980), with diameters < 300 km. The bright rings have a distinct outer boundary, and a highly circular interior. Sub-class IIIA features appear in radar images as bright rings with a centrally located bright spot. The location of the outer boundary of the bright ring can vary significantly as a function of radial direction. The general appearance and central bright spot point to a possible impact origin. An example is located at 270°S, 340°.

The last group (Class IV) is comprised of multiple ring features, in which two or more bright rings encircle a dark area which varies in size. The feature at 63°S, 322° is a concentric ring structure with ring diameters of 155 and 265 km and may be similar to multi-ringed impact basins of the Moon, Mars, and Mercury. The feature Cleopatra may also fall into this class, although its origin is not well understood (13).

The classification system described above is preliminary. Further studies are being made on the size ranges of the classes, location relative to province and elevation, and correlation with topography. An improved classification of circular features will aid in determining whether a feature is of volcanic, impact, or tectonic origin, enabling better estimates to be made of the age and geologic evolution of the surface of Venus.


FIGURE 1. Classification of circular features on Venus