Young Tectonism and Volcanism on Venus: Age Estimates from Crater Densities

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Abstract: We have found that it is feasible to estimate ages for geologic features on Venus using impact crater densities. Although [1] demonstrated that the crater population appears spatially random, areas defined on geologic criteria can have density variations that are significantly different from the mean global density. We have estimated mean ages for rifts, large volcanoes, lava flow fields, and wrinkle ridges. Our preliminary analysis suggests that volcanism, rifting, and wrinkle ridge formation have all been active within the last 100 Ma.

Observations: Using impact density to estimate age is an accepted technique for Mars, Mercury, and the Moon, but has been considered inappropriate on Venus due to the low number (~900) and apparent randomness of craters. However, there are indications that this technique can be useful on Venus. First, Figure 1 shows that rifts and large volcanoes roughly correlate with low crater density. Second, when areas are delineated on geologic criteria, their crater densities differ from the global density at a confidence level of over 95%. Table 1 shows the crater densities for lowland plains, rifts, large volcanoes, and lava flow fields. Volcanic features were mapped from locations provided by [2]. Impact crater locations were provided by [3].

We have argued [4] that the impact data support a globally synchronous resurfacing of Venus [1], and that subsequent resurfacing is associated mainly with tectonism and volcanism in the highlands. It follows that the relatively quiescent lowland plains record a background crater density reflecting the age of the global event. By comparing the densities of geologic areas to the background density (D/Do), we can estimate the ages of deformation and volcanism as a fraction of the mean global age **T**. In the following discussion, we report ages both as a fraction of **T** and in Ma, assuming that **T** = 500 Ma [1].

Model: The number of impacts in a geologic area is a function of the original age of the undeformed surface, and the timing and extent of: 1) changes in area due to deformation, and 2) resurfacing by volcanism and tectonism. This simple model assumes: 1) the plains record a background density reflecting the age of global resurfacing, 2) the cratering process is spatially random and rate-constant over the past **T** Ma, 3) the deformation and volcanism occurs instantaneously, and 4) the geologic terrain is all the same age. Clearly assumptions (3) and (4) are gross generalizations, but the model is a starting point for comparing ages of tectonic and volcanic events. Model ages represent the weighted sum of a mixture of ages in the terrain.

In volcanic terrains, little deformation is involved, and the model age is simply (D/Do)**T**. Large volcanoes have a density of 0.48 ± 0.13 (craters/million sq. km.), giving a mean age of 0.2**T** (100 ± 30 Ma). A density this low cannot be produced by steady-state volcanism over the past **T** Ma; an increasing rate or recent pulse of volcanism is required. Local stratigraphic relations between volcanoes and the surrounding features suggest that some volcanoes are older and others may be quite young. Lava flow fields have a density of 0.89 ± 0.31, or a model age of 0.4**T** (200 $\pm$75 Ma).

We have modelled the crater density of rifts as a whole, although preliminary mapping suggests that at least two ages of rifting are present. Based on preliminary mapping, we estimate that 30% $\pm$ 10% of the rifts are occupied by syn- or post-rift volcanic deposits, that <5% of the rifts have been resurfaced tectonically to the point of obliterating craters, and that the overall fractional change in area of old target due to deformation, averaged over the rift system, is 1.2 ± 0.1. The crater density of the rifts is 1.50 ± 0.20. From these ranges of values we obtain a model age of 0.4**T** (200 Ma (+ 100 Ma, -200 Ma)), as shown in Figure 2. However, many of the large volcanoes are contemporaneous with rifting based on local field relations; hence we suspect that some of the rifts are less than 100 Ma old.

Although the linear nature of wrinkle ridges does not lend itself to an area-based analysis, we have considered the proportion of impacts which post-date the ridges. Initial attempts have been made to determine relative ages of impact craters vs. wrinkle ridges in the plains surrounding Aphrodite Terra. By observing the interactions of crater ejecta and outflow deposits with small scale topography, we find that 20% of the craters postdate wrinkle ridge formation. This initial estimate places the age of wrinkle ridge formation around Aphrodite at about 0.2**T** (100 Ma).

Young Tectonism and Volcanism on Venus: Age Estimates from Crater Densities: Price, M. et al.

Conclusions: Geologically defined areas on Venus can have significant variations in crater density relative to the global mean. We used simple models to estimate ages for rifts, large volcanoes, lava flow fields, and wrinkle ridges. Although these model ages generalize complex age relationships, they clearly indicate the presence of young (~100 Ma) rifting and volcanism on Venus. Furthermore, the associations which have been observed between gravity highs, rifting, wrinkle ridges, and volcanism on Venus [5], combined with these data, make it very likely that Venus is an active planet today.

References: [1] Schaber et al., (1992) JGR 97:E8, pp. 13257-13302. [2] Head et al. (1992) JGR 97:E8, pp. 13153-13198. [3] Herrick and Phillips (1994), Icarus, in review. [4] Price and Suppe, EOS 74:43, p. 379. [5] Bilotti, Connors, and Suppe (1993) EOS 74: pp. 191.

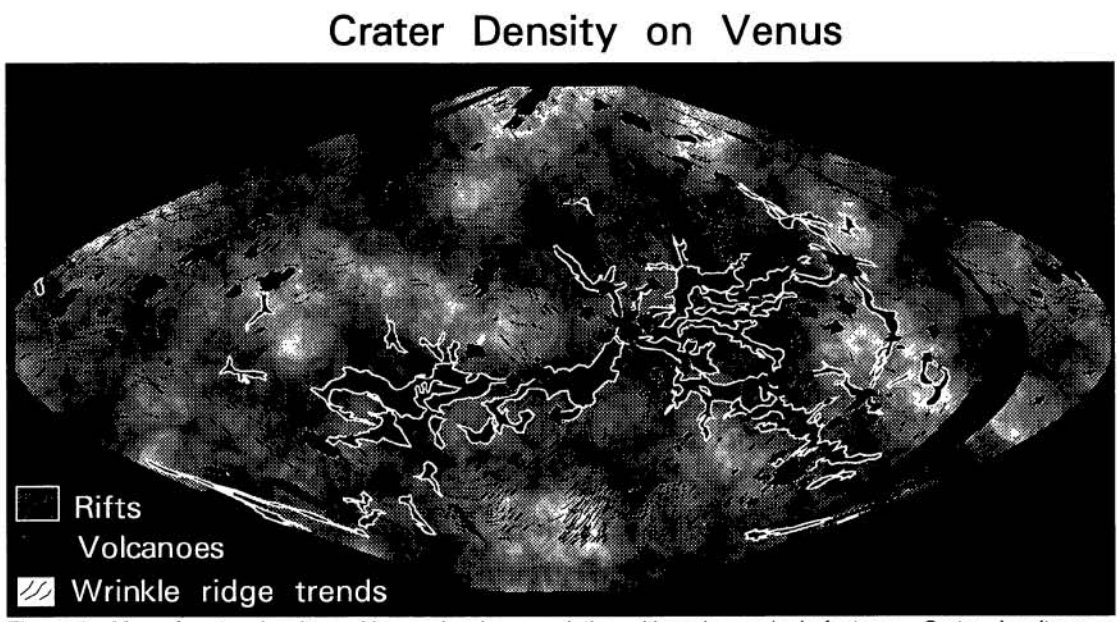

Figure 1. Map of crater density on Venus showing correlation with major geologic features. Crater density was computed using a moving 1300 km radius circle. Dark area represent low crater density--densities range from 1 to 3.5 craters/million sq. km.

Terrain	Area	Crater Density	Model Age (Ma)
Plains	344	2.06 ± 0.08	500 [1]
Rifts	36	1.50 ± 0.20	200 +100,-200
Volcanoes	25	0.48 ± 0.13	100 ± 30
Flow Fields	9	0.89 ± 0.31	200 ± 75
Wrinkle ridges	n/a	n/a	100 ± ??

Table 1. We have mapped the areas of several features, calculated their crater densities, and estimated mean ages using a simple model and assuming a global background age of 500 Ma. Areas are given in millions of sq. km.

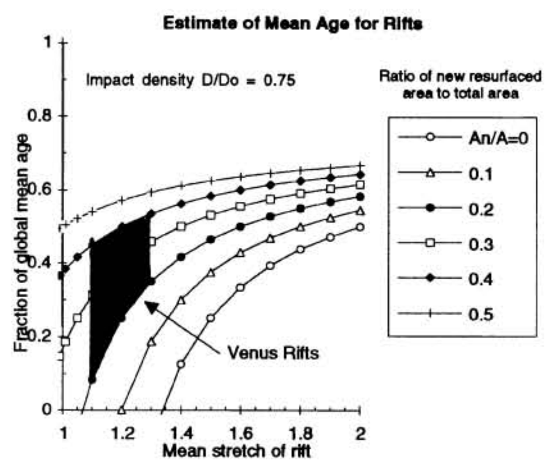

Figure 2. We have developed a simple model to estimate ages of tectonic features from the ratio of the crater density to the background global density (D/Do), the fraction of resurfaced area to the present area (An/A), and the fractional change in area of old target due to deformation (stretch). The black area shows the range of ages from preliminary estimates of these parameters for rifts with a crater density of 1.5 craters/million sq. km.