Resurfacing History of the Venusian plains based on Distribution of Impact Craters
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Abstract: Mapping and dating of the Venusian plains using units defined by the relative preservation of lobate flow morphology confirms that long-term weathering of volcanic flow complexes causes increasing degradation of flow boundaries and homogenization of flow backscatter signatures. Progressive deterioration of flow morphology correlates with increasing crater density and decreasing frequency of embayed craters, and therefore age. Plains emplacement lasted at least 100 Ma, and developed progressively into concentrated younger activity in the rifts and large volcanic rises. Simulations confirm that this history is compatible with the randomness of craters.

Previous studies have shown that it is possible to discriminate between terrains of different age based on crater density as long as the units to be dated cover at least 10^7 km^2 and are defined on geologic criteria independent of crater locations [1]. Ages may be calculated relative to a mean global age of 300 Ma. This technique, already used to show that rifts, coronae, and large volcanoes have mean ages of 80-150 Ma, is applied to the plains to assess regional age variations, if any, and to evaluate the duration of plains emplacement.

The plains have been divided into four units based on the preservation of flow morphology (Figure 1). This criterion was inspired by the work of Arvidson et al. [2], who showed evidence for progressive degradation of lobate flow morphology of Venusian volcanic deposits over time. Mapping was done at C1-MIDR scale on a global SAR mosaic normalized the the global backscatter function and displayed with a constant linear mapping of backscatter to grayscale value, to ensure consistency of map units. The units are described in Figure 2.

The map units show a consistent progression in crater density and embayment (figure 3). Highly lobate flows (Pl1=5% of the plains and Pl2=25%) are concentrated near the rifts and regional volcanic rises. They have lower crater densities and high proportions of embayed craters, and are found at higher elevations. The less and non-lobate units (Pl3=30% and Ps=35%) are associated with the lowland planitiae, have higher crater densities, and few embayed craters. The units Ps, Pl3, Pl2, and Pl1 have mean crater retention ages of 370±45 Ma, 325±45 Ma, 240±40, and 210±75 Ma respectively. Mapping the plains with this criteria has clearly discriminated regional differences in age within the plains, supporting the idea that long-term weathering causes degradation of flow morphology. The mean elevation of the plains units also decreases with age, consistent with interpretation of the less lobate units as older, cooler, denser crust.

The map constrains the resurfacing history of Venus in better detail than previously known. The plains appear to have been emplaced over a period of at least 100 Ma. The oldest regions have a mean age of 370 Ma, while the younger regions appear to record the development of the rifts and regional volcanic rises, where even younger activity has been demonstrated [1]. Simple resurfacing simulations based on crater density variations in different map units show that this plains emplacement history, followed by concentrated volcanism and tectonism in the highlands, is completely consistent with the random distribution of impact craters, and that crater randomness does not preclude dating significant regional age variations based on crater density.

The association of the younger 'plains' units with the highlands suggests that these units might better be linked with the development of the rifts and rises, and that 'global' resurfacing may be an overstatement. In fact, additional dating using refined map units may reveal even greater regional age variations in the old plains. In this case, the recent tectonic history of Venus may be better described as the progressive development of rift/rise tectonics, with older units preserved in the lowlands, and the global resurfacing hypothesis will need reevaluation. These results suggest exciting possibilities for identifying and dating regions with regional tectonic significance to better understand the tectonic evolution of Venus.

References: [1] Price and Suppe, Nature 372,1994. [2] Arvidson et al., JGR 97,1992.

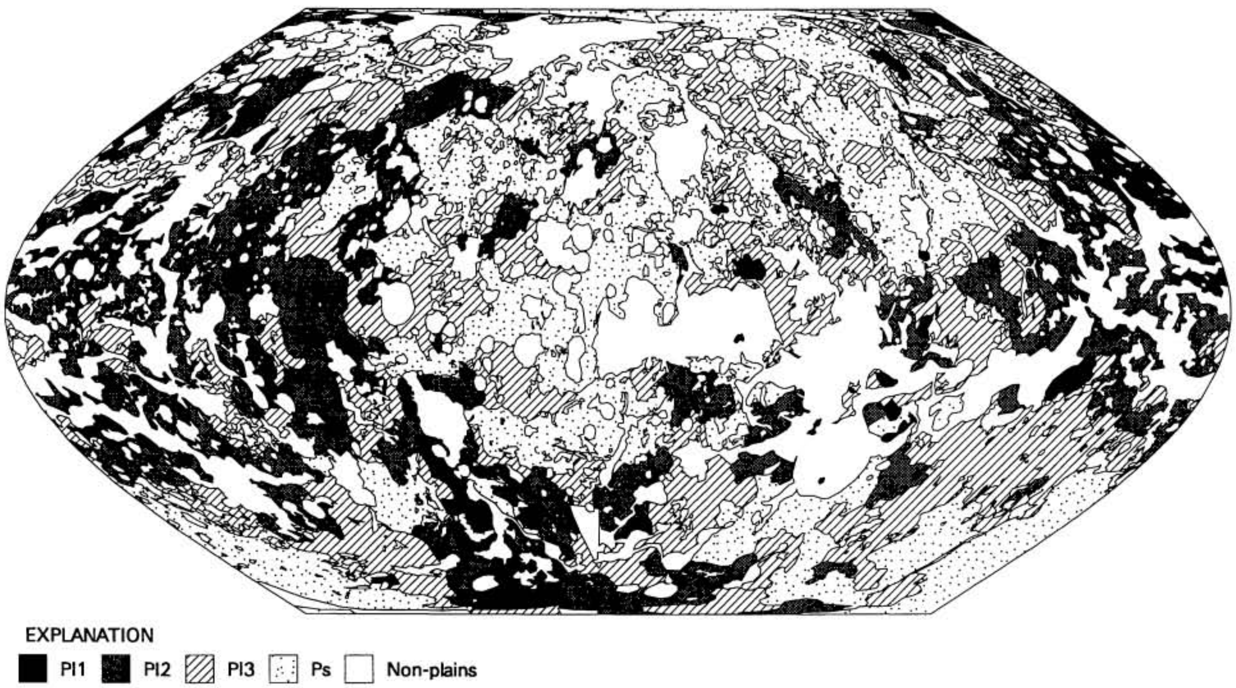

Figure 1. Map of the Venusian plains using units based on preservation of lobate flow morphology. Pl1 is the most lobate, Ps is the least. Non-plains features include tesserae, rifts, coronae, corona-like features, and large volcanoes. The concentration of lobate units Pl1 and Pl2 around the rifts and large volcanic rises suggests that these plains are associated with their development, while the smooth plains are preserved in the planitiae. These patterns are consistent with younger, hotter crust in the highlands and older, denser, cooler crust in the planitiae, and confirm the differences in impact crater density between units.

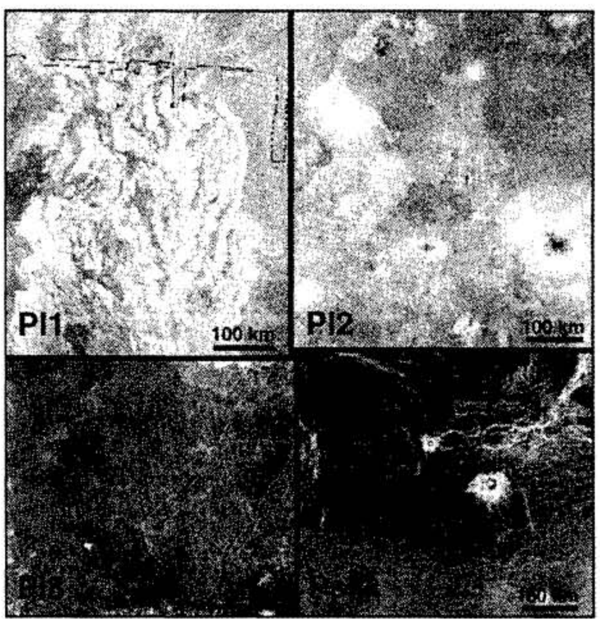

Figure 2. Plains units. Pl1 is highly lobate plains such as Mylitta Fluctus, shown here. Pl2 is plains with distinct but less dramatic flow morphology. Pl3 is plains with subtle lobate appearance, and Ps is smooth plains with no discernible flow morphology present. Images shown at similar scale and a constant backscatter stretch.

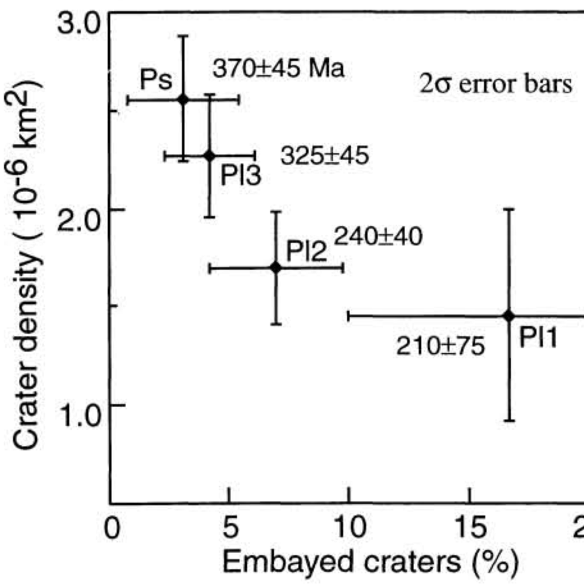

Figure 3. The lobate plains units have higher crater densities and more embayed craters than the smoother plains units. These units have clearly discriminated between terrains with different mean ages. More detailed units may be able to discrimate even greater age differences between regions, as long as map units are at least 10^7 km^2 and defined by criteria independent of impact crater locations.