DARK-FLOORED CRATER ELEVATIONS ON VENUS: IMPLICATIONS FOR CRATER-CENTERED VOLCANISM;

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Summary: Previous models for impact crater modification by igneous intrusions [1,2] suggest that crater-centered volcanism on Venus should preferentially occur at lower elevations than craters modified by independent, external volcanic flows. Dark-floored craters provide the most likely candidates on Venus for such crater-centered volcanism, and a survey of over 400 craters (D>15 km) indicates that venusian dark-floored craters preferentially occur at elevations between identified floor-fractured craters and craters embayed by external lava flows. Consequently, different styles of volcanically modified craters apparently occur at different elevations on Venus. Further, since young, bright-floored craters are rare at lowland elevations, crater modification by localized, crater-centered lavas appears to be widespread at these lowland elevations and may be relatively recent.

Background: Although most impact craters on Venus exhibit nearly pristine crater rims and ejecta units [3], such observations provide little constraint on the extent or frequency of localized modification inside these craters. The apparent replacement of bright young crater floors with dark crater floor units over time [4,5}, however, suggests that either eolian or volcanic processes have produced widespread modification of venusian crater floors without affecting surface units outside the crater rims. Since both mare-filled and floor-fractured craters on the airless Moon exhibit similar cases of localized internal crater modification [6], this abstract favors a volcanic origin for the venusian dark crater floor units.

Previous studies of venusian floor-fractured craters provide a possible test for this hypothesis. Specifically, although floor-fractured craters are rare on Venus, their distribution appears to be elevation dependent and is distinctly different from the distribution of craters embayed by external volcanic units [1,2]. By modeling crater floor-fracturing as a response to crater-centered intrusions, the effects of atmospheric pressure variations on magmatic vesiculation can explain this dichotomy in crater modification [2]. A similar dichotomy can also be predicted in the distribution of crater-centered volcanism as a function of elevation, since the effect of atmospheric pressures on basalt densities should increase regional magma depths at higher elevations over time [7]. Assuming that crater-centered volcanism is most likely when regional magmas are level with near-surface crater breccias, such variations in magma depth should favor crater-filling volcanism at lower elevations and external, crater-modifying volcanism at higher elevations. Further, since magmatic vesiculation increases as atmospheric pressures decrease [7], breccia-centered neutral buoyancy zones should be less stable at higher elevations on Venus as well [2]. Thus, crater-filling volcanism may preferentially occur at higher elevations than the identified floor-fractured craters on Venus. Since conditions on Venus are less favorable for crater-centered intrusions than on the Moon [1,2], however, crater-filling volcanism may also occur throughout the identified elevation range for crater floor-fracturing.

Dark-floored Craters: To test these predictions about the elevation of crater modification on Venus, I have compiled a data set describing the setting, size and character of crater floor units in the Magellan CD-ROM images. This data set expands the crater catalog of Schaber et al. [3] and focuses on variations in the appearance, size and location of dark crater floor units in craters over 15 km in diameter. Crater elevations are derived from the browse version of Venus altimetry in the Magellan CD's. Although many craters show a number of bright, intermediate, and dark crater floor units, the craters are divided into three main groups on the basis of their dominant crater floor albedos. For this division, intermediate crater floors are large smooth surfaces which (1) are brighter than most lowland plains units, (2) generally contain smaller dark floor units, and (3) lack the distinctly radar-bright albedos observed in craters with dark parabolic ejecta deposits.

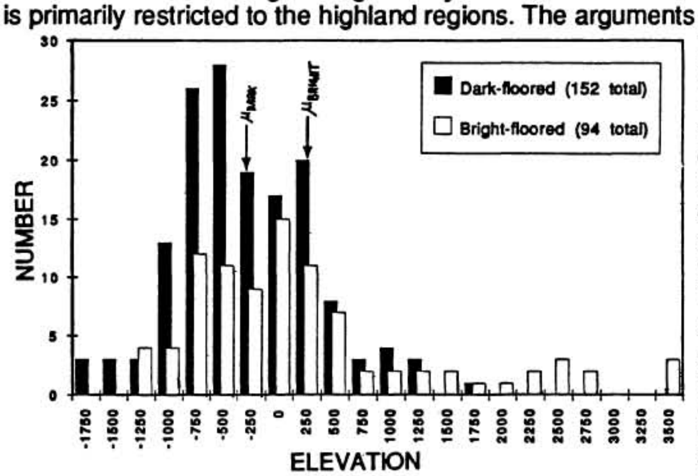
As shown by Figure 1, dark-floored and bright-floored craters on Venus show distinct differences in their elevation distributions. While dark-floored craters are concentrated at relatively low elevations (mean ~150 m below the MPR of 6051.8 km), the bright-floored crater distribution is centered at somewhat higher elevations (mean ~370 m above MPR) and it shows a pronounced tail extending to elevations over 3500 m above MPR. Using Student's T-test, these elevation distributions are statistically independent at confidence levels exceeding 99%. The intermediate-floored craters (not shown) have a distribution resembling that of the bright-floored craters, but with a slightly lower mean elevation (~250 m above MPR).

In addition, the typical size of dark crater floor units (relative to crater floor size) may vary as a function of elevation. Figure 2 shows that craters in which dark units comprise major fractions (>2/3) of the crater floor typically occur at lower elevations than craters in which dark units comprise minor or negligible fractions (<1/3) of the crater floor. Again, the two distributions are statistically independent at confidence levels of over 99%. Craters in which dark floor units comprise a moderate fraction (>1/3 and <2/3) of the crater floor are concentrated at intermediate elevations, but the distribution is closer to that of the major dark floor units than to that of the minor/negligible dark floor units.

Discussion: The average elevation of floor-fractured craters on Venus is ~580 m below MPR. Thus, although the elevations of dark-floored craters on Venus span the elevation range of the identified floor-fractured craters (figure 1), the dark-floored craters typically occur at higher elevations than the floor-fractured craters. Even the lowest class of dark-floored craters (those with major dark floor units) are statistically independent of the floor-fractured crater elevations (confidence level ~97%). In contrast, the mean elevation of externally modified, volcanically embayed craters (~410 m above MPR) can not be distinguished statistically from the elevation distributions of either the bright-floored craters or craters with minor/negligible dark floor units (confidence levels <<80%). Since the typical size of dark crater floor units apparently decreases as a function of elevation (figure 2), dark-floored craters (like floor-fractured craters) seem to preferentially occur at lower elevations while crater modification by external volcanism is favored at higher elevations.

These observations are consistent with the model for magmatic crater modification derived from previous studies of venusian floor-fractured craters [1,2]. First, the average offset of dark-floored craters to higher elevations than the floor-fractured craters matches the predicted effect of magmatic vesiculation on the stability of crater-centered intrusions. Second, the similarity in the elevations of externally embayed craters and craters with minimal/negligible dark floor units suggests a transition at higher elevations from crater-centered to crater-insensitive volcanism. Such a transition is consistent with the predicted variations in regional magma depths as a function of elevation [2,7]. Lastly, if increased regional magma depths can affect the volume of magma entering a crater [2], variations in regional magma depth also may explain the apparent size reductions of dark crater floor units as a function of elevation.

Implications: Externally modified, volcanically embayed craters are relatively rare (~5% of the observed population) and preferentially occur at highland elevations; thus, previous studies of crater loss and volcanic resurfacing have generally concluded that recent volcanism on Venus is of limited extent and is primarily restricted to the highland regions. The arguments and observations presented above, however, indicate that these views may need some modification. While crater loss appears to be limited to highland regions (eg. 8,9), the apparent transition from floor-fractured and dark-floored craters at lowland elevations to externally modified, volcanically embayed craters at higher elevations strongly suggests that (1) different styles of both volcanism and crater modification occur on Venus as a function of elevation, and that (2) a class of modified craters exists at lowland elevations which have not been included in previous studies. Since young, bright-floored craters appear to be preferentially located at highland elevations, the number of dark-floored craters at lower elevations also suggests that (3) localized, crater-centered volcanism has been widespread in the lowland plains and may be ongoing. In the latter case, recent volcanism may be possible elsewhere in the lowland plains as well.



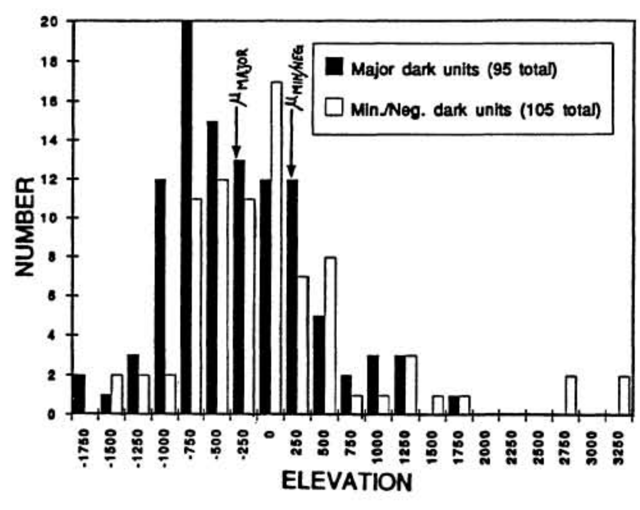


Figure 1. Histogram showing elevation distribution of dark-floored and bright-floored craters on Venus.

Figure 2. Histogram showing crater elevations for different relative sizes of dark crater floor units.

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