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DEPTH/DIAMETER RELATIONSHIPS OF FRESH CRATERS WITHIN HESPERIA PLANUM, MARS.

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INTRODUCTION

Meteorite impact craters represent important geological features for revealing the near-surface layers of a planetary surface. In the case of Mars, this characteristic has been proposed as a useful method to study spatial variations of such attributes as the distribution of sub-surface volatiles (1, 2) and heat flow (3). Using the Planetary Image Cartography System (PICS) software, we have completed a quantitative analysis of the geometry of fresh impact craters in the Hesperia Planum region of Mars (~23 - 38^{o}S, 233 - 248^{o}W), where a uniform target material and optimum viewing geometry make possible an analysis of target effects over a large geographic region. Because of the morphologic similarity to the lunar maria, it is likely that Hesperia Planum comprises a series of flood lavas that partially infilled topographic depressions within the Martian highlands (4). Measurements of partially buried crater rims suggest that the lava flows within Hesperia Planum are between 200 - 400 meters thick (5).

NEW DEPTH/DIAMETER DATA

Our measurements were made from Viking Orbiter images obtained during orbits 417S, 418S and 419S. These images provide an unusually constant range of illumination geometries (incidence angle = 63 - 80^{o}) and spatial resolution (88 - 96 m/pixel) for a large geographic area, and to our knowledge represent the best data set that exists for the quantitative analysis of the ridged plains materials on Mars. Our sample contains 109 craters in the diameter range 1.97 - 15.44 km. Of these craters, 57 are morphologically very fresh, possessing complete rims, well preserved ejecta blankets that completely surround the parent crater, have radial striations upon the ejecta lobes or sharp distal ramparts, and have no superposed impact craters (cf. 6, 7).

Our depth/Diameter (d/D) data for the 57 pristine Hesperia Planum craters show significant scatter, but particularly for craters < 5 km dia. (Fig. 1a, 1b). We have divided the population of fresh craters into two categories, denoted as "shallow" and "deep" (the "deep" craters are ~50 - 100% deeper than the "shallow" fresh craters of the same diameter). Once the spatial distribution of these craters is investigated (Fig. 1c), differences in their distribution is evident. "Deep" craters are in general located in the northern part of Hesperia Planum that is investigated here, while "shallow" craters are more often found in the south. Clearly this relationship is non-exclusive, but the spatial pattern does appear to be a real phenomenon.

We have also investigated the possible existence of the equivalent "deep" and "shallow" craters for fresh craters larger than 6 km in diameter. From the d/D plot (Fig. 1b), it is less clear that two populations of large craters exist, so that we have separated craters that have the highest d/D ratios from those with lower ratios but the same diameter. When the spatial distribution of these two classes of large craters are compared (Fig. 1d), we see a less uniform trend. From Fig. 1d, we therefore infer that whatever property of Hesperia Planum is responsible for affecting craters smaller than 6 km diameter, this attribute does not affect larger craters.

DISCUSSION

Two mechanisms may explain this poleward shallowing of fresh craters: 1) spatial variations in the thickness of the lava flows that comprise the surface material of Hesperia Planum, and 2) latitudinal variations in the amount of volatiles in the near-surface (top 500 m?) of the target. The thickness of the Hesperia Planum lava flows is believed to vary from more than 400 m in the northwest of our study area to less than 200 m to the southeast (5), and the underlying materials are most likely to be heavily cratered terrain similar to the materials that outcrop around the perimeter of Hesperia Planum (4). In order for target properties to affect the geometry of the crater, we assume that the crater cavity must be excavated to the depth of the interface between the lava flows and the underlying materials. The alternative method for modifying small crater geometry in Hesperia Planum is one that involves a spatially-variable concentration of volatiles in the top few hundred meters of the target at the time that the craters were formed. This idea is not new, indeed it was the preferred mechanism proposed by Cintala and Mouginis-Mark (8) to explain the variations in crater depth/diameter ratios. Fanale et al. (9) have modeled the situation where volatiles were driven towards the poles over Martian history, and the trends revealed for the small craters (Fig. 1c) would support this poleward migration model. Our current analysis of the Hesperia Planum craters may also show that for craters < 5 km in diameter, there is a gradual transition in the amount of volatiles present within the target. In particular, if a spatial variation in the amount of volatiles were the controlling factor in crater geometry, then we would expect to see a relationship between the crater's latitude and d/D.

A further test of the latitudinal variation in d/D ratio is to consider the geometry of other craters in Hesperia Planum that have well preserved rim crests but lack the continuous ejecta blankets that were a feature of the pristine craters. We have also measured the depth and diameter of 48 additional craters smaller than 6.0 km diameter that fall into this category, and have separated these craters into those that have high and low d/D ratios, using the same subdivisions that were applied to the pristine craters with ejecta blankets. When the spatial distribution of these craters without ejecta blankets is investigated, the same latitudinal variation can be seen as for the pristine craters: craters with large d/D values are typically equatorward of 30°S, while low d/D craters are found at all latitudes. From inspection of De Hon's (5) thickness map, the ridged plains at certain latitudes in this area are interpreted to vary from < 200 m in the east to > 400 m in the west. Indeed, it is apparent that all but two of the 24 craters with a large d/D ratio are equatorward of 30°S, but are formed in parts of Hesperia Planum that have estimated thicknesses between < 200 to > 400 m. Thus we feel that this east-west variation in plains thickness (which is probably the entire range of plains thicknesses within our study area) was not the primary physical characteristic of the target that caused some craters to be unusually deep or shallow. We therefore believe that the spatial variation in the amount of volatiles at shallow depth is the most reasonable explanation for the observed spatial distribution in crater geometries.

CONCLUSIONS

Our analysis of the d/D information has revealed that craters < 6.0 km dia. were most likely affected by a latitudinally variable layer of volatiles. Craters at higher latitudes are shallower than craters of the same diameter that are closer to the equator. This relationship appears to be true both for craters with well preserved ejecta blankets and for deeper craters that lack ejecta but have well preserved rims. While we are unable to quantify the change in the amount or depth of burial of the volatiles that we propose to have been responsible for the shallowing of these craters, our observations add to the current body of evidence that volatiles existed within the shallow Martian crust. Furthermore, these volatiles must have been present quite recently because they affected some of the freshest impact craters, which we infer to be quite young (<1 byrs?) due to the lack of erosion of their ejecta blankets and rim crests.

The Viking Orbiter data that we used are particularly well suited to this form of digital analysis, due to their uniform spatial resolution, large area of coverage of a single geologic unit, and the small range of illumination geometries; the use of the digital Viking Orbiter data for other areas of Mars may thus permit the qualitative inter-comparison of volatile concentrations based on the geometry of fresh meteorite craters. The depth of the largest crater with a high d/D ratio in any area may define the maximum thickness of the volatile-depleted layer during the time interval over which the craters formed. In addition, once the Mars Observer Laser Altimeter (MOLA) topographic data become available, MOLA measurements may also be useful for investigating the former distribution of volatiles on Mars.

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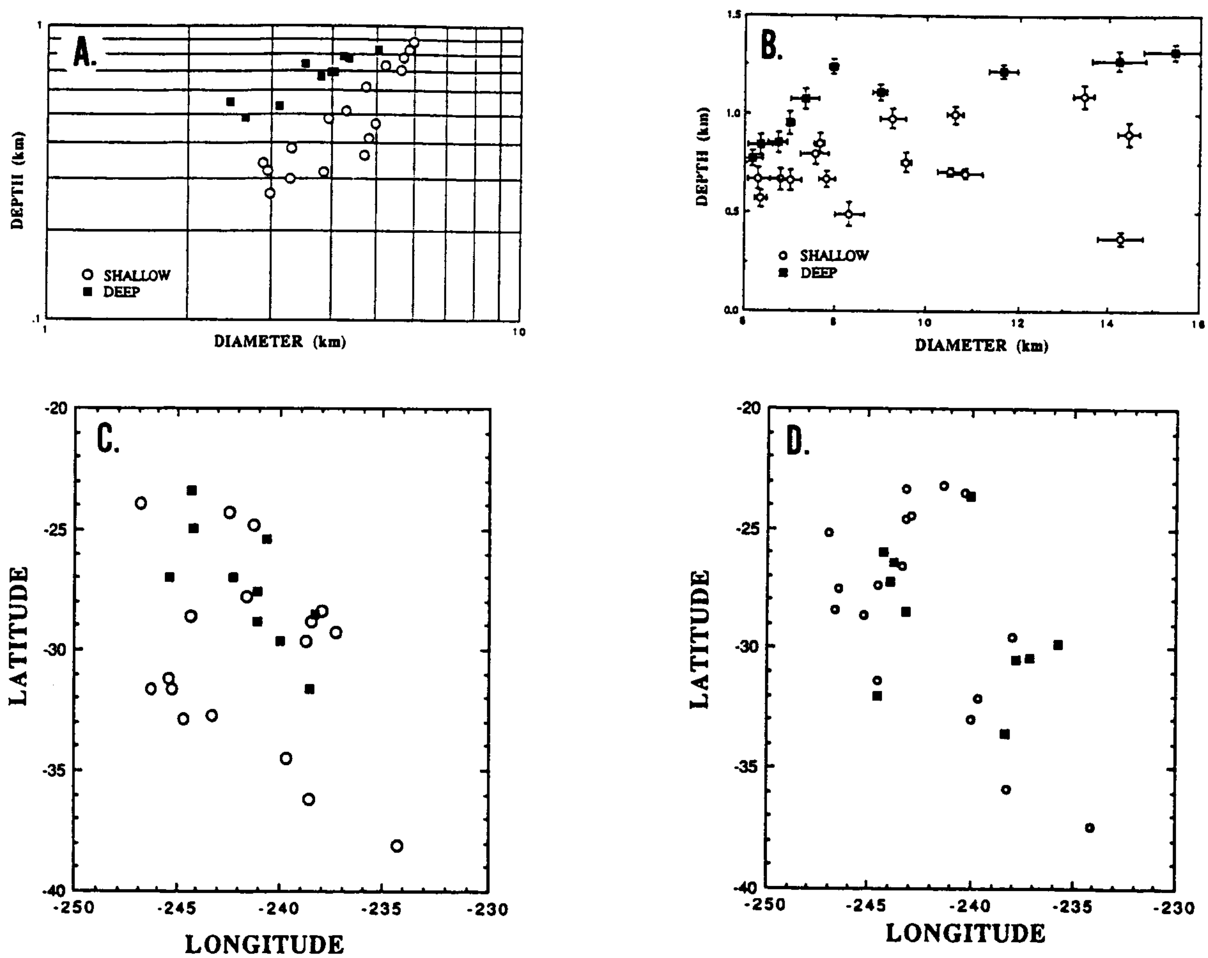

Fig. 1 A) d/D plot showing craters smaller than 6.0 km dia. Crater population has been subdivided into two classes of craters that appear to be "deep" or "shallow" for each diameter. B) d/D plot of pristine craters larger than 6.0 km in dia. Note that the scales used here are linear to expand the scatter of data points. Craters with the largest d/D ratio are called "deep" craters, while smaller d/D values are associated with "shallow" craters. C) Spatial distribution of the small fresh craters identified in Fig. 1a. Note that shallow craters are preferentially located poleward of 30°S, while "deep" craters are predominately equatorward of this latitude. D) Spatial distribution of deep and shallow fresh craters in the diameter range 6.0 - 15.44 km, as identified in Fig. 1b. Note that there does not appear to be any systematic pattern to the distribution of these two classes of crater, suggesting that the excavation depth exceeds the thickness of the near-surface volatile layer.