YIELD STRENGTHS OF MARTIAN COMPLEX CRATERS;

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The transition from simple bowl-shaped craters to shallow flat-floored complex craters has been reported to be between 5 and 10 km for the planet Mars [1,2,3]. This morphologic transition marks the onset of slump terrace formation which has been thought to be the result of gravitational instability. However, studies [4] indicate that under static conditions gravitational instability is insufficient to explain crater slumping. Instead, it has been suggested [4,5,6,7] that slump terraces form immediately after impact when elastic energy (seismic and acoustic) exceeds the yield strength of the target material. The objective of this study is to derive martian surface yield strengths from the slump terrace geometry of complex martian craters. Possible variations in yield strength due to target material, latitude (volatiles), and crater morphology are also examined.

A non-inertial theoretical model of crater slumping that assumes negligible internal friction and a perfectly plastic medium has been proposed [4]. Using a slip line field analysis, the model predicts the width and location of slump terraces as a function of surface yield strength. A simple numerical approximation to this model is given as

$$W \approx \frac{c}{\rho g} \left[\frac{1 + 16\lambda^2}{16\lambda^2} \right] \tag{1}$$

where W is the terrace width, c is yield strength, ρ is target density, g is gravitational acceleration, and λ is the depth/diameter ratio prior to terracing. When tested on lunar complex craters [8], this model predicted a relatively constant surface yield strength of 10 to 30 bars. Although inconsistent with laboratory measurements of rock properties [9], anomalously low yield strengths are apparently achieved during the cratering process.

In order to derive martian surface yield strengths, 95 complex craters were identified for study in martian quadrangles 4, 5, 10, 11, 18, 19, 25, and 26. These quadrangles were selected based on their abundance of fresh complex craters, diversity of target materials, and continuum of latitudes ranging from the north to south pole. Diameters of complex craters were measured from Viking orthographic images. For each crater the target material, latitude, and ejecta morphology [10] were recorded. As was done in the lunar study [8], only widths of the large outer "first order" terraces were measured with the maximum and minimum widths representing the upper and lower error bars, respectively. Extreme care was exercised in delineating slump terraces from slump blocks. Slump terraces are defined as curvilinear blocks of relatively constant width and no surface deformation that were produced shortly after the excavation stage of impact cratering. Slump blocks, however, are discontinuous, have largely varying widths and deformed surfaces, occur in crater scallops, and may be the result of smaller impacts occurring near the rim of the crater long after the initial impact.

Evaluation of equation (1) for yield strength requires an estimate of the depth/diameter ratio prior to "first order" terracing. The initial crater diameter was reconstructed by subtracting twice the terrace width from the final crater diameter. As an approximation to the method used in the lunar study [8], the initial diameter was plotted on a martian crater depth/diameter curve [2] in order to derive the initial depth prior to "first order" terracing. However, since craters on the martian depth/diameter curve are energetically stable this method will consistently underestimate the initial depth/diameter ratio [11]. When this method is applied to data for lunar complex craters [8] the initial depth/diameter ratio is underestimated by approximately 30%, but still offers a reasonable approximation.

Results of this analysis indicate a linear trend between "first order" terrace width and crater diameter (Fig. 1), similar to that observed for the Moon [8,12]. Furthermore, no correlation was found between terrace width and latitude, crater morphology, or target material. Since yield strength is directly related to terrace width (equation 1) this would suggest that the terracing phenomenon is indicative of an impact cratering process and not planetary surface properties. This conclusion is consistent with yield strengths indicated in Fig. 2 which are similar to those calculated for the Moon [8] and confirm the suspicion [13] that the effective yield stength decreases slightly as the crater diameter increases.

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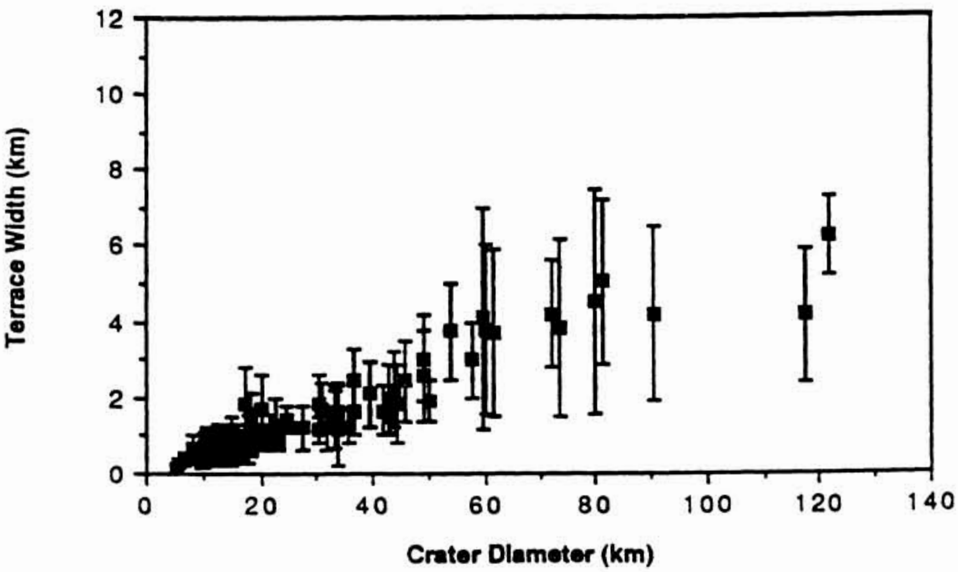

Fig. 1 Terrace width versus crater diam. for martian complex craters.

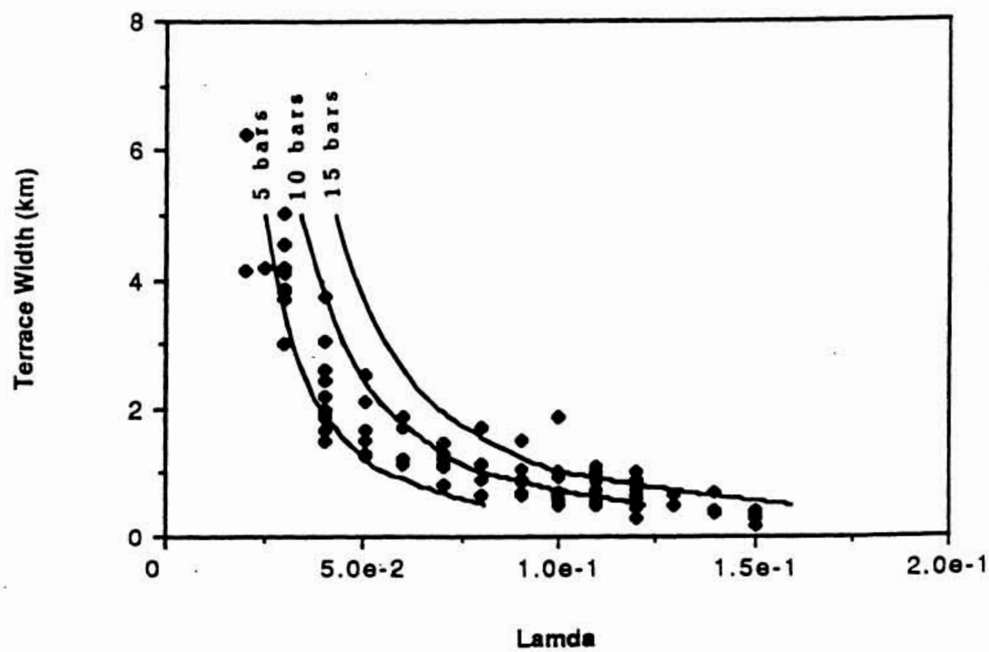

Fig. 2 Terrace width versus lamda (initial d/D) for martian complex craters. Lines of constant yield strength are shown.