THE CRATERING RECORD OF YOUNG PLATY-RIDGED LAVA ON MARS: IMPLICATIONS FOR MATERIAL PROPERTIES. Colin M. Dundas[1], Laszlo Keszthelyi[2], Veronica J. Bray[1] and Alfred S. McEwen[1], [1]University of Arizona, Lunar and Planetary Laboratory, Tucson, AZ 85721 (colind@lpl.arizona.edu), [2]Astrogeology Team, U. S. Geological Survey, Flagstaff, AZ.

Introduction: The origin of platy-ridged surfaces in the Elysium Planitia region has been a subject of recent controversy. They were originally suggested to be lava [1], but other suggestions have included a frozen sea [2] or periglacially modified ice-rich terrain [3]. A variety of observations have supported the lava model for surfaces in this region [4-7], but some observations supporting other models remain to be addressed. In this work we consider crater densities on the platy-ridged surfaces. Crater densities on the plates are higher than on the intervening areas [2, 8], and it has been argued that this is inconsistent with an origin as rafted plates on a lava flow, where age differences should be geologically insignificant.

We propose that this difference is instead due to target material effects on cratering. Target properties affect the crater size produced by a given impactor [e.g. 9], and this can affect the resulting size-frequency distribution [e.g. 10]. We suggest that this effect explains much of the difference in crater densities.

Model: We use pi-group scaling [e.g. 9, 11-12] to estimate final crater sizes. Specifically, we use equations from [12] that incorporate both strength and gravity scaling to calculate transient crater diameter, and estimate the final crater diameter as 1.3 times that of the transient crater. Different parameterizations exist for different targets such as dry soil or hard rock, which differ in part due to porosity effects. An important parameter is the effective strength of the material. Typical "effective strength" of a hard rock target is 6.9 MPa, while desert alluvium has a value of 65 kPa, and some regoliths may be only a few kPa [9,11].

Terrestrial rubbly pahoehoe (a platy-ridged lava analog) [4] suggest that plates are composed of a breccia, typically with decimeter-scale clasts and little or no welding. The areas between the plates (often with polygonal texture) are relatively coherent vesicular lava similar to the surface of a lava lake. To illustrate the nature of the scaling effect, we consider several models. We treat the brecciated plates as dry soil and test model strengths of 65 kPa and 10 kPa. The first is that of alluvium, somewhat analogous to a mix of breccia clasts and dust; the second illustrates a more extreme case. We consider two models for inter-plate areas: nominal hard rock, and a 'dry soil' with a strength of 2 MPa. (The hard rock model may be inappropriate for vesicular basalt due to high porosity; however, equation of vesicular basalt with soil is also subject to uncertainty.) We reduce the effective strength since porosity has a marked effect on basalt strength [13]). These models are schematic to some extent, since we lack detailed constraints on the Martian surface properties, and the terrestrial analogs are also generalized. For the smallest craters in hard rock, spallation may cause error in modeled diameter [14].

We used the scaling relations to calculate crater densities on different surfaces, given the same impactor flux and the same time. The objective of this modeling is to illustrate the nature and potential scale of this effect, not to reproduce a particular size-frequency distribution (SFD) in detail. Hence, we make several assumptions. The impactor flux is given by a power law $N(d \geq D)=A*D^{-3}$, where d is the diameter. The exponent -3 is chosen arbitrarily, but is not unreasonable, and produces crater SFD slopes similar to model isochrons [15]; the coefficient A is chosen to give one crater larger than 1 km diameter in the stronger targets, and we assume a counting area of 10^6 km^2 for plotting purposes. We assume all projectiles have a velocity of 10 km s^{-1} and impact at an angle of 45°.

SFDs calculated in this fashion are shown in Fig. 1. There is a difference between the crater densities in the different model targets, which can be quite significant for small craters. At larger sizes the SFDs converge as the role of strength relative to gravity is reduced.

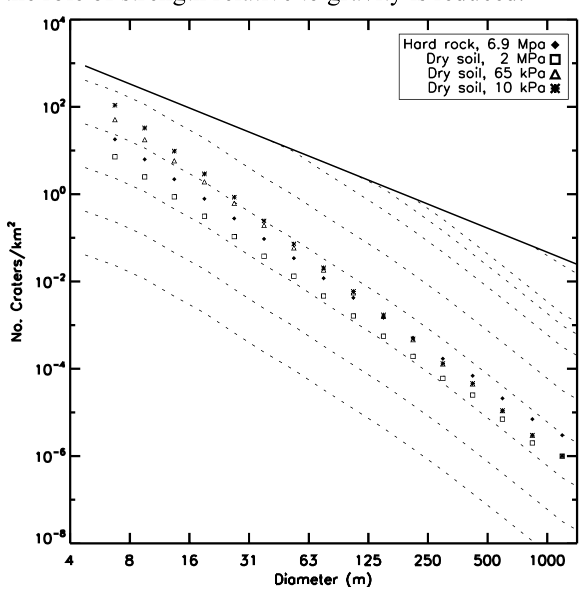

Figure 1: Modeled crater size-frequency distributions for the same impactor flux and time but different target properties. The target can have a significant effect on the apparent crater age of the surface. Isochrons follow [15].

Discussion: Numerous observations (including detailed morphologies, kinematic modeling, radar sounding, composition and the geologic context) indicate that the Martian platy surfaces are lava [4-7]. We find that cratering models based on a terrestrial analog suggest that crater density differences should occur on plates and areas between them even though the ages are identical. Hence the reported discrepancy in crater ages [2, 8] can be explained in the context of the lava model. We note that experiments in bombing lava targets [16] produced factors of several difference in crater size using identical bombs; variation in crater size and thus SFD on lava surfaces is consistent with terrestrial experimental evidence.

Constraints on material properties are not strong in detail; for instance, we do not know the amount of dust trapped in the rough breccia surface, or the clast size or degree of welding, all of which could significantly affect the effective strength. Such parameters probably vary considerably across the surface of the flow, and also vertically; the flow core is likely to be relatively massive, and the breccia thickness varied [4]. Moreover, the nominal strength values for known materials are rather generalized. While we could tune the target properties to produce particular crater density ratios, this would be of minimal practical value.

Murray et al. [2] found that the density contrast between plates and inter-plate areas was ~20%, while Page et al. [3] reported a factor of 10-20 difference. Several factors could contribute to this variation: [3] counted smaller craters, where the role of strength is greater (Fig. 1); their counting area was also smaller, and could have particularly extreme difference in material properties. Crater SFDs may also be affected by other factors; if the area was previously mantled by dust or volcanic ash, the low-lying polygons would be more deeply mantled, and would have lost craters formed in the mantle. Fig. 2 shows an example of an inter-plate area that may currently be partially mantled.

The effect of target properties on crater SFD depends not only on the ratio of crater sizes produced by a given impactor, but also on the slope of the projectile population. For instance, consider a simple example where the crater size produced by each projectile was doubled. For a -3 power law exponent such as we have assumed, this would lead to a factor of eight difference in the density of craters of a given size.

Target properties are not well known in many cases; they can reasonably be neglected above some crater size, and the properties of regoliths are probably broadly similar. However, for small craters, the target may have a significant effect on SFD; this is particularly relevant in comparing crater densities between two surfaces. This may affect other questions pertaining to small craters on Mars and other planets; for instance, crater densities on ejecta and melt pools of large lunar craters show a similar discrepancy [17].

Conclusions: Crater SFDs are affected by target properties, an effect which could be mistaken for differences in age. The properties of terrestrial rubbly pahoehoe suggest that crater densities would be higher on plates than between them, as observed on Mars. This may account for crater density differences on Martian platy-ridged lava surfaces, although other factors such as differential mantling may also be relevant; the cratering record is consistent with lava-flow formation timescales and a rubbly pahoehoe analog.

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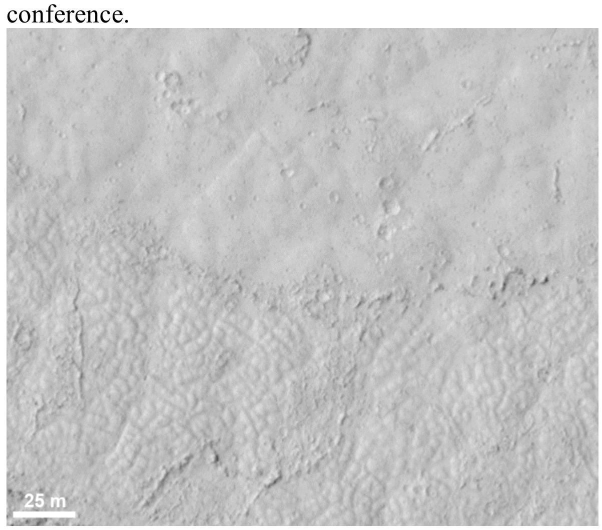

Figure 2: Inter-plate area in platy-ridged terrain (HiRISE image TRA_000854_1855). Polygonal textures are distinct at the bottom. The top has a muted appearance, possibly due to dust mantling.