SMALL IMPACT CRATER STATISTICS: A TOOL FOR ANALYSIS OF GEOLOGIC PROCESSES IN MARTIAN VOLATILE-RICH SURFACES. Daniel C. Berman, William K. Hartmann, and Matthew R. Balme, Planetary Science Institute, 1700 E. Ft. Lowell Rd., Suite 106, Tucson, AZ 85719; bermandc@psi.edu.

Introduction: The discovery in 2006 of small, new craters that formed on Mars during the previous decade [1] described single formation events, apparently random in time and space, interpreted as small primary impacts, not secondaries. The best statistics were among craters with 10-20 m diameters. The observed formation rates are less than a factor 3 below the rates derived in the most recent "2004 iteration" of the isochron crater chronometry system of Hartmann [2]. The difference may be much less than a factor 3 [3, 4]. Our plots show totals of primaries plus "field secondaries" but the difference allows room for numbers of "field secondaries". The discovery of a measurable rate of formation among decameter-scale craters (craters in the size range about 4 to 50 m) has great significance. As statistics improve through ongoing HiRISE detections [4], we are able to date very small, geologically young units formed in modern Martian time (say, $<10^5$ y old), and distinguish them from earlier units (say, 10^8 y old), not to mention from Noachian units formed in early geologic time (say, 3.5×10^9 y old). As an example, the currently measured rates suggest that a geologically inactive area of 10 km^2 will collect and retain about 1 primary impact crater in the diameter bin of 8 to 11 meters in about 100,000 years.

Objectives: The objective of this study is to apply these advances to interpretation of Martian geological processes. Firstly, we update the available statistics on crater formation rates at various sizes, combining MOC and HiRISE data, and making systematic new counts in various young areas at HiRISE resolution. We collaborate with HiRISE efforts and an ISSI-sponsored team in this effort. Such efforts should refine our knowledge of primary production rates, proportions of secondaries, and positions of the isochrons in our "isochron diagram," which shows the size-frequency distribution (SFD) of the total number of primary and secondary craters formed on surfaces of various specified ages (10^6 y, 10^7 y, 10^8 y, etc.) [2,5,6]. Plots of crater counts on this diagram, from a given Martian geological unit, give easily readable crater retention ages, i.e., survival times, for craters of a range of sizes.

Secondly, we use the newly refined isochron diagram to compare the behavior of decameter-scale craters in putatively ice-rich areas with their behavior in adjacent, putatively ice-poor "control areas" to show how these kinds of data can be used to interpret Martian geological processes. Here, we document and survey occurrences of small crater losses in ice-rich areas and document how crater populations vary from one type of icy terrain to another. Interpretiation of these data allow us to analyze the processes involved in small crater loss, such as sublimation or glacier-like flow. Our goal is not just to study decameter-scale phenomena in ice-ich terrains, but also to develop and demonstrate a new tool in the geological tool kit. Traditional crater count studies [2,5] give information in terms of stratigraphy and age of formations mapped in two dimensions, but we note that craters shallower than a certain depth are being rapidly lost in certain types of terrains, while larger craters, penetrating into deeper layers, are more stable. This means we can derive qualitative and quantitative information about structure and processes in the third dimension of depth, not to mention the "fourth dimension" of time.

Once the production SFD is identified for decameter-scale craters it is an extremely valuable tool, because small craters accumulate more quickly than large ones. This means we can get crater retention ages for decameter craters (i.e., crater survival times for craters of that size) on small units (areas as small as a few km on a side). We can study loss processes of these small topographic features, involving surface layers only a few tens of meters deep. And from the rollover of the production SFD at smallest sizes we can perhaps even clarify losses of weak vs. strong meteoroids in the Martian atmosphere.

We have found that presumably ice-rich materials show major losses of small-scale crater losses, compared to adjacent "control surfaces," in which small craters are well preserved [6]. By comparing with such control surfaces, the basic observation of the phenomenon of small-crater loss is independent of any considerations of theory, interpretation, derived isochron shapes, issues of secondary craters, etc. (We note that the crater size distribution on the non-icy "control terrain" typically fits previously estimated production isochron shapes, indicating good preservation of all the small craters in the non-icy terrains.)

Initial Results: Figures 1 and 2 show our initial counts from regions identified as young and relatively unmodified. In Fig. 1., the crater SFD on a lava flow in Eastern Amazonis Planitia, shows an age of ~100 My down to a diameter of ~2-3 meters. Figures 2 shows similar results for a young volcanic shield, approximately 100 My old. Whether the turndown at

D = 2-3 m is due to atmospheric loss is currently uncertain.

Initial counts on an ice-rich region in Western Elysium Planitia (Fig. 4) show a distintly different pattern. Craters diameter D < 31m appear to follow an isochron at a few My, and sharp, "fresh-looking" craters at D < 8m follow an isochron of only 100,000 y. This suggests active modification of the upper 3-10m on those timescales, which correspond to recent cycles of high-obliquity and climate modification.

Future Work: We will pursue counts of young pristine surfaces down to smaller diameters to establish the true SFD. We anticipate that these will clarify histories of putative ice-rich surfaces.

References: [1] Malin, M.C., et al. (2006) *Science* 314, 1573-1557. [2] Hartmann, W. K. (2005) *Icarus* 174, 294-320. [3] Kreslavsky, M.A. (2007) *7th Internatl. Conf. on Mars*, Abstract 3325. [4] Ivanov, B.A. (2009) *Lunar Planet Sci. Conf.*, Abstract 2283. [5] Hartmann, W.K., and Neukum, G. (2001) *Space Sci. Rev*. 96, 165-194. [6] Hartmann, W.K., and Werner, S.C. (2009) submitted to *Earth Planet. Sci. Lett.*

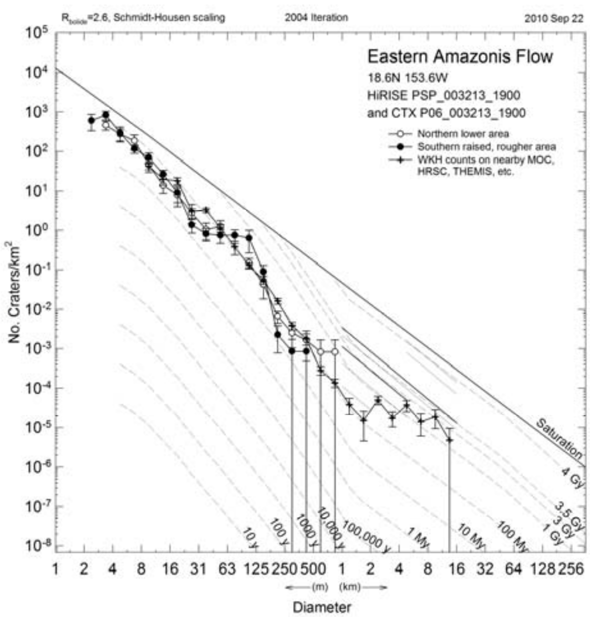

Figure 1. Crater SFD for a young lava flow in Eastern Amazonis Planitia, showing a good fit to the isochrons.

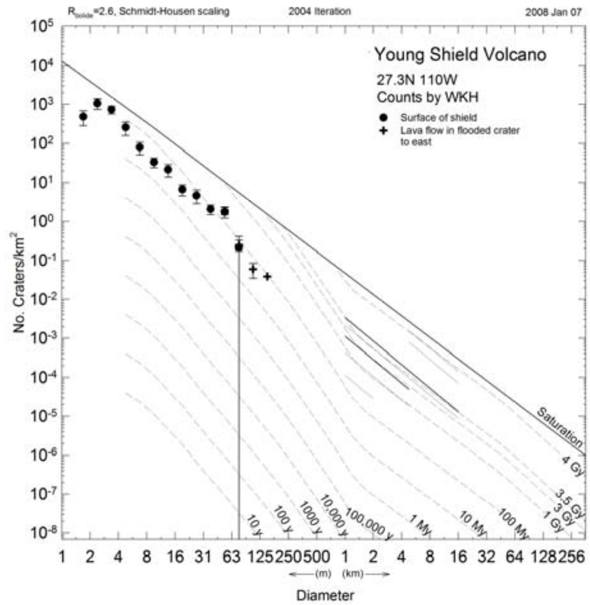

Figure 2. Crater SFD for a young shield volcano, showing a good fit to isochrons, and possible turndown at D~3m.

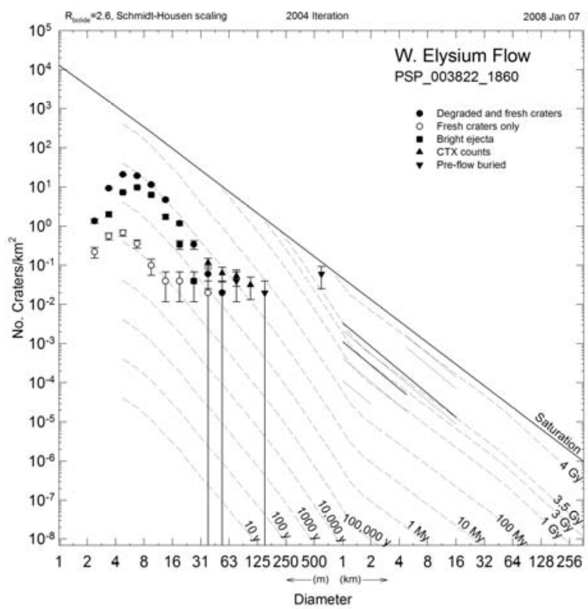

Figure 3. Crater SFD for an ice-rich region in Western Elysium Planitia, showing losses of sharp-rimmed craters at D < 31m .