MAJOR LATITUDE-DEPENDENT DEGRADATIONAL EVENTS ON MARS FROM CRATER DEPTH AND DIAMETER MEASUREMENTS: Joseph M. Boyce, Hawaii Institute of Geophysics and Planetology, University of Hawaii, Honolulu, Hawaii: jboyce@higp.hawaii.edu.

Introduction: The objective of this investigation is to provide deeper insight into the history of major gradational events on Mars through studying the effects of the responsible gradational processes on the morphology of impact crater populations.

We have approached this study by measuring the depth and diameter of 5128 craters in the 6-200 km diameter range (5083 measured from Mars Orbiter Laser Altimeter {MOLA} Digital Elevation Model {DEM} data utilizing the IMPACT Program of *Mouginis-Mark et al.* [1] and 964 craters measured from MOLA shot data) in widely distributed, and representative areas, that together, covers ~ 2.25 x 10^7 km^2 **(**Figure 1). These data are used as a basis for analysis of trends in the depth/diameter distributions and in determining relative age of those trends using crater density.

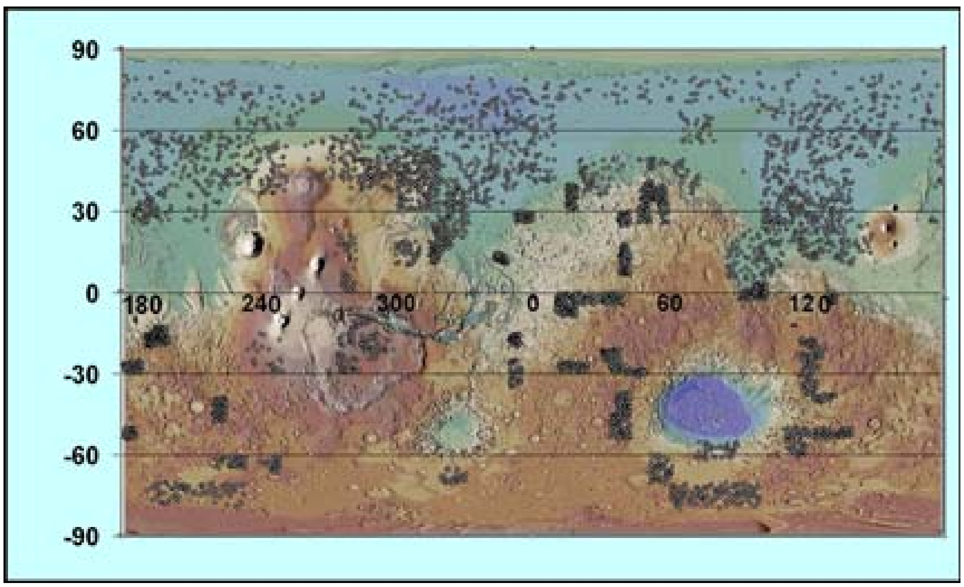

Figure 1. Map of the location of craters measured in this study.

This investigation is underpinned by the basic tenet of geomorphology that there is a cause and effect relationship between landforms and the processes that produce and subsequently modify those landforms. Consequently, those processes can be inferred by the characteristics of the morphology of the landforms they produced. It should also be kept in mind that while inferring processes (such as gradational processes) from morphology can be done with reasonable confidence, determining the environments (such as climatic conditions) in which those processes operated is much more problematic. However, often other data (e.g., geologic context or geographic distributions) can provide supporting evidence to either constrain or even confirm models that connect the particular process to the environment that fostered it. This then provides a basis for using impact craters to investigate past surface and near surface environments on Mars.

This study also takes advantage of two unique traits that make impact craters particularly useful for morphologic studies. Impact craters are 1) the only landform whose initial shape is generally known with relatively accuracy [2, 3, 4, 5, 6], which allows comparison with their observed shapes to determine the nature and amount of changes, and 2) produced continuously and uniformly on planetary surfaces, hence providing a means of estimating relative ages of modifying events (e.g., see, 7).

Results and Discussion: In general, the data suggests that location (in particular latitude), terrain type and terrain age have been important factors in controlling the development of the dr/D (d_r = depth measured from average rim crest to deepest point on crater floor, and D = crater diameter measured from rim crest to rim crest) relationships of craters on Mars. In this study, the focus is on the importance of latitude.

Mid-Latitudes: Scatter plots for the d_r/D distributions for craters in the mid-latitudes (~ +/- 45°) of Mars show that the depths of craters in Noachian-age terrain are bimodal compared with younger terrain in the same latitude range (Figure 2, 3). The two modes are separated by a relatively unpopulated gap that, based on crater density, developed in Late Noachian/Early Hesperian [8]. The presence of this gap suggests the abrupt onset and cessation of a brief episode of terrain degradation at the end of the Noachian, and adds support to previous findings [e.g., see 9, 10, and 11]. Figure 2 also shows that the younger terrain includes only one strong mode. The craters in this mode are relatively deep and appear to have undergone only modest and continuous modification (i.e., shallowing) since their formation. In addition, these regions often include unusually shallow craters that examination of images confirms have been burial by volcanic or sedimentary materials that blanket those local areas.

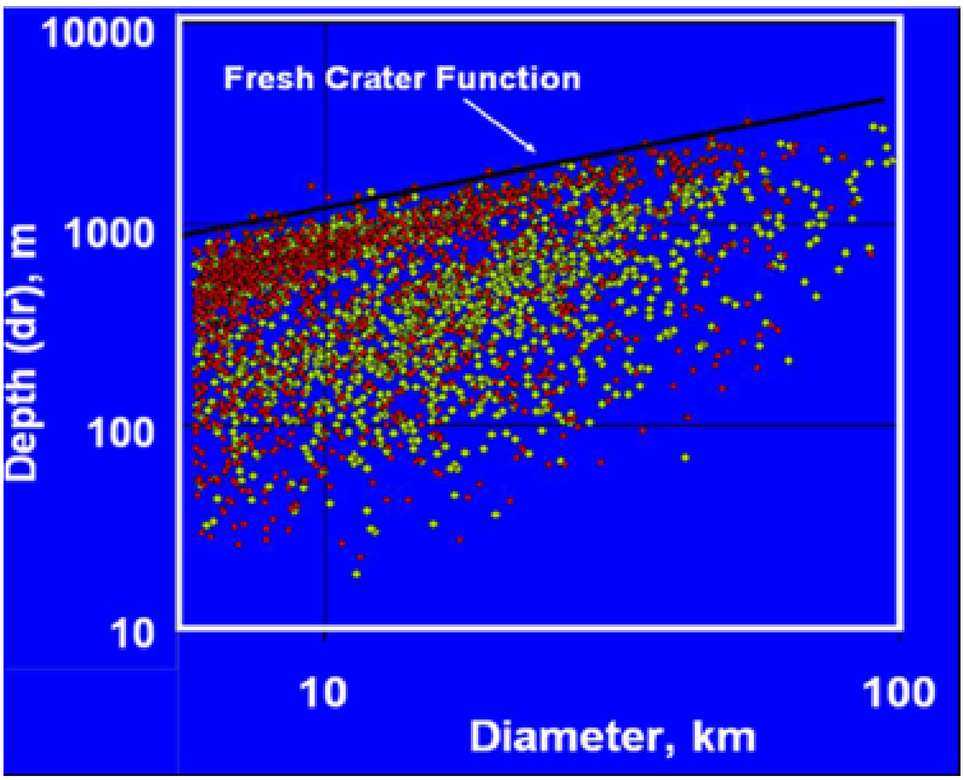

Figure 2. Scatter diagram showing depth/diameter relationships of craters in the mid-latitudes of Mars. Green is craters in Noachian terrain and red are craters in younger terrain. The anomalously deep crater of Isidis and S. Utopia has been excluded for simplicity.

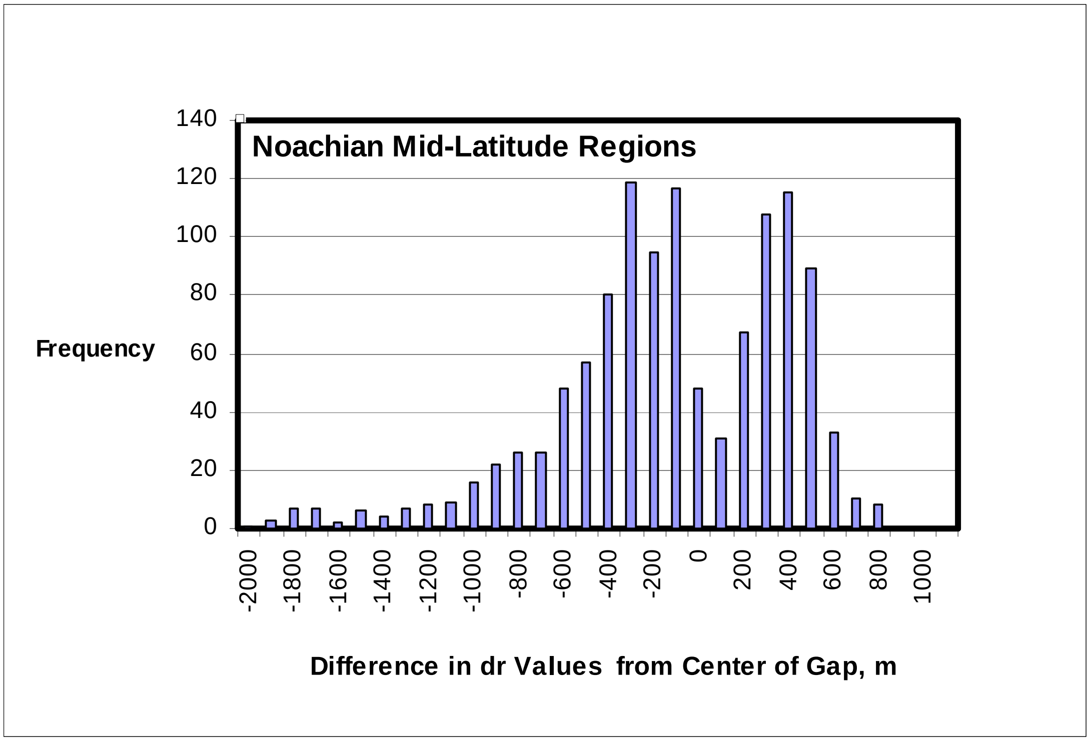

Figure 3. Histogram of crater depths in Noachian-age terrain measured from the gap between modes.

Furthermore, a comparison of depths of craters in Figure 2 with the depths of fresh craters (12) of the same size provides a measure of the amount of degradation during each episode. For example, the relief (i.e., d_r) of a fresh 20 km diameter crater (predicted $d_r = \sim 1800$ m) that formed in mid-latitudes during the Middle/Early Noachian would have been reduced by a total of ~ 1450 m by the present. In addition, ~ 350 m were lost throughout the Noachian, while ~ 400 m were lost during the episode that produced the gap. The remainder of the relief (~ 700 m) was lost during the Amazonian/Hesperian. Remarkably, considering the probable duration of the gap (i.e., a few tens of millions of years [7]), as much as 10 μ/yr of relief may have been lost from the example crater during the episode that produced the gap. Following this time the rate dropped by nearly two orders of magnitude thereafter.

High-Latitudes: In contrast to the mid-latitudes, the d_r/D scatter plots for craters in high-latitude (> 45˚) terrain of all ages and types show only one major mode (Figure 4). Like in the mid-latitudes, these plots often include some unusually shallow craters that result from burial by volcanic or sedimentary materials. The unimodal nature of the populations suggests that the processes responsible for the Late Noachian episode of intense degradation were not active in the high-latitude. In addition, compared to the mid-latitude terrain, relatively fewer deep craters < ~ 30 km diameter are found in high-latitude terrain. Such a paucity of deep craters could be due to a Late Amazonian mantle of materials tens to hundreds of meters thick such as that described by *Mustard et al.* [13] and *Forget et al.*, [14], or could be due to the affects of weak target materials. However, the presence of a few fresh craters in high-latitude terrain argues against the latter alternative.

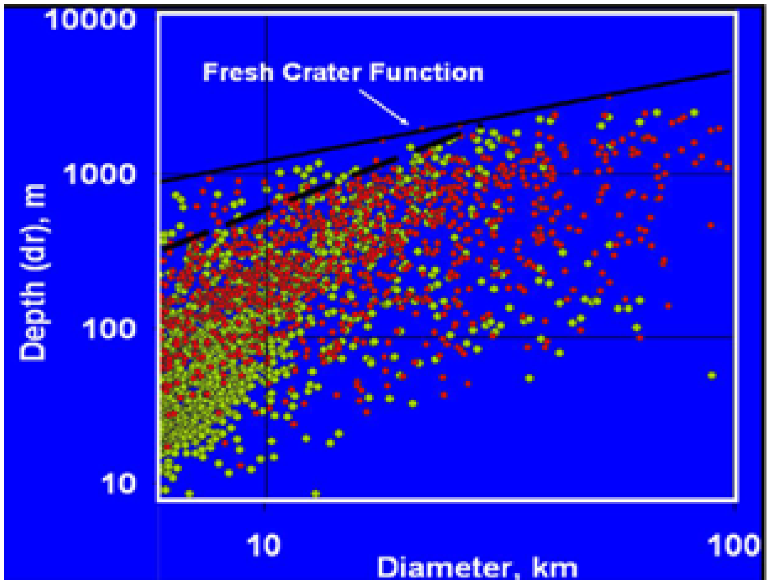

Figure 4. Scatter diagram of depth/diameter relationships of craters in high-latitudes of Mars. Red are craters in Noachian terrain and green are craters in younger terrain. Dashed line is the boundary between a sector where fresh deep craters are scarce and where shallower craters are common.

Conclusions: These observations suggest that a major period of degradation occurred at the end of the Late Noachian, where rapid erosion, possibly fluvial, reduced the topography of landforms only in the mid-latitude region. Previous workers have recognized this event and ascribe it to fluvial erosion or sapping. The effects of this Late Noachian-age degradational episode are not recognized in crater d_r/D distributions in high-latitude terrains. This suggests that the operation of processes responsible for producing the distribution were latitude (i.e., temperature) dependent. This would be most consistent with processes that require liquid water on the surface, as well as indicating that the poles of Mars were in approximately the same position as they are presently. In contrast, craters younger than Noachian age appear to have been degraded principally by infilling (probably eolian) and/or burial by volcanic materials. Furthermore, the scarcity of fresh craters in high-latitude regions hints at processes, such as regional mantling, that recently has rapidly reduces crater topography.

References: [1] Mouginis-Mark P. J. et al (2004) *J. Geophy. Res.,* doi:1029/2004JE002328; [2] Pike, R.J., (1980), Proc. *Lunar and Planet Sci Conf. 11th*, 2159-2190; [3] Garvin, J. B., et al., (2000), *Icarus, 144*, 329-352; [4] Boyce, J.M., et al (2006a), *Geophy. Res. Lett.*, L06202, doi.10.1029 /2005GL024462; [5] Boyce, J. M., P.J. Mouginis-Mark, H. Garbeil, and L. A. Soderblom (2006b), Lunar Plant Sci. XXXVII Abst # 2354.; [6] Stewart, S, and G. Valiant (2005) *Meteoritics and Plant. Sci*, 41, (10), 1509-1537; [7] Hartmann, W. K. (2005), Martian cratering 8: Isochron refinement and the history of Martian geologic activity. *Icarus,* 174, 294-320; [8] Scott, D. H., and K. L. Tanaka, (1986), *U.S. Geol. Sur. Misc. Invest. Map, I-1802-A*; [9] Craddock, R., and T. Maxwell (1993) , *J. Geophys. Res*., 98(E2), 3453-3468; [10] Craddock, R., and A. D.Howard, (2000) *J. Geophy. Res.,* 10.1029/2001 JE001505; [11] Forsberg-Taylor, N. K., et al. (2004), *J. Geophy. Res., 109(E0)*, 5002, doi:10 1029/2004 JE002242; 11908; [12] Boyce, J. M. and H. Garbeil, (2007), *Lunar Planet. Sci.* XXXVI, Abs # 1931 [13] Mustard, J.F., C.D. Cooper, M.K. Rifkin, (2001), *Nature,* 412, 411-414; [14] Forget, F., R, M, Haberle, F., Montmessin, B. Levrard, and J. W. Head (2006), , *Science*, 311 (5759), 368-371;.