THE FIRST AUTOMATIC SURVEY OF IMPACT CRATERS ON MARS: GLOBAL MAPS OF DEPTH/DIAMETER RATIO. T. F. Stepinski and Erik R. Urbach, Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston, TX 77058, tom@lpi.usra.edu, erikurbach@yahoo.com

Abstract. The new, global catalog of 75,919 impact craters on Mars has been compiled entirely by a computer algorithm. Using crater depths listed by the new catalog global maps of depth/diameter ratio are created. The global pattern of crater depths is consistent with the existence of the cryosphere at depths that decrease toward the poles.

Introduction: If left to traditional manual surveys, the fraction of cataloged craters to the craters actually present in the available and forthcoming data will continue to drop precipitously. The only practical solution to a comprehensive surveying of craters is to automate the process of their detection. Using the topography-based crater detection algorithm (CDA) [1,2] we have generated the catalog of Martian craters having diameters D ≥ 3 km. This is the first ever catalog of craters due entirely to a computer algorithm. The limit on the size of detected craters is set by the resolution of topographic data used for crater detection. Presently, the highest resolution *global* topographic coverage is provided by the 128 pixels/degree MOLA Mission Experiment Gridded Data Record (MEGDR) [3].

Methods. Our CDA is a two stage system that first identifies round depression on Mars and then uses machine learning technique to separate true craters from false positives. The application of our CDA to the entire surface of Mars requires subdividing the surface into 356 overlapping tiles. The craters are identified and measured at each tile separately and the results from individual tiles are concatenated into a single catalog from which duplicate detections are eliminated. In its present version the catalog lists coordinates of the center of each crater, its diameter, depth, and an underlying geological unit.

Results. The catalog lists 75,919 craters ranging in size from 1.36 km to 347 km. Fig.1 shows the exceedance probability of crater diameter, *D*, for all craters in the catalog. Exceedance probability, *P(D>X)*, is a probability that a randomly chosen crater has diameter larger than X. It represent a convenient way of displaying distribution of crater sizes. For comparison, Fig. 1 also shows exceedance probability of crater diameter in manually collected Barlow catalog [4] that lists 42,283 craters. The exceedance probability curve levels off for craters with D < 3 km setting a limit on statistical completeness of the catalog; the completeness limit of the Barlow catalog is about 5 km. Fig. 2 shows the density of craters in the new catalog. The density is calculated using a moving circular window of radius 250 km. It reflects the combined effect of true distribution of craters and the existence of some biases in the methodology due to different rate of automatic detection between different surfaces.

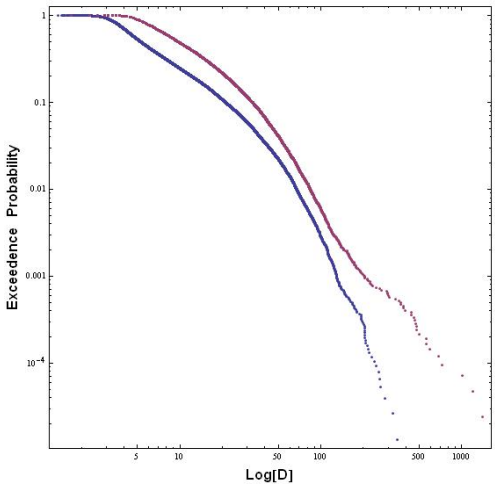
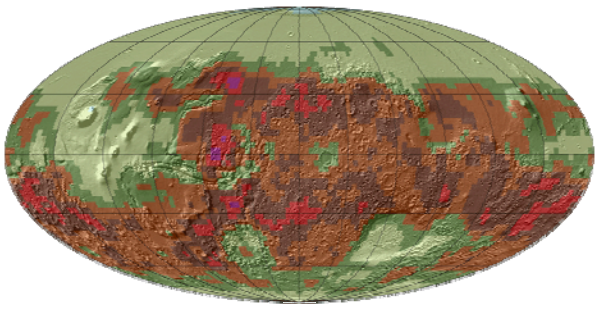


Figure 1: Exceedance probability of crater diameter *D* in the new catalog (blue) and the Barlow catalog (red). The curves level off at small values of *D* due to declining fraction of detected craters.



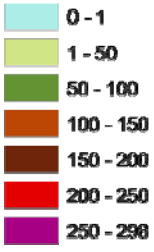


Figure 2: Crater density derived from our catalog. Craters of all sizes are included. The numbers given in the legend are the number of craters in a circular window having radius of 250 km.

The new catalog makes possible mapping the relative depths of craters over the entire Martian surface. For

this purpose we have divided all craters into six size bins, D < 5 km (35,738 craters) , 5 km ≤ D < 10 km (21,614 craters), 10 km ≤ D < 15 km (6594 craters), 15 km ≤ D < 20 km (3788 craters), 20 km ≤ D < 25km (2180 craters), D ≥ 25 km (5971 craters). Using craters from each bin separately, maps of depth/diameter ratio (d/D) are constructed using the moving average technique. Fig. 3 shows maps of (d/D) for bins 2, 4, and 6.

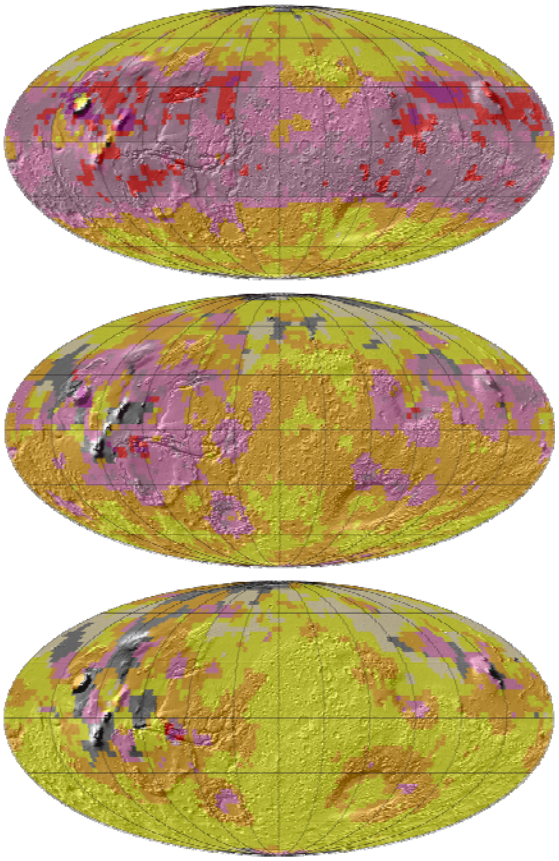


Figure 3: Global maps of spatial distribution of (d/D) on Mars. Maps of (d/D) constructed for craters 5 km ≤ D < 10 km (top), 15 km ≤ D < 20 km (middle), D ≥ 25 km (bottom). Pixels that lacks sufficient number of craters in their neighborhood to calculate moving average are shown in gray.

Discussion: The maps reveal existence of different spatial patterns of (d/D) distribution. (1) For small craters with D < 10 km (the first two size bins) there is a clear latitudal pattern. The Martian globe is divided into two zones, the equatorial zone ($Zone_E$, predominance of reddish colors on the map) extending from the equator to the latitude of up to ±40°, and the high latitude zone ($Zone_{HL}$, predominance of yellowish colors on the map) extending from to the latitude of ~ ±40° to the poles. In $Zone_E$ the craters are relatively deep, whereas in $Zone_{HL}$ the craters are relatively shallow. (2) For craters with D > 25 km (the sixth size bin) there is no obvious spatial pattern; throughout most parts of the globe the carters of these sizes have the same, low values of relative depths. (3) For 10 km < D < 25 km craters (the third to fifth size bins) some limited latitudal dependence is observed and some regional dependence is also noticeable. The patterns on Fig. 3 can be explained by an existence of the cryosphere with the depth of its upper boundary significantly lowered in the equatorial regions, just as predicted by models based on ice stability concept [5,6,7]. Calculations [8,9] of viscous relaxation indicate that the style of crater modification depends on the depth of the cryosphere relative to the crater size. For a relatively deep cryosphere viscous relaxation leads to significant decrease of crater's (d/D) value. For a relatively shallow cryosphere there is no significant modification of crater's (d/D) value. In $Zone_E$ the high values of (d/D) for D < 10 km craters indicate absence of viscous relaxation and no cryosphere up to the depths of ~ 1 km. In $Zone_{HL}$ the low values of (d/D) for D < 10 km craters indicate presence of viscous relaxation and cryosphere located just below the surface.

Overall, the new catalog serves two purposes. First, it demonstrates the feasibility of surveying craters by automatic means; further development will make possible surveys of sub-kilometer craters. Second, the new catalog makes possible new types of analysis including creation of the global map of craters depth. The global pattern of crater depth appears consistent with the existence of the cryosphere at latitude-dependent depth. Two regions on Mars, Isidis Planitia and Utopia Planitia appear to have unusually high concentration of craters with high values of (d/D).

References. [1] Stepinski, T. F. et al. (2007) *LPSC XXXVIII*, Abstract #1338. [2] Stepinski, T.F. et al. (2007) *Icarus*, submitted. [3] Smith D. et al. (2003) NASA Planetary Data System, MSG-M-MOLA-5-MEGDR-L3-V1.0. [4] Barlow, N.G., (1988) *Icarus*, 75(2), pp. 285- 305. [5] Clifford S. M. and Hillel D. (1983) *JGR, 88*, 2456-2474. [6] Fanale F. P. et al. (1986) *Icarus, 67*, 1-18. [7] Clifford S. M. (1993) *JGR, 98 E6*, 10,973-11,016., 121-133. [8] Parmentier, E. M. and Head, J. W. (1981) *Icarus, 47*, 100-111. [9] Jankowski, D. G. and Squyers, S. W. (1993) *Icarus, 106*, 365-379.