CONSTRAINTS ON THE FORMATION AND MODIFICATION OF LOBATE DEBRIS APRONS THROUGH CATEGORIZED CRATER COUNTS. Daniel C. Berman, David A. Crown, and Emily C.S. Joseph, Planetary Science Institute, 1700 E. Ft. Lowell Rd., Suite 106, Tucson, AZ 85719; bermandc@psi.edu.

Introduction: The Martian mid-latitudes are regions of high scientific interest as they are zones where the effects of ice on the surface geology are prominent and representative of geologically young periods of volatile-driven activity [e.g., 1-5]. Recent research has focused on descriptions of small-scale landforms observed in high-resolution images, including gullies, arcuate ridges, and viscous flow features, as well as widespread ice-cemented mantling deposits interpreted to be relicts from Late Amazonian obliquity-driven ice ages [e.g., 5,6]. Extensive mid-latitude glaciation has been proposed on the basis of analyses of these latitude-dependent mantles, debris aprons and lineated valley fill in eastern Hellas and in the fretted terrain along the dichotomy boundary, rock glaciers at the base of Olympus Mons, and fan-shaped, cold-based glacial deposits on the NW flanks of the Tharsis volcanoes [e.g., 6-8]. Susbsurface radar sounding data have recently shown lobate debris aprons in the eastern Hellas and Deuteronilus Mensae regions to be composed predominantly of water ice [9,10]. In conjunction with analyses of apron surfaces, we have counted and characterized the morphologies of small craters on apron surfaces in order to constrain the geologic history of the aprons.

Morphologic Characteristics of Small Impact Craters on Apron Surfaces: We have examined the degradation of impact craters on apron surfaces to assess typical sequences of crater degradation that help us to interpret crater-size frequency distributions (SFD). Craters exhibit fresh, degraded/flat-floored, and filled morphologies. For accurate age interpretations, we need to understand degradational morphologies and to discriminate populations that provide age constraints on deposits that mantle apron surfaces from those that represent the formation/emplacement of the apron mass. We have noted significant signs of burial and partial exhumation of craters on apron surfaces, including morphologic signatures similar to “ring-mold” craters [11] that preserve textures of the surrounding terrain in their interior, such that they are best interpreted as filled craters, rather than craters showing central mounds due to impact into ice as suggested by [11].

Crater Count Methodology: Crater SFD statistics have been compiled using established methodologies [12-15]; all impact craters (primaries and isolated secondaries) on a given surface in a specific diameter range are counted while avoiding areas of obvious secondary chains or clusters. These data are then plotted on the isochrons defined by [13-15] to assess relative age (Martian time-stratigraphic age) and estimate absolute age. Deviations from isochron shape over specific crater size ranges, along with categorization of crater type provide further information on erosional and depositional processes affecting the surfaces of interest.

Potentially ice-rich surfaces can be geologically complex given uncertainties in ice content and distribution, and mantling and degradational history. In mid-latitude zones, surfaces may have undergone multiple cycles of mantling. We assume fresh (bowl-shaped) craters superpose even the youngest of these and that filled craters are filled with mantling deposits and thus indicate a formation age of the landform/surface that has been mantled. Layered mantling deposits on the floors of craters, as well as degradational textures resembling mantle materials on surrounding surfaces support this interpretation. Degraded and flat-floored craters may have formed before the most recent mantling episode, but have not accumulated much fill.

Study Areas: We have conducted crater count analyses on lobate debris aprons in the Deuteronilus Mensae region along the dichotomy boundary [cf., 16] and in the region east of Hellas Basin. In Deuteronilus Mensae, we have counted craters on two large complexes of aprons (northern and central) with a total area of 13,442 km^2 (5,113 km^2 of which have been categorized). In eastern Hellas, craters have been counted on 19 separate aprons, with a total area of 17,663 km^2, and categorized by their morphology on nine of those (9,605 km^2).

Deuteronilus Mensae Debris Apron SFD: The distribution of all craters superposed on the northern debris apron complex in the study area (Fig. 1) shows one segment that follows the isochrons (~500 m - 2+ km), indicating a formation age of ~1 Gy during the Early Amazonian Epoch (range Late Hesperian-Middle Amazonian). The distribution of filled craters mimics that for all craters but the depletion of small crater sizes (relative to the isochrons) is greater, consistent with mantled debris apron surfaces. The distributions of degraded and flat-floored craters match the isochrons from 250 m - 1 km diameters, giving an age of ~100 My. The distribution of fresh craters shows a segment that follows the isochrons (~60 - 500 m), consistent with the several-My age estimates of obliquity-driven Martian mid-latitude mantling deposits.

Distributions of craters superposed on the central debris apron complex show similar results, but without a good fit to the isochrons for all craters. A resurfacing event may have occurred at about 100 My. Degraded craters suggest ages of 10s of My. The various potential mantling/resurfacing ages estimated from debris aprons can be attributed to a combination of highly mobile surface materials, the presence of ice and the degradational effects of loss of ice, and a complex history of erosion and mantling [3].

East Hellas Debris Apron SFD: The distribution of all craters superposed on all 19 debris aprons in eastern Hellas shows an age of ~500 My. Individual aprons show a range of ages, from 10s of My to several Gy, depending on the crater size range examined. For all craters on debris apron 12 in eastern Hellas, for example (Fig. 2), a segment follows the isochrons (~250 m – 2 km), indicating a formation age of ~800 My during the Middle Amazonian. As in Deuteronilus Mensae, the distribution of filled craters mimics that for all (and degraded) craters but the depletion of small crater sizes (relative to the isochrons) is greater, consistent with mantled debris apron surfaces. Fresh craters show an age of ~100,000 years, indicating a recent mantling episode.

Craters of various degradation states superposed on eastern Hellas debris aprons reveal three separate categories of ages. The degraded and filled craters, which may reveal apron formation ages at large diameters, show ages in the range of 500 My – 1 Gy. However, these ages are not shown in all aprons, due to the small size of aprons and thus the lack of larger superposed craters. As the counts move to smaller craters, a resurfacing age is revealed, indicating the preserved mantling deposits, typically between 10 Myr and 500 Myr. Fresh craters reveal a third category, the age since the most recent mantling episode, typically less than 10 Myr.

Summary: Compilation of crater counts using CTX images and analysis of SFD, including diameters of 100 m and larger, coupled with categorization of crater morphologies provides important insights into interpretation of the formation and modification of lobate debris aprons. Continued analyses of ice-rich features using categorized crater counts will help to further understand Martian climate change and geologic evolution.

References: [1] Berman D.C. et al. (2005) *Icarus 178*, 465-486. [2] Berman D.C. et al. (2009) *Icarus 200*, 77-95. [3] Christensen P.R. (2003) *Nature 422*, 45-48. [4] Head J.W. et al. (2003) *Nature 426*, 797-802. [5] Mustard, J.F., et al. (2001) *Nature 412*, 411-414. [6] Head J.W. et al. (2006) *EPSL 241*, 663-671. [7] Head J.W. et al. (2005) *Nature 434*, 346-351. [8] Crown D.A. et al. (2005) *JGR 110*. [9] Holt J.W. et al. (2008) *Science 322*, 1235-1238. [10] Plaut J.J. et al. (2009) *GRL 36*. [11] Kress A.M. and Head J.W. (2008) *GRL 35*. [12] Berman D.C, and Hartmann W.K. (2002) *Icarus, 159*, 1-17. [13] Hartmann W.K. (2005) *Icarus, 174*, 294-320. [14] Hartmann W.K. (2007) *7th Intl. Conf. on Mars, abstract 3318*. [15] Hartmann W.K. (2007) *Icarus, 189*, 274-278. [16] Chuang F.C. and Crown D.A. (2009) USGS Map 3079.

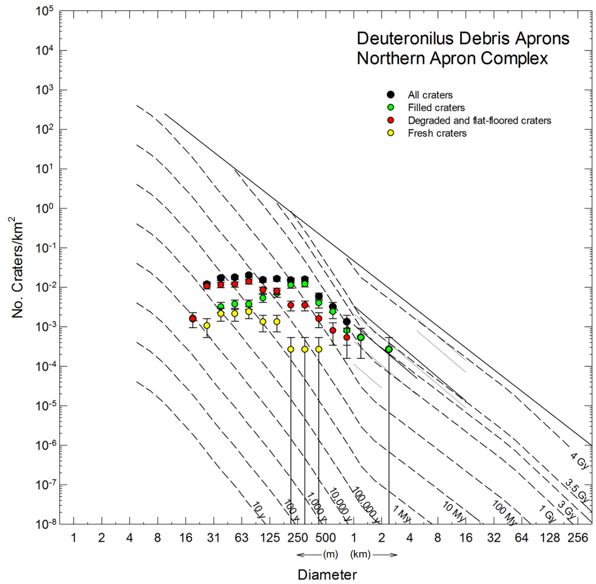

Figure 1. Crater size-frequency distributions for northen debris apron complex in Deuteronilus Mensae. N_{all}=411, N_{filled}=151, $N_{degraded/flat}$=159, N_{fresh}=24, A=3,513 km^2.

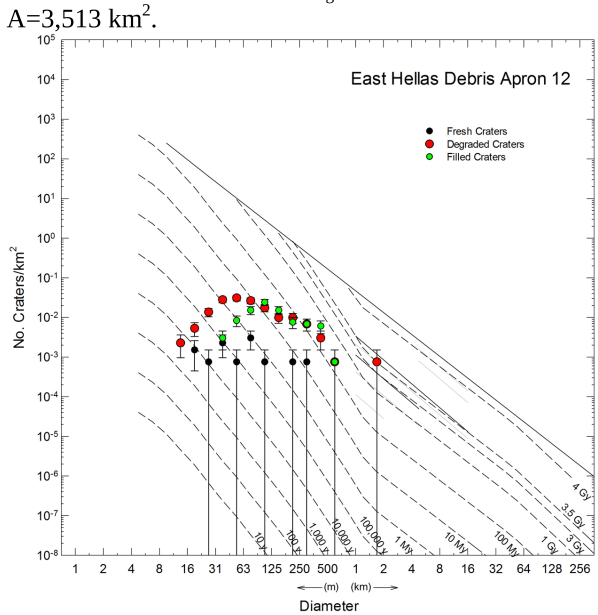

Figure 2. Crater size-frequency distributions for lobate debris apron 12 in eastern Hellas. N_{all}=334, N_{filled}=115, $N_{degraded}$=205, N_{fresh}=14, A=1,313 km^2.