DEBRIS-COVERED GLACIER DEPOSITS IN A TRIO OF IMPACT CRATERS IN THE SOUTHERN MID-LATITUDES OF MARS: EVIDENCE FOR ICE ACCUMULATION AND INTERCRATER FLOW IN CONNECTED CONCENTRIC CRATER FILL. Michael J. Beach and James W. Head. Dept. of Geo. Sci., Brown University, Providence, RI 02912 (Michael_beach@brown.edu).

Introduction and Methods: Concentric crater fill (CCF), lobate debris aprons (LDA), moraine-like ridges (MLR), and similar ice-related deposits occupy the interiors of craters in certain mid-latitude ranges in both the northern and southern hemispheres of Mars [1-8]. Recent analyses have focused on mapping the nature and distribution of features in these CCF deposits on a regional to global basis to look for patterns of accumulation and flow [8]. We have begun a detailed analysis of these occurrences in order to use impact crater size-frequency distribution data to date them [9] and assess how these patterns might be related to phases of regional ice deposition and glaciation in the Amazonian history of Mars [10-13]. As part of this analysis and using CTX and MOLA data, we have examined a trio of craters centered at 41°S, 153.8°W (SW of Tharsis on the west rim of Newton Crater); this setting offers a unique opportunity to study intracrater and intercrater ice-related deposits and their evolution within adjacent and overlapping crater interiors (Fig. 1) in a narrow latitude band. We address the following questions: Are these examples of CCF related to viscous flow of ice-cemented regolith or to debris-covered glaciers? Is there evidence for local accumulation and flow in crater interiors? If so, how much and in what directions? Is there any evidence of inter-crater ice deposits at the time of CCF formation? Is there any residual ice beneath the present surfaces? What was the age or ages of CCF formation in these craters?

We utilized CTX data superposed on gridded MOLA data to map the characteristics of the crater floors, walls, and exteriors (Fig. 1). Individual MOLA profiles and gridded data profiles (Fig. 2) permitted assessment of the depths of these craters and their deviation from fresh crater morphometry [14] due to processes operating subsequent to their formation. Geological sketch maps of surface lineations and flow-like features permitted assessment of patterns of floor movement, and correlation with distinctive features on the crater walls (Fig. 1).

Analysis and Interpretation: Stratigraphic superposition relationships of ejecta deposits indicate that Crater C (diameter = 15.8 km) postdates Crater B (11.8 km) and that Crater A (10. 5 km) is the youngest. None of the three craters appear to show the topography typical of pedestal [12] or excess ejecta craters [11, 15], indicating that there was unlikely to have been a regional blanket of snow and ice at the times of their formation. Superposition of a small pedestal crater on the rim of Crater A, however, provides evidence of the presence of ice deposits distributed beyond the crater interiors and perhaps regionally in extent [11-12, 16-17] subsequent to their formation. Geologic sketch maps (Fig. 1) show that the crater floors are characterized by three units: 1) A regionally flat, but sloping lineated and textured terrain that is smooth at the hundreds of meters scale but very rough at the meters to tens of meters scale. The linear and arcuate features mapped in this unit reveal major patterns of flow direction, as indicated by arrows. 2) A very rough unit, characterized by hills and hummocks of the order of tens to hundreds of meters in relief, occurring on the floor at the base of the walls, commonly at the terminus of the flow directions. 3) A hummocky unit, located in Crater B, that is dominated by hollows and depressions that appear to be formed in unit 1, and which appear similar to sublimation pits observed in other examples of CCF [6-7]. Two types of impact craters exist on the floors: bowl-shaped craters, and ring-mold craters (RMC) [2]; the latter provide good evidence for the presence of buried glacial ice below a sublimation lag of rocky material [2,18]. Crater walls are characterized by: 1) vertically textured slopes ending at the margins of the crater floor in spatulate, convex outward depressions. Superposed young gullies characterize these features and together these are similar to crater interiors seen elsewhere in Newton crater interpreted to be the source regions for debris covered glaciers on the crater floors [18]. For the most part, this unit correlates positively with the source regions for the flow directions in the smooth floor unit (Fig. 1). 2) Parts of the crater walls are relatively smooth and untextured. 3) Other parts of the walls are characterized by horizontal often parallel bands or lineations of different albedo, similar in some cases to features that have been interpreted as trim lines marking the location of past ice highstands [19].

Discussion and Conclusions: Together, the topography and geologic maps of these craters permit us to assess their nature and evolution. Characteristics and patterns of the floor and wall units show: 1) Smooth floor units generally tilt in a N-S direction, broadly in the direction indicated by the surface flow-feature vectors; 2) Surface flow vectors can be traced back to textured wall units interpreted to have been accumulation zones for ice that became debris covered and formed the lobes on the floor; these lobes show distinctive indications of convergence, deformation and coalescence and indicate that surface flow patterns are evidence for flow of ice and debris completely across the crater floor; 3) Ring-mold craters [2] provide evidence that glacial ice existed below the current surface debris layer and that these floor units were debris-covered glaciers, not ice-assisted creep of crater wall talus; 4) The presence of the hummocky floor unit in the southern part of craters B and C occurs at the distal ends of the flow vectors; this unit is interpreted to result from the convergence of surface flow in the southern parts of the craters and its crumpling and deformation into the current configuration of hummocky terrain. 5) The location of the horizontal wall bands interpreted to be trim lines just above the hummocky terrain suggests that these represent previous highstands of glacial ice in the crater interior; 6) The complex flow patterns of craters A and B, compared to the relatively simple patterns of Crater C are interpreted to indicate that there was glacial ice flow between craters B and A. Both craters B and A show a fundamentally similar background pattern of N-S oriented wall units and broad flow vectors, but the NE portion of Crater B has been disrupted by divergence of flow from B through the low point of the common rim, into crater A, distorting the generally N-S flow pattern of both craters. 7) The unusual pitted unit in the northern part of Crater B is interpreted to have been the result of this late-stage interflow from Crater B into Crater A through the breached rim (Fig. 2). Late-stage stretching of ice and the overlying debris cover could result in more exposed ice in this location and enhanced sublimation to form the pits. 8) The presence of features interpreted to be trim lines and the current topography permit assessment of the previous levels of ice thickness and the location of the top of the ice when flow ceased. The locations of the spatulate depressions provide evidence for the most recent active ice flow levels [18]. These lie at the margins of the floor unit in craters B and C, but are perched 100-200 m above the floor unit in Crater A. This suggests that sublimation and subsidence of the floor unit in A has occurred since they formed. The interconnection and evidence for flow between B and A indicate that ice must have been at least as high as the lowest point in the common part of the wall; currently, this lies ~200 m above the surface of the floor unit in B, indicating the surface of the ice has subsided at least this amount since that time. 9) The general flow directions (N to S) at this latitude (~41 S) are consistent with global CCF flow patterns [8] and indicate poleward flow at these latitudes in contrast to concentric flow at higher latitudes. This is consistent with the interpretation [8] that at these latitudes at least late-stage ice accumulation and flow is focused on the colder pole-facing slopes. 10) Precise ages of the floor units are often difficult to obtain due to the presence of sublimation and other modification and degradation processes. However, our data are consistent with the formation of these units in the last several hundred million years. (11) RMCs, sublimation pits (Fig. 1), and current shallow floor depths of the three relatively fresh craters (Fig. 2) all suggest that significant ice (as much as 350, 500, and 270 meters in A, B and C respectively) lies buried below the surface debris cover today, representing an accessible mid-latitude record of Martian glacial conditions and ancient atmosphere.

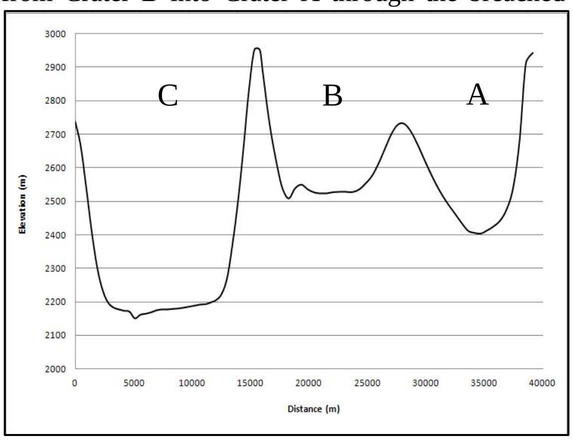

Figure 2: Altimetric profile from MOLA gridded data (see Fig. 1 for location).

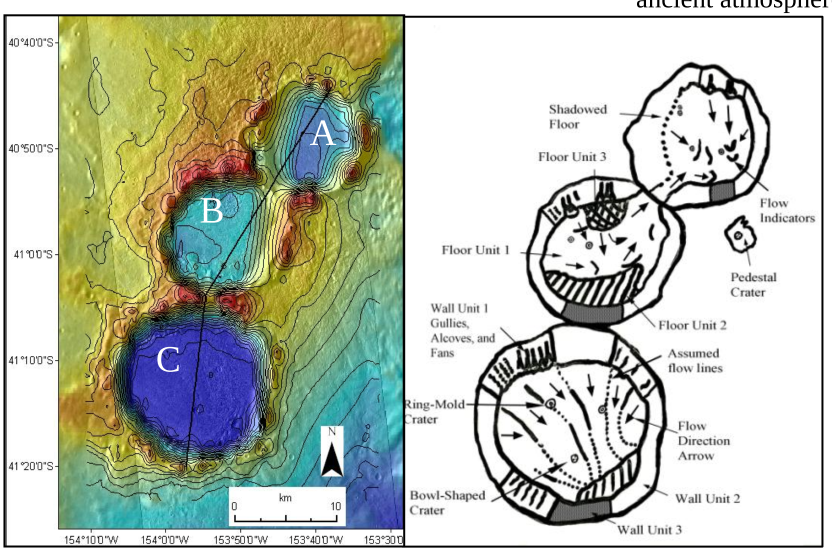

Figure 1: Left; MOLA gridded data (50 m contours) of study area overlain on CTX image. Right; geologic sketch-map showing flow directions.

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