RING-MOLD CRATERS (RMC) IN LOBATE DEBRIS APRONS (LDA) IN THE DEUTERONILUS MENSAE REGION OF MARS: EVIDENCE FOR SHALLOW SUBSURFACE GLACIAL ICE IN LOBATE DEBRIS APRONS. L. R. Ostrach, J. W. Head and A. Kress, Department of Geological Sciences, Brown University, Providence, RI 02912 USA (Lillian_Ostrach@brown.edu).

Introduction: The surfaces of lobate debris aprons (LDA) in the northern mid-latitudes of Deuteronilus Mensae contain craters with unusual morphologies. Previous work [1-6] suggests the range of morphologies of these superposed craters to be evidence of an ice-rich substrate undergoing modification by sublimation processes. Kress et al. [2] and Kress and Head [3] identified and classified a range of unusual crater forms superposed on LDA and lineated valley fill (LVF) in Mamers Valley and identified a number of candidate formational and degradational mechanisms to explain the observed morphologies (Fig. 1-3) [4]. Two crater types are recognized in LDA/LVF regions: 1) bowl-shaped craters, interpreted to be relatively fresh craters in regolith as observed in most areas of Mars, and 2) ring-mold craters (RMC), which are generally rimless craters with a circular moat surrounding an inner circular plateau with a number of different morphologies [2-5]. The results of these studies [2-5] strongly suggest that the surface textures and geological relationships of RMC's and bowl-shaped craters indicate that the lineated surface of LDA/LVF is close to a primary surface of sublimation till, and that buried glacial ice remains within several tens of meters below the present surface of LDA/LVF deposits.

If this interpretation is correct, examination of the presence of RMC's and bowl-shaped craters in a region containing significant LDA's and application of this method of analysis may aid in testing for the presence of ice entrained in these deposits. Multiple theories of origin for LDA exist (Fig. 4): 1) rock-fall: material falls from the escarpment and forms a talus/debris pile which subsequently undergoes slumping, 2) ice-assisted creep: presence of interstitial pore ice promotes creep (analogous to terrestrial rock glaciers), and 3) primary ice/debris-covered glacier: large amounts of primary ice accumulate an insulating debris-cover, differential sublimation processes dominate over geologic time [7]. Volumetric and morphology analyses [7] suggest a debris-covered glacier endmember and here we show that analysis of RMC's implies the presence of shallow buried ice within LDA.

Study Approach: High-resolution CTX images P02_001848_2241, P03_001848_2242, and P01_001373_2242 were mosaicked to form a composite image of the study area, a group of isolated massifs and accompanying LDA deposits, at 44°N, 29°E. We systematically mapped the presence of RMC's and bowl-shaped craters, as well as the extent of LDA deposits and primary flow directions (Fig. 5).

Description of Region: The study region is located in the center of the Deuteronilus Mensae region of Mars, an area well-documented in the literature for the abundance of ice-related features and flow. Distinctive surface morphologies, including compressional ridges, lobes, and sublimation pits can be distinguished in the composite image and material flow direction can be identified (Fig. 5) which strongly implicates that viscous flow processes, coupled with the presence of an ice-rich material, dominated apron movement. Additional support for the presence of significant ice entrained in the LDA's is the presence of RMC's. For this study region, 188 RMC's were identified on the apron surfaces in various morphologies and apparent degradational state, with the majority (>50%) located in the southern-most portion of the LDA complex.

Discussion of Results: In the 188 RMC sample, a wide range of sizes exists. Calculated diameters were determined from the edges of the outer moat and for this group, diameters range from ~61m to ~670m. The RMC's generally range much larger diameters than generally smaller bowl-shaped craters. This supports the hypothesis that RMC's are due to the spallation process resulting from impacts into an ice-rich surface [4] and thus the presence of RMC's may be an indicator of significant ice deposits in the near subsurface. This is consistent with the debris-covered glacial origin for these landforms.

104 bowl-shaped craters were identified within the areal extent of the LDA's in this region, and the locations of these craters are much more widespread than the RMC's. Bowl-shaped craters exhibit a range in diameter, ~60m to ~480m, measured from the crater walls, and little variation in morphology is observed (Fig. 6). These results generally support the model that bowl-shaped craters impacted into dry or ice-cemented regolith while RMC's represent impacts into buried ice. The overlap in sizes may reflect the presence or absence or different depth to ice (Fig. 1-3, 6).

Conclusions: These data 1) support the presence of significant residual ice in the LDA, 2) suggest that it is at a shallow level, 3) suggest that it is relatively pure ice, and 4) support a model of LDA as debris-covered glaciers rather than pore-ice-assisted creep of talus and rock-fall.

References: [1] N. Mangold (2003) *JGR*, 108, 8021. [2] A. Kress et al. (2006) *LPSC 37*, #1323. [3] A. Kress and J. Head (2007)

B-V 46, #44. [4] A. Kress and J. Head (2008) *LPSC 39*, Abst. #1273. [5] A. Kress et al. (2008) *LPSC 39*, this volume [6] B. McConnell et al. (2007) *Mars 7*, #3261. [7] L. R. Ostrach and J. W. Head (2008) *LPSC 39*, this volume.

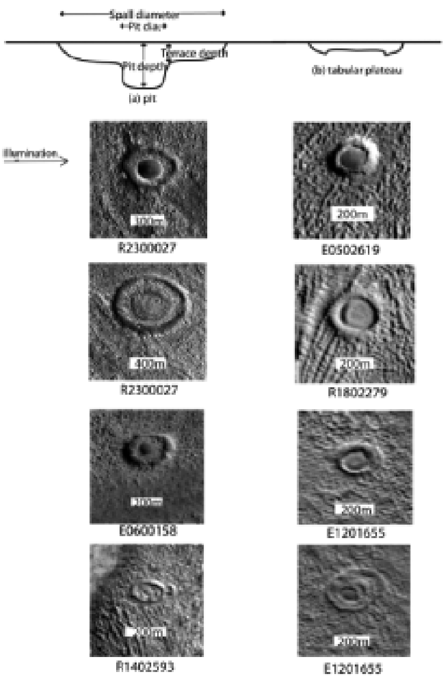

Fig. 1: RMC on LVF/LDA in Mamers Valles compared to profiles of experimental craters formed in ice substrates, from [4].

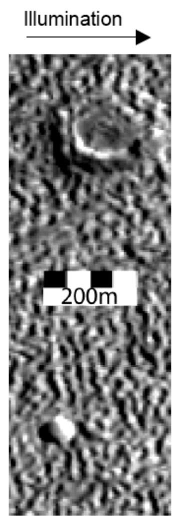

Fig. 2: (above) Small bowl-shaped crater on LVF located within Mamers Valles (bottom); RMC in adjacent part of LVF (top). From [5].

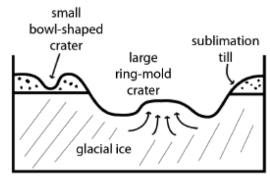

Fig. 3: (above) Two-substrate model for the bowl-shaped and ring-mold craters in LDA/LVF. Small impacts penetrate only sublimation till while larger impacts penetrate shallow glacial ice,. From [5].

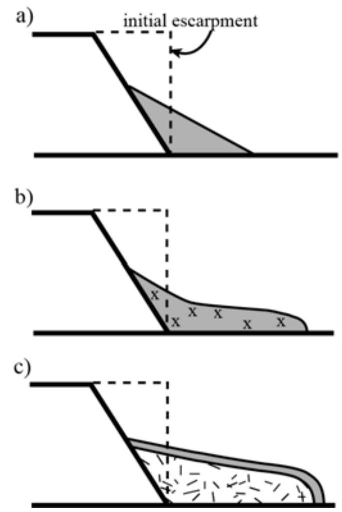

Fig. 4: (top right) Deposits that would result from various origins for an LDA. a) Rock-fall: debris from the escarpment forms a talus pile at the angle of repose. b) Interstitial ice: ice-assisted creep dominates, forming a concave-up, lobate deposit analogous to terrestrial rock glaciers. c) glacial ice: primary ice entrained in the deposit accumulates a debris-cover that insulates the ice core; distinct sublimation features are observed.

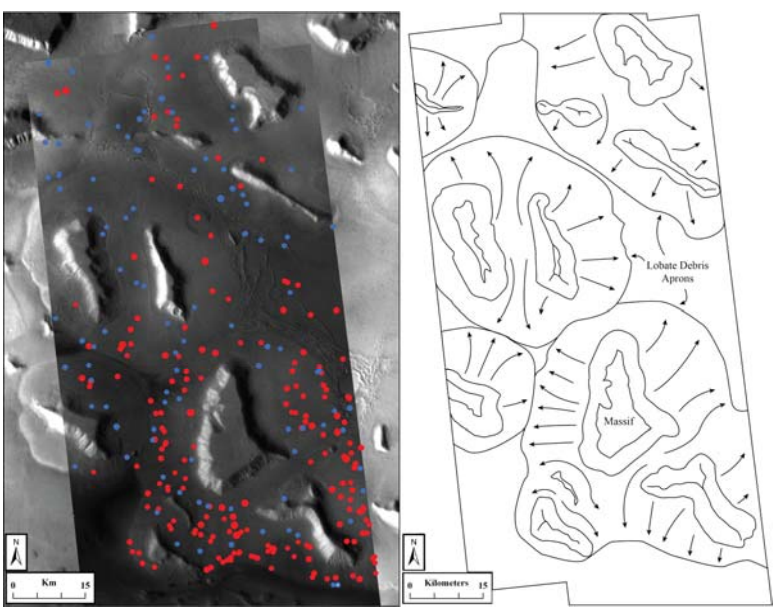

Fig. 5: Left: CTX mosaic of the study region. Bowl-shaped craters are blue dots, RMC's are red dots. Right: Geologic sketch map showing LDA extent in this region and general flow directions in the deposits.

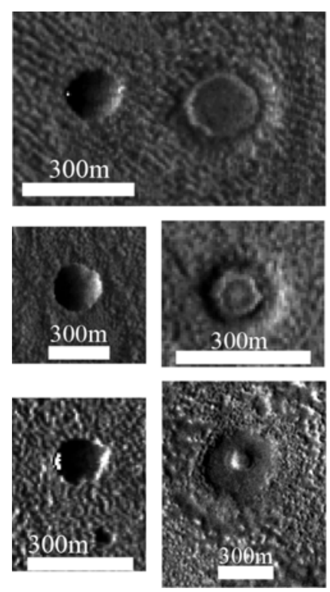

Fig. 6: Bowl-shaped craters (left) and RMC (right) from the study region. Variable morphology is present in the RMC's but the bowl-shaped craters are generally uniform. Illumination from left, North is up.