INTERNAL STRUCTURE OF A LOBATE DEBRIS APRON COMPLEX IN EASTERN HELLAS: EVIDENCE FOR MULTIPLE MID-LATITUDE GLACIATIONS ON MARS. E. Quartini[1], J. W. Holt[2] and T. C. Brothers[2] [1]Dipartimento di Scienze della Terra e Geologico Ambientali, Univerity of Bologna, Bologna, Italy 40100 (enrica.quartini@studio.unibo.it), [2]University of Texas Institute for Geophysics, Jackson School of Geosciences, University of Texas, Austin, TX 78758 (jack@utig.ig.utexas.edu); (tcbrothers@mail.utexas.edu)

Introduction: Lobate debris aprons (LDA) in the middle latitudes of Mars were first recognized to be ice-related features using high resolution images of the surface of Mars that allowed detailed analyses of their peculiar morphological characteristics, including geometry and surface lineations [1-5]. With the more recent addition of orbital radar sounding data, it has become possible to investigate the internal structure and composition of LDAs which have been confirmed to be deposits of almost pure water ice protected by a thin layer of debris [6-7].

We infer the past depositional history of an LDA complex located in the eastern Hellas region by conducting a multi-facet analysis of its surface lineations and internal structure, composed of multiple subsurface reflections as first detected by [6]. We also use this set of observations to constrain topography at the base of the LDA (important for ice flow) and to address hypotheses on the formation of the LDA.

Methodology: Using a mosaic of CTX images (6 m/pixel resolution) and the Mars Orbiter Laser Altimeter (MOLA) [8] surface as reference Mars topography, we produced a detailed analysis of the geometry and surface lineations of the studied LDA. The internal structure of the LDA has been probed analyzing 37 orbital tracks from the Shallow Radar [9] on the Mars Reconnaissance Orbiter (MRO). SHARAD is capable of distinguishing reflectors separated by ~0.1 μs in time, which corresponds to ~9 m in ice or ~5 m in rock; it therefore provides sufficient resolution to investigate subsurface interfaces within debris-covered glaciers. Radar data used in our analysis have been checked against surface clutter using a simulation developed at the University of Texas Institute for Geophysics. Reflections in the subsurface of the LDA were then identified and mapped in radargrams using software designed for seismic interpretations.

Results: The boundaries of the studied LDA deposit have been traced and its unit distinguished from both the surrounding material and the massif material (Fig.1). The main criteria used to map the LDA deposit are the presence of lineations and textures on its surface, and the presence of alcoves [5, 10]. This morphological analysis highlights the existence of individual lobes that appear to have flowed and coalesced together to form the LDA complex (Fig. 1).

The studied LDA is the only one among more than 90 LDA complexes recognized in eastern Hellas [2, 5, 11] with evidence for multiple subsurface radar reflections. This is probably due to both the larger extent of this LDA complex compared to others in the region and the relatively smooth terrain surrounding it that significantly diminishes the amount of surface clutter.

In the subsurface, the LDA deposit can be divided into an upper, thicker, and homogeneous unit which we interpret as composed of pure ice [6], and a lower, thinner, and remarkably more complex unit. This unit is characterized by multiple reflections that are highly discontinuous and variable in character (Fig.2). We interpret the lower unit as a basal, ice-rich (due to ease of radar penetration) deposit buried beneath the major icy deposit. In order to map the extension and geometry of the basal deposit we simplified its interpretation by tracking its uppermost subsurface detection (hereafter called sub1) and the very deepest subsurface reflection (hereafter called sub2) and assumed that the intervening reflections, enclosed by sub1 and sub2, represent internal stratigraphic complexity of the deposit itself (e.g. multiple ice-rich layers and point scatterers such as boulders).

Mapping of the lower unit has shown that it varies in thickness and distribution, has embayed topographic lows and creates a smoother subsurface base for the upper icy deposit. It is therefore reasonable to assume that the presence of this buried deposit may have played a role in controlling the emplacement and flow of the upper icy unit of the LDA.

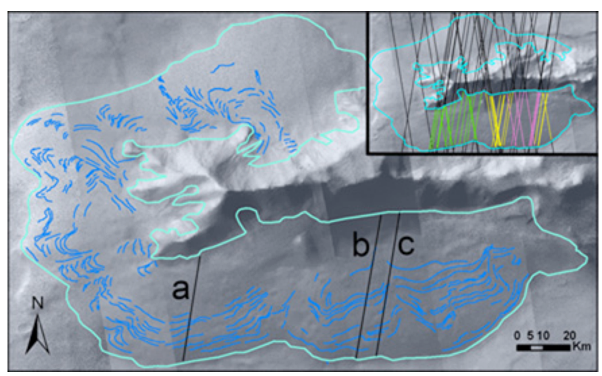

Figure 1. *CTX mosaic showing the extent of the LDA deposit and the locations of three observations (labeled a, b and c) shown in panels A, B, and C respectively in Fig. 2. In the upper right corner is shown the coverage of SHARAD observations over the LDA complex and the distribution of different types of basal unit detections: diffuse reflections (green), complex reflections (yellow), strong reflections (pink).*

The geographic variability of subsurface detections beneath the LDA was assessed by dividing the detection into three different groups. Each group is defined according to the character of basal detections in the subsurface of the LDA (Fig.2): we distinguish diffuse, complex and strong reflections. Mapping the occurrence of each type revealed that their distribution strongly correlates with the location of individual lobes within the LDA.

Discussion: The presence of a basal deposit beneath the LDA that varies in geometry and structure might have played a significant control on the emplacement and subsequent flow of the above icy unit. The basal deposit seems to have filled in some topography and created a smoother surface over which the upper deposit was deposited (Fig.3). From this perspective, an exhaustive and quantitative analysis of the basal condition of LDAs is essential for the reliability of future LDA flow models.

We rely on the internal structure detected with SHARAD in order to put constraints on the formation of the LDA. Two different origins have been hypothesized for LDAs: formation from the coalescence of multiple, independent flows [5] and formation from the retreat of a major ice sheet [12]. We assume the former would generate deposits with more diverse internal structures corresponding with invididual lobes while the latter scenario would more likely produce a uniform composition and internal structure at any location within the deposit. Although our observations do not exclude the ice sheet retreat scenario (especially for the upper deposit), the observed spatial variability of reflectors in the basal deposit of the LDA, which we interpret as variability in the internal structure of the deposit, may support the hypothesis of coalescence from individual flows.

Finally, the detection of a buried basal unit may represent an important piece of information when trying to address questions of long-term climate change on Mars. The existence of this unit suggests that multiple events of deposition and subsequent retreat of ice due to cyclical changes of the Martian climate [13-14] are recorded in the stratigraphy of some LDAs.

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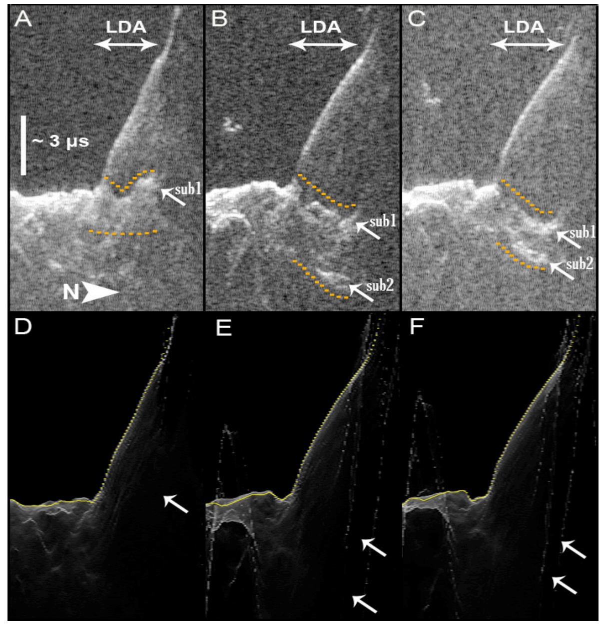

Figure 2. *(A,B,C): radargrams (in time delay) showing diverse types of subsurface detections (enclosed within dashed lines); sub1 and sub2 are indicated with arrows; for scale, 3µs are equivalent to a depth of ~250 m in ice. A) diffuse reflections; B) complex reflections; C) strong reflections. (D,E,F): clutter simulations used to confirm the validity of subsurface interpretations. See Fig. 1 inset for map of reflection type.*

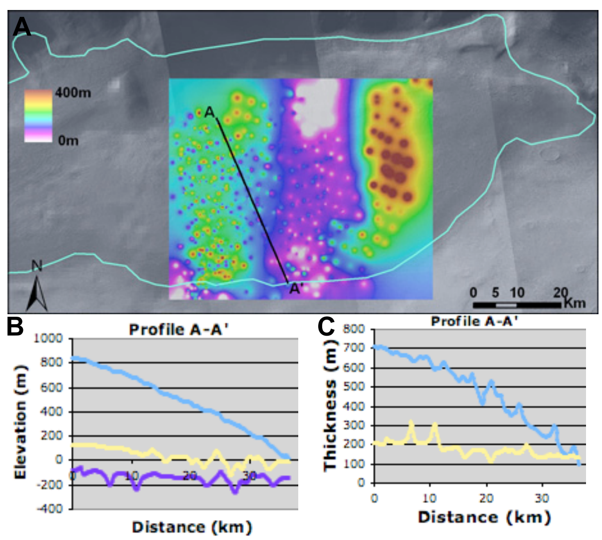

Figure 3. *A) Interpolated grid showing the basal deposit thickness; B) Elevation plot of profile A-A': LDA surface (blue), sub1 (yellow), sub2 (purple); C) Thickness plot of profile A-A': upper deposit thickness (blue), basal deposit thickness (yellow).*