AGE AND STRATIGRAPHIC RELATIONSHIPS IN MASSIF-DEBRIS-APRON TERRAIN IN WESTERN PHLEGRA MONTES, MARS.

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Introduction: Recent work has been done to re-evaluate the flow features identified in Viking data as lineated valley fill (LVF), lobate debris aprons (LDA), and concentric crater fill (CCF) [1-2]. Morphometric and morphological analyses of image, topography, and radar data [3-10] show evidence for large reservoirs of Amazonian non-polar, nearly pure ice in these deposits. Many studies have focused on the dichotomy boundary in northern Arabia Terra and Eastern Hellas, but many other locations in the northern and southern mid-latitudes of Mars also contain LVF, LDA, and CCF, including the Phlegra Montes region. SHARAD has recently returned data from this area that strongly supports the hypothesis that LDA are debris-covered glaciers [11].

LDA in the Phlegra Montes Region: The Phlegra Montes range from the northeast part of the Elysium rise at ~30° N to the northern plains at ~50° N, coincident with the latitudes (35° – 55° [6]) within which LDA, LVF, and CCF are found. LDA deposits occur in the valleys between and on the flanks of these mountains. Safaeinili et al., 2009 [11] focused on a certain group of massifs ~ 36.5° N, ~162° E that are surrounded by LDA (Fig. 1, Fig. 2).

The main morphological units of this region are: 1) the massifs of Phlegra Montes, often showing pits and small ridges and having several steep-sided alcoves cutting into them, interpreted as Hesperian-Noachian degraded highland material [12]; 2) the surrounding plains; 3) the marginal, smooth unit, which often shows a small scarp where it abuts the massifs, lineations emanating away from the massifs, and occasionally lobate features that seem continuous with nearby LDA patterns; and 4) LDA and CCF (Fig. 1).

LDA morphology and flow patterns. LDA in the Phlegra Montes region exhibit the same surface characteristics as do LDA deposits in other locations: lineations both along flow and sub-parallel to the lobe margin; ridge-and-trough and pit-and-butte texture; smaller lobes within the larger deposit, of which many can be traced back to source alcoves; and a surface crater population comprised of bowl-shaped and ring-mold craters [1-3,5,6,9,10] (Fig. 1).

Flow patterns indicate that flow was generally away from the group of massifs (Fig. 1, Fig. 2) but more complex than simply radial outward flow (as in

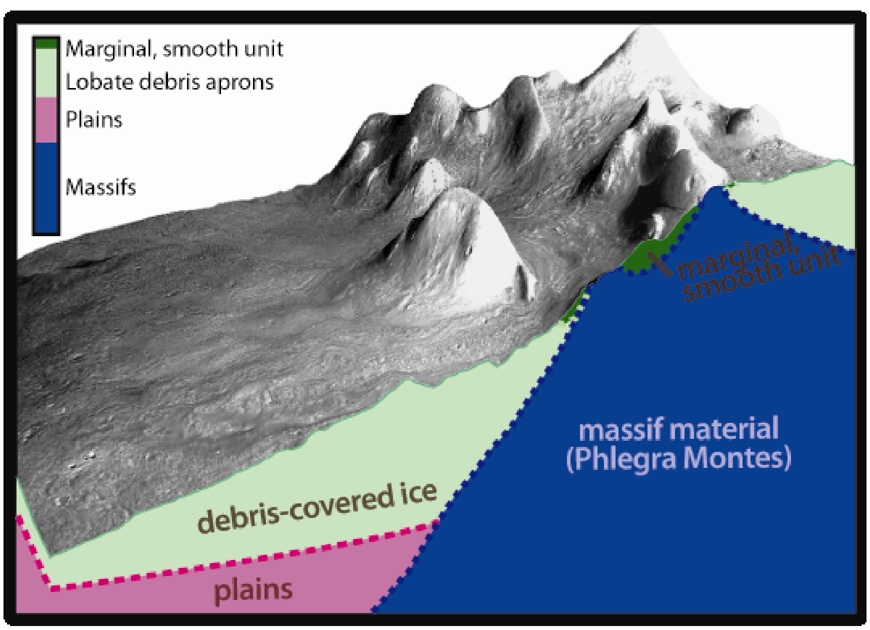

Figure 1: Perspective view and schematic cross-section of massifs surrounded by LDA in the Phlegra Montes region, looking southeast. Colors show the geologic units of this region as identified from geomorphological mapping and SHARAD data [11]. Image center is N, E. CTX mosaic overlain on HRSC DTM h1423. 5x vertical exaggeration.

the circumferential LDA of [13]). Flow patterns are integrated within the deposit, lobes clearly flow around massifs, and some appear to be deflected by other lobes.

Crater populations and implications for climate history. Crater counts on CTX data yield estimates of ages for some of the LDA, CCF, and crater ejecta deposits in this region (Fig. 2). Both Hartmann [14] and Neukum [15] production functions were used to analyze the crater populations. Dates on crater ejecta deposits show that all the craters dated are older than the CCF and LDA and range from Late Hesperian to middle Amazonian. LDA and CCF are middle-late Amazonian, consistent with the ages of LDA along the dichotomy boundary [3,5,6,9,10]. Crater counts may overestimate the surface age of LDA and CCF, if the ring-mold crater hypothesis is true [10].

Ring-mold craters are interpreted to indicate impacts into nearly pure ice buried below a debris layer [10], so debris layer thickness can be estimated from the depth of non-ring-mold craters (as in [10]). Such estimates give an average of ~20 m for debris layer thickness, which, because this is approximately the same as the vertical resolution of SHARAD (15 m in free space [16]), potentially explains why SHARAD does not detect a dielectic contrast associated with this surficial debris layer (it is too thin).

Conclusions: SHARAD detects subsurface structure and dielectric contrasts consistent with nearly pure ice under a relatively thin debris cover in the Phlegra Montes region [11] and in other locations in the Martian mid-latitudes [7,8]. The results of this study show that the geomorphology (integrated flow patterns, typical LDA surface textures, surface crater types) and surface ages (middle-late Amazonian) of LDA and CCF in the region are also consistent with debris-covered glaciers [3,5] as a model for LDA formation. The constraints on deposit age, structure, and composition provided by SHARAD data and this study, in conjunction with climate and rheological models, may help reveal how the formation and preservation of LDA and CCF fit into the history of ice on Mars.

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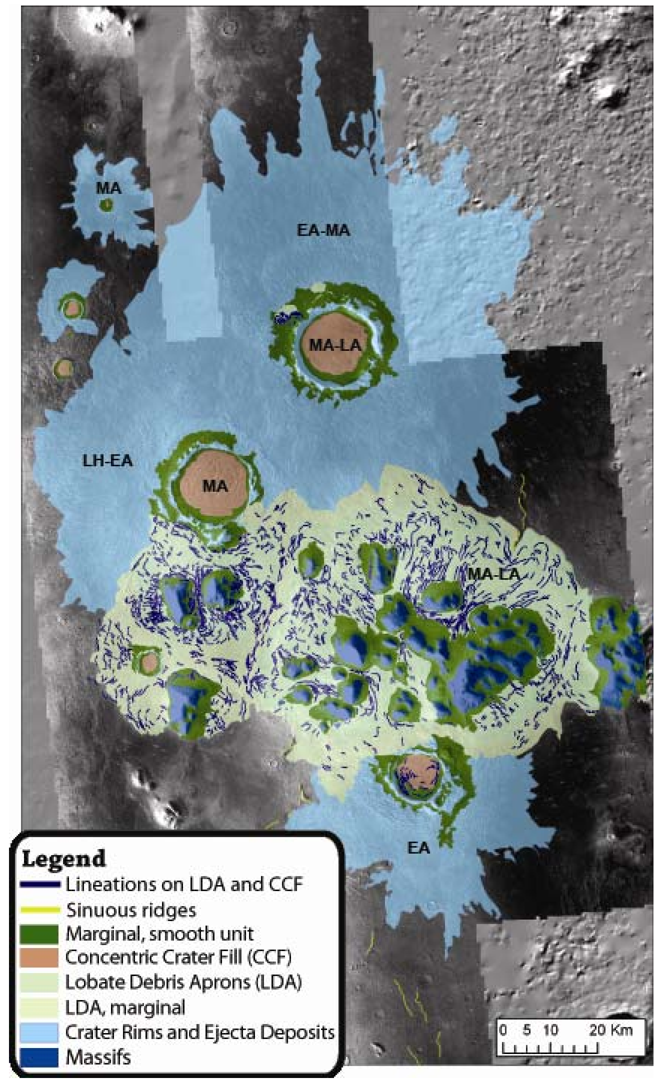

Figure 2: Sketch map of different geomorphologic units in the Phlegra Montes region. Ages of deposits that were analyzed with crater counts are indicated in black letters: LH = Late Hesperian, EA = Early Amazonian, MA = Middle Amazonian, and LA = Late Amazonian.