LAYERED DEPOSITS ON NOCTIS LABYRINTHUS PLATEAUS: A VOLCANIC AIRFALL ORIGIN?

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Introduction: Recent studies have found records of explosive activity on Mars [1,2], but they remain paradoxically low in proportion compare to lava flows, considering Mars's low atmospheric pressure which should allow magma fragmentation at a lower proportion of volatile content in magma comparatively to Earth [3]. We investigated evidence for such an explosive activity in Noctis Labyrinthus.

Layered deposits in Valles Marineris: Several studies have described layered deposits (LDs) on top of plateaus around Valles Marineris (VM) [e.g. 4] and various hypotheses were proposed to assess their origin: pyroclastic, ice-dust mixture, or fluvial/lacustrine [4, 5]. Similar looking deposits were also found at Arsia Mons and were interpreted as pyroclastic deposits [6]. It was found by [7] that Tharsis volcanic activity could have resulted in the deposition of >100m thick layers of pyroclastic material extending hundreds of km away from the source.

Here we sought such deposits on Noctis Labyrinthus (NL) walls, and found LDs capping mesas and surrounding plateaus (Fig. 1). These LDs are associated with paleo-bedforms that extend from plateaus to the underlying walls [8].

Datasets and Methods: The Murray Lab CTX mosaic [9] was used to assess the presence of LDs and paleo-bedforms. We also used HiRISE [10] and CaSSIS [11] images locally to identify morphological details. LD morphometric analysis (thickness and steepness) was carried out using CTX Digital Terrain Models (DTMs) produced from stereo-pairs using the Ames Stereo Pipeline [12].

LDs on mesas and plateaus were mapped as polygons in ArcGIS. The distribution of slope paleo-bedforms was investigated by creating a buffer zone extending 2 km away from the plateaus edges, which was then split into 1 km-wide sections. For each section, we assessed the presence of bedforms and recorded, if present, the average direction of crestlines. The slope value and aspect of each section was also calculated using the MOLA global DTM.

Results: LDs on NL plateaus consist of a thick, smooth, clearly stratified mantling material crosscut by the trough walls, with a light-toned layer visible at the top and/or within the deposits (Fig. 1). LD thickness varies from tens of meters to >150 m.

LDs are thicker on top of north-facing walls, where internal layering is also well exposed (Fig. 1). LD outcrop slope measured with CTX DTMs show that

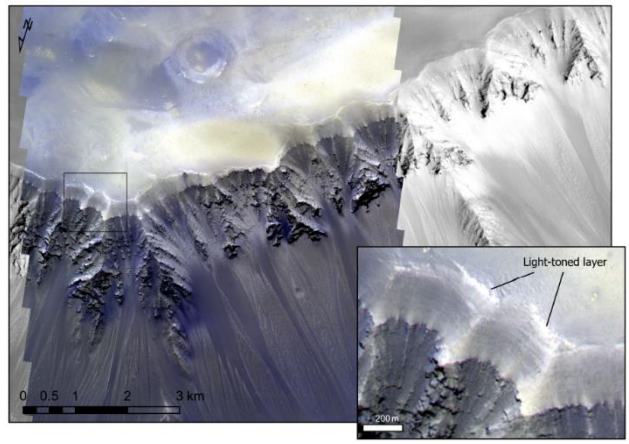

Figure 1. Light-toned layered deposits in Noctis Labyrinthus (9.44°S; 94.60°W) on CaSSIS NIR-RED-BLU composite (MY35_012306_190_0) and CTX Murray-Lab mosaic (background).

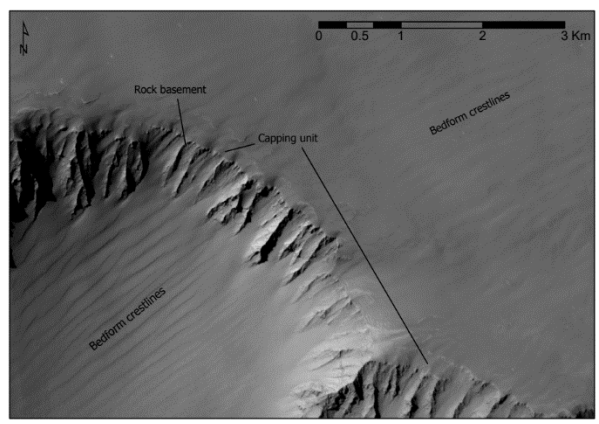

Figure 2. South-facing walls and mesa in NL with paleo-bedforms [8] on the slope and the plateau. (9.54°S; 95.39°W - CTX Murray-Lab mosaic)

they are more gentle (21.3 ± 3.4°) than the basement rock underneath (>30°).

On top of the south-facing walls, the LDs are thinner and their slope is less steep than on the north-facing walls (Fig. 2). Stratification is much less apparent than on north-facing slopes. South-facing slopes also display more frequent paleo-dunes (Fig. 3 – [8]). The walls that are covered by the smooth material also display solifluction lobes perpendicular to the slope (Fig. 4). These lobes are readily distinguished from bedforms, the crestlines of which have a tendency to follow the NNE-SSW direction (Fig. 3), independent of slope aspect.

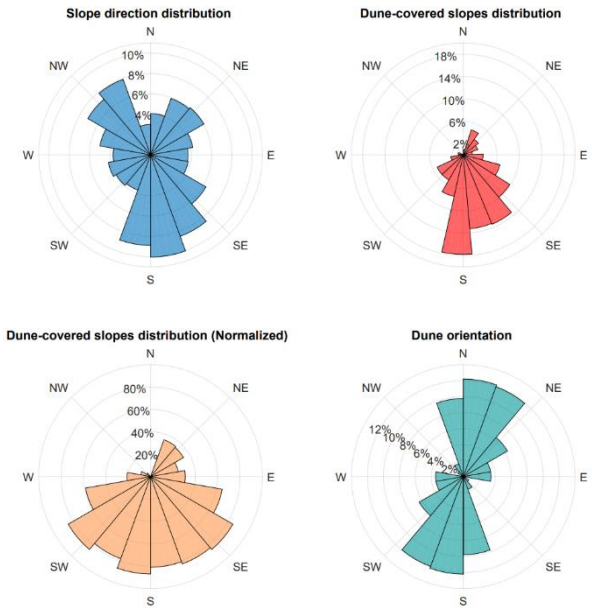

Figure 3. *Top-left*: Frequency of every slope direction within the ROI. *Top-right*: Frequency of slope aspect covered by paleo-dunes. *Bottom-left*: Standardized TR with respect to TL. *Bottom-right:* Direction of paleo-dune crests.

Discussion: The LDs in NL are similar to those found in VM [4, 5] and at Arsia Mons [6]. Light-toned layers were interpretated in VM as alteration layers [4]. Asymmetric thickness between north and south-facing deposits as well as frequency of paleo-dunes on slopes could be due to aeolian transport from top of plateau downslope. As discussed in [8], granular transport on slope is no longer active, and dune material is cemented. Smooth material removal above south-facing slopes may have gradually thinned this deposit, which re-accumulated on the underlying slope, masking the internal layering (Fig. 2). Aeolian transport and the low angle of repose suggest that the smooth material once had a granular mechanical behavior, which is consistent with volcanic airfall origin, for instance volcanic ash. Moreover, the viscosity of solifluction lobes implies the presence of interstitial ice before cementation. Ice is thought to have played a role in shaping VM [13], and could have also contributed to cementation [14]. While thawing of ice has been proposed to be the cause of valley networks and sinuous ridges in VM LDs [15], we could not find such landforms associated with the LDs on NL plateaus and mesas. In VM, LDs are mostly found on early Hesperian terrains, which are covered by more recent deposits when getting closer to Syria Planum and Noctis Labyrinthus [16], suggesting that the environment conditions prone to valley network development in NL were no longer met.

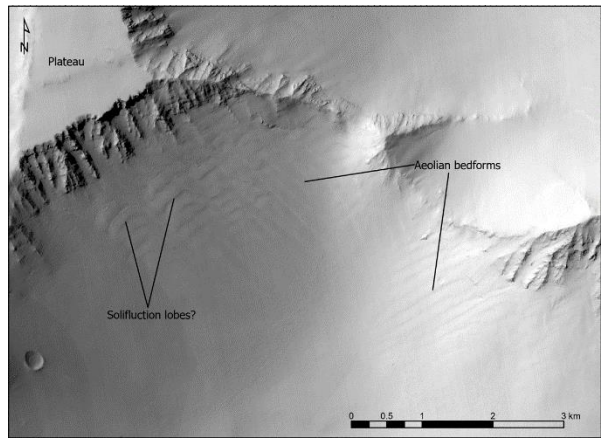

Figure 4. Slope displaying both solifluction lobes and paleo-dunes. (5.44°S; 99.18°W – CTX Murray-Lab mosaic)

Conclusion: LDs located on the NL plateaus and mesas are similar in morphology as those previously observed in VM covering early Hesperian terrains. Past aeolian activity and morphological characteristic are consistent with a granular material, for instance of pyroclastic origin. The long-lasting volcanic activity of the Tharsis volcanoes is the most likely source.

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