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Geomorphological Evidence of Local Presence of Ice-Rich Deposits in Terra Cimmeria, Mars

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1. Introduction:

Evidence of shallow ground ice has been widely observed in the north and south mid-latitude regions of Mars such as: debris-covered glaciers [e.g., 1, 2]. There are also SHARAD observation [4] of ~70 m thick ice deposits in the mid-latitude regions. Global circulation models suggest that obliquity oscillations caused the mobilization of ice from polar regions and its re-deposition at lower latitudes [5, 6]. Although the obliquity variations are not predictable for periods more than 20 Ma ago [8], it is likely that the surface of Mars, during the Amazonian, has repeatedly undergone such climate changes leading to deposition and degradation of ice-rich material [e.g., 8, 9, 10]. This study describes well-preserved glacial-like deposits in Terra Cimmeria, which are defined here as valley fill deposits (VFD) (Fig. 1-a). They are located on the floor of a valley system which bears a record of Amazonian-aged fluvial and glacial processes [11].

2. Morphological characteristics:

Several deposits on the flat floors of S-N trending valleys south of Ariadnes Colles (34°S, 172°E) are characterized by (1) widths and lengths of a few kilometres, (2) convex-upward surface topography (Fig.1-b), and (3) pits and crevasses on their surfaces. These VFD are located a few tens of kilometres east of Tarq impact crater. Several of the VFDs are situated within the visible ejecta blanket of Tarq crater (Fig.1-a). The crater ejecta are observable on the surface and surrounding area of those VFDs. The VFDs have individual surface areas of a few km^2 to a few tens of km^2 (Fig1-b). In some cases they are located in the centre of the valley floor, whereas in other cases they cover the entire width of the host valley, indicating their post-valley formation. The valley width could reach up to a few kilometres, in some areas. Using a HiRISE DEM, we observed that one VFD has a thickness of ~30m. The latitude dependent mantle is also partly covering the VFD, and the surface of the VFD is exposed where the LDM has been degraded or sublimated.

The surfaces of VFD show only few impact craters with diameters equal or smaller than ~700m. Craters larger than 70m are mostly degraded, their rims show

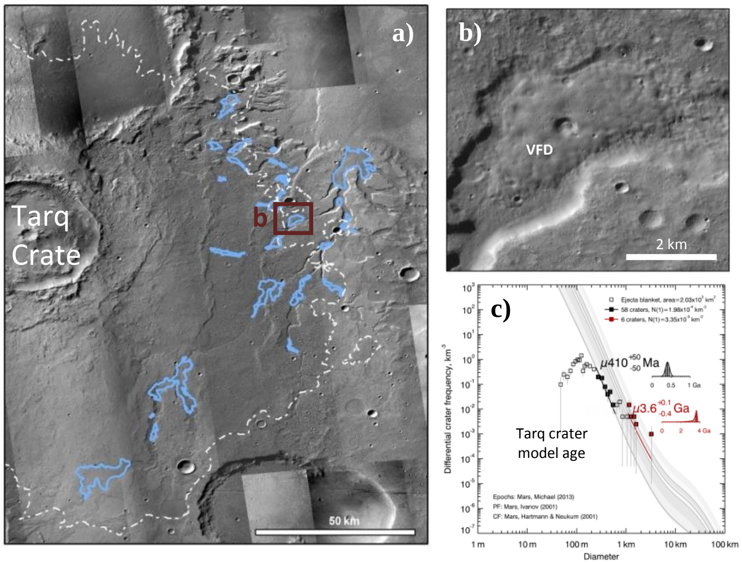

Fig. 1: a) An overview of the study area. The solid blue line represents the VFD locations. The dashed white line shows the Tarq Crater ejecta blanket. b) Zoom to one of the VFD, on the floor of a fluvial valley. c) Absolute model age corresponding to the ejecta blanket of Tarq crater. The data are plotted as a differential presentation of CSFD. μ is a function representing the uncertainty of calibration of the chronology model [3] (Epoch boundaries from [7]).

almost no positive relief (at CTX resolution) and they have flat floors. Where higher resolution data are available, we can observe linear features, cracks, and crevasses (lateral and transverse) on surface of VFD. Transverse crevasses may indicate tensile stress caused by viscous flow of the deposit. In several cases, in front of the VFD margins there is a zone up to ~3km of length, where the valley floor is covered by rough sediments. We interpret this rough zone as sediment accumulation similar to moraine-like material in front of a glacier. At the contact between the VFD and the valley walls, we observe several pits which most likely formed due to ice sublimation. These pits are aligned along the border of the VFD.

3. Absolute model age estimation: In order to understand the absolute model age (crater retention age) of the VFD, we analysed crater size-frequency distributions (CSFD) on CTX and HiRISE (where available) images using the method described in [3]. It should be noted here that there are uncertainties to derive a confident absolute model age of these deposits due the small area and small number of craters on VFD, in addition to the resurfacing phase(s) which may have most likely modified the crater morphology and their visible dimensions.

We suggest that the model age of the VFD surface is ~µ25 (±10) Ma, which corresponds to very late Amazonian (for µ definition see the Fig.1-c caption). The resurfacing event has roughly a recent age of ~µ3.4 (+2/-1) Ma and corresponds to late emplacement(s) of a thin layer of dust, airfall, and/or ice-rich material covering the VFD. In addition to the VFD, we also measured the CSFD on the ejecta blanket of Tarq crater, using a mosaic of CTX images. The result shows a model age of ~µ410 (±60) Ma for the impact crater (Fig.1-c), which corresponds to the end of the middle Amazonian, and a model age of ~µ3.6 (+0.1/-0.4) Ga for the base age.

4. Discussion: The VFD is characterized by a convex-upward shape, transverse crevasses, sublimation pits, and association with moraine-like deposits. These characteristics suggest that VFDs are ice-rich deposits with a thickness of a few tens of meters. The VFD was later partly covered by LDM which shows evidence of degradation, such as retreating boarders, sublimation pits, and scalloped depressions.

Our geomorphological observation suggests a link between the ejecta blanket of Tarq crater and the VFD distribution. It is, however, unclear whether the VFD formed 1) prior to the impact event, 2) contemporary to the impact, or 3) posterior to the impact and replacement of the ejecta blanket. In the first case, the emplacement of the ejecta blanket on a widespread ice layer would result in ice melt and mobilization into the valley. This case explains the VFD distribution but not the VFD model age. In the second case, the impact event may have occurred in ice-rich strata which, subsequently, have distributed a mixture of ejected material and ice, in other words, icy ejecta in the surrounding area. The ejected material deposited on the valley floor would have been preserved by the valley wall and therefore agrees with our interpretation. This case is consistent with the VFD distribution, our geomorphological observations, and a younger model age than the ejecta blanket. In the third case the VFD deposition may have taken place long after the Tarq impact event. This case is in agreement with our model age, but does not fully support our observations of their local distribution within the limits of the Tarq ejecta blanket and the fluvial valley. Therefore, the second scenario of impact into icy strata resulting in ice distribution in the area and ice deposits been preserved by the valley wall fits our geomorphological interpretations.

We conclude that the presence of ice-rich VFD provides local evidence of an episodic and multi-event process of ice emplacement in the mid-latitude regions of Mars during the Amazonian period.

5. Future work: Our next step is to look at the SHARAD radargrams of the VFD, aiming to observe the presence or lack of subsurface reflection. It should be noted here that the VFD covers a relatively small area which may not be in favour of a clear SHARAD observation. Additionally, the VFD location in a region with high relief (valley floor) may as well cause topographical clutter in a radargram.

References:

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