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The steps inside scalloped terrains, exhumed stratification or/and gradual erosion in Utopia Planitia, Mars

A. Séjourné (1), F. Costard (1), J. Gargani (1), R. J. Soare (2) and C. Marmo (1)
(1) Univ Paris-Sud XI, Laboratoire IDES, UMR 8148, Orsay, France, (2) Dawson College, Dep. of Geography, Montreal, Canada (antoine.sejourne@u-psud.fr / Fax: +33 169154863)

Abstract

Scallop-shaped depressions in Utopia Planitia show several bright steps. Here we report the preliminary results of a study using High Resolution Imaging Scientific Experiment (HiRISE) images and HiRISE Digital Elevation Model (DEM). The morphology of the steps in relation to the topography of depressions shows that their origin could be related to either exhumation of layers or gradual expansion of depressions.

1. Introduction

The western part of Utopia Planitia (UP) in the northern lowlands of Mars contains scallop-shaped depressions [1], [2], [3], [4], [5]. They are thought to be thermokarstic in origin, i.e. modification an ice-rich regolith by thawing or sublimation of ground-ice [1], [2], [3], [4], [5].

The depressions show several bright steps presumed to be exposed layers [1], markers of recessional ponded water [3] or slumped-thawed material [4] (Fig. 1).

Here we have two aims: (i) study their morphology in relation to the topography of the depressions using HiRISE images and new released HiRISE DEM; and (ii) discuss their origin.

2. Geological background

Western UP is covered by two geologic units. The Vastitas Borealis Interior unit (ABv_i) [6] which is interpreted to be Late Hesperian-aged desiccated "wet" sediments. The ABv_i is overlain in the west by the Late Amazonian-aged Astapus Colles unit (ABa) which is interpreted to be an ice-rich mantle or flow [6]. Moreover, a global climate model of water cycle predicted the atmospheric deposition of a dust and ice during Late-Amazonian low-obliquity period in western UP [7].

3. The staircase-like shape of scalloped terrains

Inside scalloped terrains greater than 50 m in diameter there are often 2 or 3 steps. The steps are concentric and parallel to the N-facing curved margin with a width of ~8 m (Fig. 1). According to the HiRISE DEM, the depressions have a N-S asymmetric profile, the S-facing slope is gentler (~1.2°) than the steep N-facing slope (~6°) (Fig. 1). The steps are ~1.5 m high and are found on the S-facing slope. We observed an increase of the number of steps with the depression depth.

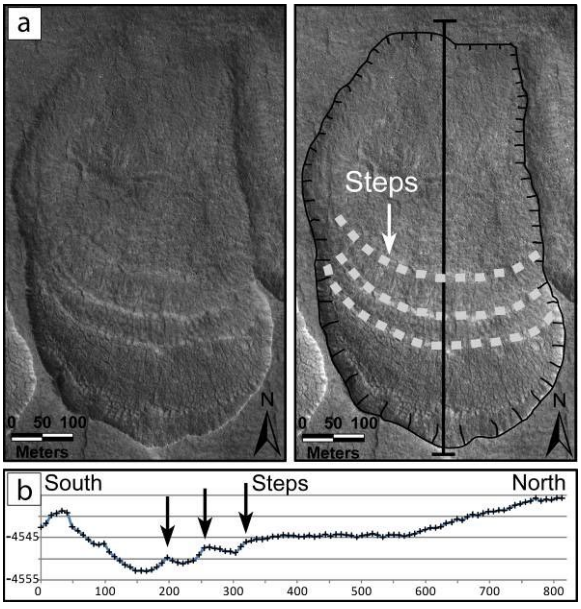

Figure 1: Scalloped terrains with many steps (HiRISE image PSP_001331_2260; new HiRISE DEM DTEEC_001938_2265_002439_2265_U01).

4. Possible origins

4.1 An exhumed stratification

UP is constituted by multiple deposits (of different origins) assuming a possible stratification. Indeed, many craters show concentric crater fills or layered

remnants interpreted to be possible layers [8], [9]. Inside depressions, the step morphology; a continue length and a constant width is reminiscent of exhumed layers (Fig. 1). The topographic transverse profiles show a succession of benches and steps (Fig. 1). The depressions are similar to cuesta-like structures on Earth. Cuestas are formed by differential erosion in a tilted strata substrate. Thus, the steps could represent more resistant layers to erosion and benches friable layers (Fig. 2).

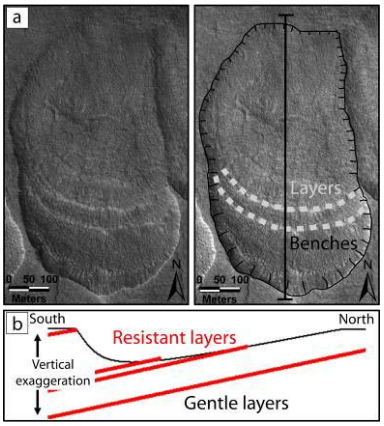

Figure 2: Steps as exhumed layers (HiRISE image PSP_002439_2265).

4.2 A gradual expansion of depressions

The morphology of the steps, a scarp-parallel shape, may underline a genetic relationship with the N-facing scarp (Fig. 1). On Earth, thermokarst lakes could display several terraces formed by their gradual growth [9]. On Mars, in the same way each step inside scalloped terrains could mark the progressive deepening of the depression (Fig. 3). The expansion of depressions was suggested to be southward [5]. Thus, the southernmost step inside depressions could mark the last erosion cycle (Fig. 3). So, the formation of the steps could be related to slump deposits or to erosion remnants of the expansion of depressions. Indeed, it was proposed that the steps are the remnants of retrogressive thaw-slumps [4] or terraces of recessional lake-water [3].

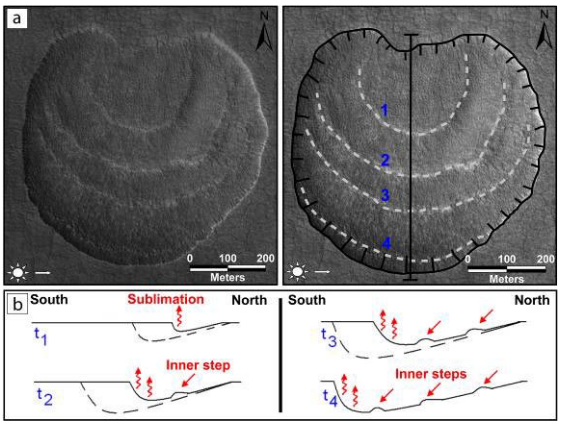

Figure 3: Steps as markers of gradual expansion of depressions (HiRISE image PSP_002439_2265).

3. Discussion/Conclusion

Here we report the study of bright steps inside scalloped depressions in Utopia Planitia. Their morphology on the S-facing slope could be explained by several hypotheses. On one hand, the cuesta morphology of scalloped terrains may indicate an exhumed stratification revealed by erosion. On the other hand, the N-facing scarp-related morphology may support a progressive expansion of the depressions. We also suggest that the progressive expansion of depressions may have revealed the stratified structure of the regolith. We will discuss the arguments for the different hypotheses.

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