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Thermokarst, mantling and Late Amazonian Epoch periglacial-revisions in the Argyre region, Mars

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1. Introduction

Metre to decametre-deep depressions that are rimless, relatively flat-floored, polygonised and scallop-shaped have been widely observed in Utopia Planitia (*UP*) [e.g. 1-5] and Malea Planum (*MP*) [6-8]. Although there is some debate about whether the depressions formed by means of sublimation or evaporation, it is commonly believed that the terrain in which the depressions occur is ice-rich. Moreover, most workers assume that this "ice-richness" is derived of a bi-hemispheric, latitudinally-dependent and atmospherically-precipitated mantle that is metres thick [2,4,6-10].

Here, we have three aims: (1) report/discuss the presence of Late Amazonian Epoch depressions in the Argyre region (Fig. 1) that are morphologically similar to those in *UP* and *MP;* (2) show that the depressions in the Argyre region comprise two disparate types; and, (3) suggest that if these disparities are mirrored in *UP* and *MP*, then the hypothesized synonymy between "ice-rich" terrain and an "icy" mantle perhaps ought to be reconsidered.

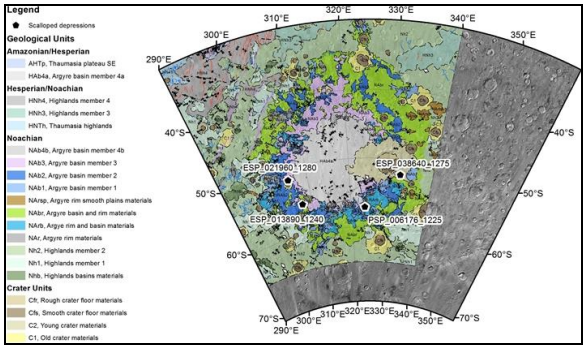

Figure 1 - Geological-unit map of the Argyre region, adapted from [11]. The brown pentagons represent thermokarst-like depressions that are commonplace in *UP* [e.g. 1-5].

2. The geological context

The Argyre basin lies in the southern hemisphere of Mars. It was formed by the impact of a large body ~3.9 Gya. Despite its age the basin, associated rim-materials and marginal highlands show geological modifications and revisions by a wide-range of processes - tectonic/volcanic, fluvial, aeolian, glacial and periglacial - possibly through to the present day [11]. For example, in addition to the thermokarst-like depressions discussed below, other putative periglacial-landforms thought to have originated in the Late Amazonian Epoch have been identified in the region: a) low and high-centred polygons [12]; b) sorted polygons [13-14]; c) open-system pingos [15]; and, d) gelifluction lobes [14].

Having studied all of the available HiRISE images (n=1101) that cover the Argyre region (290-360^{0}E, 30-70^{0}S; n=1101) we have identified two different types of possible periglacial-depressions.

3. Type 1 (in-ground) depression

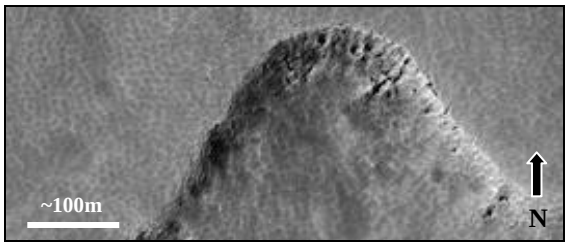

Figure 2 - Polygonised "Type 1" depression in *AP* (HiRISE ESP_013890_1240; 307.523^{0}E, 55.615^{0}S). Note the clustered pitting in adjacent polygon-junctions at the northern rim of the depression.

Type 1 depressions display various plan-forms: elongated, rounded, drop-like, elliptical and, sometimes, scalloped. Depression-length (long axes of the depressions defined by the outermost closed contour line) ranges from ~85-1000m; widths range from ~50-500m. Depression margins are continuous, sharp albeit rimless and well-defined; depression sides lack deep gravitational-slope processes or fan deposits at the floor. Generally, the floors are flat or slightly concave up.

In all instances, depression-margins, -sides, -floors and even the terrain beyond the depressions themselves, are incised by small-sized (~5m) and non-sorted polygons. Many of these polygons show

relatively-dark centres surrounded by light-coloured metre to sub-metre troughs. Sometimes, polygon-junctions within the depressions are pitted; where this pitting is clustered, it occurs amongst adjacent junctions (Fig. 2).

Invariably, the depressions are embedded in terrain that is barely cratered. If present, boulders are infrequent and, often, are underlain by the small-sized polygons.

The Type 1 depressions are distributed radially on/along the southern rim of the *AP* impact-basin (Fig. 1) in four geological units (cf. Fig. 1: NAbr, NArb, impact-associated materials; C1 and C2, crater-impact materials that postdate the Argyre impact event) [11]. The radial distribution of the depressions occurs in a tight latitudinal-band (~52^0-57^0S).

4. Type 2 (on-ground) depression

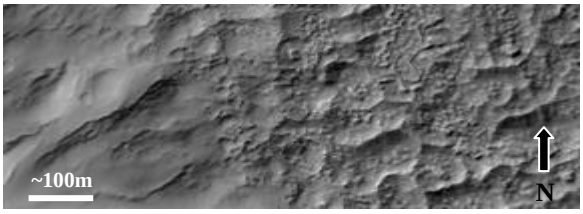

Figure 3a - Mantled terrain (on the left) dissected by small, rimmed and irregular "Type 2" depressions or pits (centre/centre-right) Note the smoothness and un-polygonised texture of the former (HiRISE PSP_007648_1440; 322.285^{0}E; 35,714^{0}S).

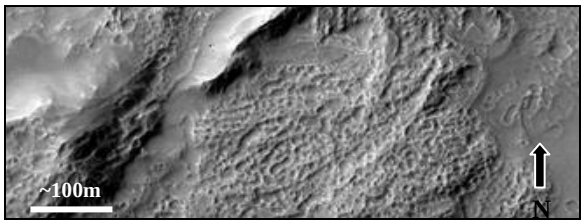

Figure 3b - Mantled terrain (on the left), pitted densely (centre-centre-tight) by "Type 2" depressions (HiRISE PSP_007033_1455; 321.183^{0}E, 35.000^{0}S).

Type 2 depressions are shaped irregularly, often with raised edges or rims, and lack marginal troughs (Fig. 3a-b). Invariably, the distribution of these depressions is dense (Fig. 3a-b). Individual depressions range in diameter from metres to decametres; collectively, the depressions are expansive (showing surface coverage on a kilometre-scale) and ubiquitous (observed from 315-354^{0}E and from ~31-50^{0}S), unlike Type 1 depressions whose distribution across the Argyre region is sparse. Generally, the floors are concave up. Most type 2 depressions exhibit no *in situ* polygonisation.

In all cases the Type 2 depressions are nested in mantle-like material that blankets the underlying topography and bedforms. The latter becomes visible if and only when the mantle exhibits discontinuity or dissection. Thus, bouldering is observed only where mantled terrain is absent (cf. boxed-in area, Fig. 4).

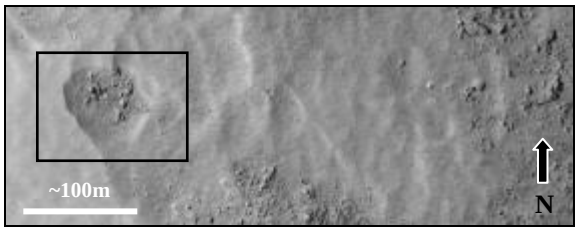

Figure 4 - Boulders observed in hollows where mantled material is being lost, possibly by sublimation (HiRISE ESP_021960_1280; 305.499^{0}E, 51.706^{0}S).

5. Discussion

In discussing the origin and development of the putatively periglacial and possibly "thermokarstic" Martian-depressions, previous workers have not differentiated between depressions that are "in-ground" (Type 1) and "on-ground" (Type 2).

Here we have highlighted the two depression-types and suggest that these stratigraphical and morphological differences could be indicative of origins and, consequently, of host materials that are dissimilar.

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