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Possible open-system (hydraulic) pingos in the Argyre impact region of Mars

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1. Introduction

A group of small-sized mounds (~100–750m, see large white oval, Fig. 1) occur to the north of the Argyre impact basin, Mars. The shape, size, summit characteristics and clustering of the mounds, as well as a suite of geomorphological and geological features in the surrounding terrain, are suggestive of open-system (hydraulic) pingos (***HPs***) on Earth [1–7]. ***HPs*** are perennial water-ice cored-mounds that occur in permafrost (cold-climate and non-glacial) environments; they form and grow as the result of artesian pressure [1–7]. Here, we compare and contrast the Martian mounds and their geological context with a possible and terrestrial permafrost-analogue. Some preliminary work has discussed the possibility of ***HPs*** on Mars but, as of yet, strong candidate-sites on the Red Planet have been few in number [8–9].

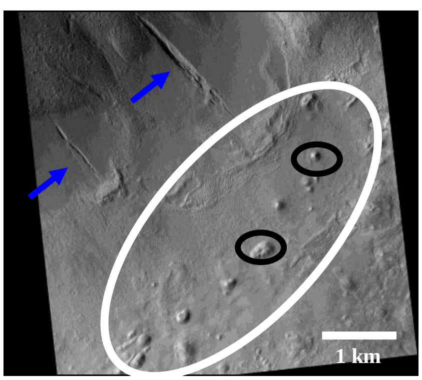

Figure 1: Small-sized mounds downslope of graben-like features. HiRISE image ESP_020720_1410, 317.714^0 E, 38.431^0 S; 25 cm/pixel. North is at the top. Image credit, NASA/JPL/ University of Arizona.

2. A putative periglacial-landscape in Argyre Planitia (AP)

North of the Argyre impact basin, Mars (317.714^0 E, 38.431^0 S), small-sized mounds are clustered downslope of numerous linear (graben-like) cavities (see blue arrows in Fig. 1). Mound morphology ranges from circular or sub-circular to elongate. Numerous mounds show summit depressions, shaped irregularly; in some instances depression margins are highlighted by patchy bright material (Fig. 2a–b). One of the mounds (see small black upper oval in Fig. 1) displays a debris-fan at its base and an associated erosional-valley cut into its eastern flank (Fig. 2b). The pristine and unmodified morphology of the scar and fan suggest a relatively youthful age.

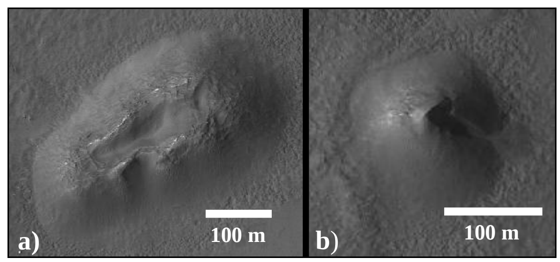

Figure 2a-b): Sub-images of HiRISE image ESP_020720 that shows (see small black ovals in Fig. 1) a) elongate mound with an irregular summit-depression and bright patchy materials around its margin. b) circular mound with a linear valley cutting its eastern flank and an associated debris-fan at its base; note the bright patchy materials near its the summit to the left of the erosional channel. North is at the top.

Linear (graben-like) cavities also are observed upslope of the mounds; they could be indicative of faulting and of basement structural-control of the local if not regional landscape; some structures could be deeply-seated due to the Argyre impact-event and post-impact adjustment. The linear cavities form in and are bridled by high-albedo, smooth-textured terrain. In the literature, this type of terrain often is described as a latitude dependent and possibly ice-rich or cemented mantle (***LDM***) [10–12]. In turn, the linear cavities and the ***LDM*** are deformed by small-sized polygons (~5–20m in diameter); the latter could be the work of thermal-contraction cracking [13–14]. The unaltered or intact geometry of the polygons suggests that they postdate the formation of the linear cavities. Sinuous braided-channels that dissect the cavity floors and the polygonal-patterned ground point to subsequent hydrological activity. Arcuate ridges occur upslope of the ***HP***-like mounds and downslope of the linear cavities. These ridges could be terminal moraines, staking a line of furthest advance for glaciers that otherwise have ablated by sublimation or thaw [15]. Depending upon ambient conditions at the time of their formation, surface or near-surface melt-water might have been associated with the glacial system of which the ridges were a part.

3. Hydraulic pingos on Earth

Hydraulic pingos are perennial ice-cored mounds that occur in permafrost environments on Earth [1–5]. Mound morphology is varied, i.e. circular to elongate, and mound long-axes extend from metres to hundreds of metres [1–7]. Often, the ***HPs*** occur in groups or clusters, principally on valley floors and sides or in outwash plains [1–7]. Sometimes, the ***HPs*** occur on polygonised terrain formed by thermal-contraction cracking and underlain by ice or sand wedges at the polygon margins [1–7]. The ***HPs*** are thought to be the work of artesian pressure delivering sub- or intra-permafrost water to the location of mound development. Here, under freezing temperatures, an ice core forms and uplifts the sediments overlying it, creating a permafrost mound [1–7]. When an ***HP*** degrades, as the result of its ice core dissipating by thaw or sublimation, a summit depression or cavity may form [1–7].

Three principal geological-pathways are generally invoked to explain the formation of the ***HPs****:*

(1) the presence of geological faults and structural discontinuities, which putatively deliver juvenile water to or near-to the surface where the ***HPs*** occur [1-7,16].

Figure 3: An ***HP*** in Greenland. Note the crater-like depression at the pingo summit. Also, a small spring has initiated the formation of a run-off channel [16].

(2) a (potential) hydraulic gradient that moves sub- or intra-permafrost melt-water downslope, in areas of topographical relief, and towards a point(s) of emergence under artesian pressure where the permafrost is thin or weak [2].

(3) a sub-category or variant of (2),: permafrost thaw in the accumulation area of glaciers, allowing melt-water infiltration [4], or thaw at the base of wet-based glaciers [17]. In either case, the melt-water migrates downslope, through the sub-permafrost that lies beyond the glacier's margin and, once again, emerges under the influence of artesian pressure to form ***HPs*** where the permafrost is relatively thin or weak.

4. Hydraulic pingos in AP?

Absent of a spade or a shovel, validating or invalidating a Martian landscape interpretation is difficult. However, we have constructed an ***HP*** formation-hypothesis based upon a possible cold-climate analogue on Earth that shows striking similarities to the studied Martian landscape.

As noted above, the shape, size, summit characteristics, clustering and slope-side location of the Martian mounds are consistent with permafrost regions on Earth where ***HPs*** are commonplace. In addition, the marginal presence of structural cavities, cavity-centred gully-flow, the ***LDM*** and arcuate ridges, are suggestive of a landscape where freeze-thaw cycling has been active. The fact that the mounds occur within this landscape assemblage brings the discussion concerning the possibility of ***HPs*** on Mars a step further than has been the case hitherto.

To the extent that this permafrost mound-hypothesis highlights recent activity in and around the Argrye basin, it points to a treasure trove of far-reaching (~3.93 GA to the present and local to possibly global scales) geological, hydrological, and climatological data [18-19].

5. References

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