POSSIBLE HYDRAULIC (OPEN-SYSTEM) PINGOS IN AND AROUND THE ARGYRE IMPACT BASIN, MARS. R.J. Soare[1], S.J. Conway[2], J.M. Dohm[3] and M.R. El-Maarry[4]. [1]Geography Department, Dawson College, Montreal, Canada H3Z 1A4 (rsoare@dawsoncollege.qc.ca), [2]Department of Physical Sciences, Open University, Milton Keynes, United Kingdom MK7 6AA, [3]Earth-Life Science Institute, Tokyo Institute of Technology, Meguro, Tokyo, Japan 152-8551, [4]Physikalisches Institut, Bern Universität, Berne, Switzerland 3012.

Introduction: Groups of small-sized mounds (~100–750m, see large white oval, Figure 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, would be expected where open-system (hydraulic) pingos (***HPs***) are observed on Earth [1–7]. ***HPs*** are perennial (water) ice-cored mounds that form and grow by means of artesian pressure in areas of thin or discontinuous permafrost and periglacial activity [1–7].

Some preliminary work has discussed the possibility of ***HPs*** on Mars but, heretofore, strong candidate-sites on the Red Planet have been few in number [8–9]. By contrast, we have identified numerous locations within and around the Argyre impact-basin where mounds similar in kind, distribution and geomorphological/geological context to those observed in Figure 1 are found.

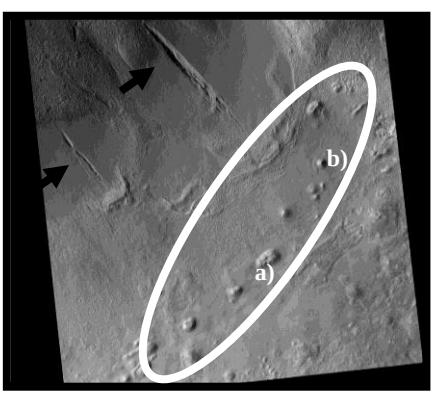

Figure 1: Small-sized mounds in a linear array downslope of possible structural-cavities in which gullies have formed. HiRISE image ESP_020720_1410 (317.714^0 E, 38.431^0 S; 25 cm/pixel). North is at the top. Image credit, NASA/JPL/University of Arizona.

Pingo-like mounds in and around the Argyre impact-basin: North of the Argyre impact-basin, Mars (317.714^0 E, 38.431^0 S), small-sized mounds are clustered downslope of numerous linear (possibly graben-like) cavities (see 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 (Figs. 2a–b). One of the mounds (2b) displays a debris-fan at its base and a possible erosional-trough cut into its eastern flank (Fig. 2b). The pristine and unmodified morphology of the scar and fan suggest a relatively youthful age.

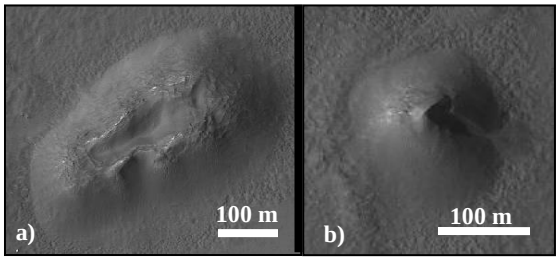

Figure 2a-b): Sub-images of HiRISE image ESP_020720 that shows (see small black ovals in Fig. 1): a) elongate mound with an irregular summit-depression and bright patchy materials on its margin. b) circular mound with a linear valley cutting its eastern flank and an associated debris-fan at its base;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

Linear cavities 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 light-toned, smooth-textured terrain that subdues the underlying topography. 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.

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; 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 glacial outwash-plains [1–7], see Fig. 3.

Figure 3: ***HPs*** on outwash plain, Iterlagssûp Kûgssua, Disko, central west Greenland [16].

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 the work of artesian pressure delivering sub- or intra-permafrost water to the location where the mounds originate and evolve. 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, a summit depression or cavity may form [1–7], see Fig. 4.

Figure 4: An ***HP*** in Søndre Strømfjord, west Greenland. Note the crater-like depression at the pingo summit and a run-off channel initiated by a spring [17].

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

(1) the presence of geological faults and structural discontinuities that are thought to deliver juvenile water to or near-to the surface where the ***HPs*** occur [1-7,17].

(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 where the permafrost is thin or weak [2].

(3) a sub-category or variant of (2): permafrost thaw in the accumulation area of glaciers engenders melt-water infiltration [4] or thaw at the base of wet-based glaciers [18]. In either case, the melt-water migrates downslope, through the sub-permafrost that lies beyond the glacier's margin and, once again, emerges to form ***HPs*** where the permafrost is relatively thin or weak.

Discussion: Absent of exploring Mars by foot and using a pick or a shovel to dig up the near-surface regolith, validating or invalidating periglacial interpretations of Martian landforms is difficult. With this in mind, we present a Martian-mound formation-hypothesis that is robust, resting on three disparate but related footings: 1. key morphological similarities, e.g. shape, size and summit characteristics, between pingo-like Martian mounds and ***HPs*** on Earth,; 2. clustered distribution and slope-side location of the Martian mounds, consistent with the distribution and location of ***HPs*** in terrestrial permafrost-environments; and, 3. spatially-associated (albeit putative) periglacial and proglacial landscape features - e.g. small-sized polygons and arcuate (moraine-like) ridges - that are commonplace in cold-climate landscapes on Earth where ***HPs*** occur.

The observation of ***HP***-like mounds on Mars, specifically, in and around the Argyre impact-basin, is the first time in the literature that these landforms have been putatively identified on a regional scale. Moreover, the possible-markers of structurally-delivered water at some of the mound sites suggests that geo-hydrological activity in and around the study region could be more recent and substantial than has been thought hitherto.

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