Possible crater-based pingos, paleolakes and periglacial landscapes in the high latitudes of Utopia Planitia, Mars

Conference or Workshop Item

POSSIBLE CRATER-BASED PINGOS, PALEOLAKES AND PERIGLACIAL LANDSCAPES IN THE HIGH LATITUDES OF UTOPIA PLANITIA, MARS. R.J. Soare[1], G. Pearce[1], S. Conway[2], J.M. Dohm[3]. [1]Department of Geography, Dawson College, 3040 Sherbrooke St. West, Montreal, Canada H3Z 1A4 (rsoare@dawsoncollege.qc.ca); [2]LPGN, CNRS/Univ. Nantes, 44322, Nantes, France (susan.conway@univ-nantes.fr); [3]Department of Hydrology & Water Resources, Univ. of Arizona, USA (jmd@hwr.arizona.edu).

Introduction: On Earth, hydrostatic or closed pingos are perennially ice-cored mounds that are diagnostic of (a) ponded water (current or past); (b) freeze-thaw cycles; and, (c) ice-rich, continuous permafrost [1-2].

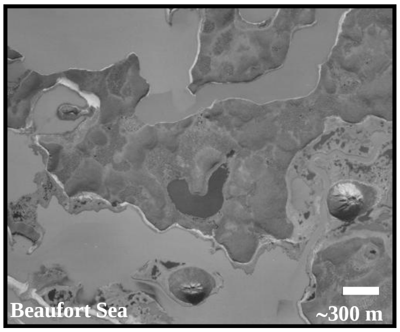

Figure 1: Assemblage of closed-pingos, Tuktoyaktuk Coastlands, northern Canada. Thermokarst lakes envelope the pingos; small-sized (and unsorted) polygonal patterned-ground is ubiquitous (air photo A2797-35-1993, National Air Photo Library, Ottawa, Canada).

Similar environmental conditions could be deduced were closed pingos observed on Mars [3-9]. Moreover, if these landforms were to occur on very late Amazonian rock materials, this would point to relatively recent boundary conditions of temperature and atmospheric pressure that are higher than many workers have thought possible.

In 2005 we used a small set of MOC images to describe two crater-floor landscapes in northern Utopia Planitia (UP) where mounds consistent in appearance, distribution and geological traits with closed pingos on Earth, at least those located in the Tuktoyaktuk Coastlands (TC) of northern Canada, were observed [3-4]. Based on HiRISE and MOC images, (not available at the time of our earlier work) we revisit the closed pingo hypothesis and do two things. First, we broaden the scope of the pingo hypothesis by integrating the observations of four other crater-floor landscapes with similar mounds. Interestingly, each of these craters are located within a tight latitudinal band (64.5-68.9^0 N). Second, we link the atmospheric processes that could be responsible for the formation of crater-based perennial ice-domes at latitudes >~70° N [10] to the emplacement of water-ice (and the subsequent formation of crater-based paleolakes) at the lower latitudes where the putative pingos have been observed.

Mound morphology and traits (Mars) (Fig. 2): The Martian crater-floor mounds are elongate to circular/sub-circular; they range in diameter from tens to hundreds of metres and are clustered (~2.5 mounds/km^2) at or near the floor centres. A few of the mounds display a ring-like appearance. All of the mounds are nested in small-sized (~25-150 m in diameter) polygonal patterned-ground that is unsorted. Some of the polygons exhibit an orthogonal orientation around the mounds; others, cross-cut the mounds.

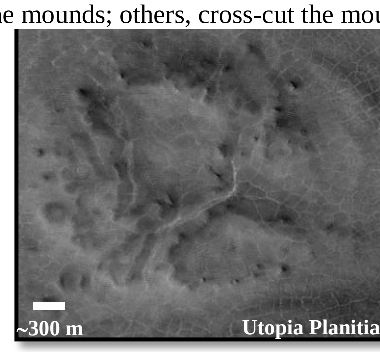

Figure 2: Crater-floor mounds in a field of small-sized and unsorted polygonal patterned-ground. El Maarry et al. [11] have suggested that the size, type and location of these polygons could be indicative of endogenic paleolakes (PSP_007780 _2450_RED, 64.5° N; 67.3° E).

Pingo morphology and traits (Earth):. Closed pingos range in shape from elongate to circular/sub-circular; diameters vary from a few to hundreds of metres. Often, as is the case in the TC, closed pingos occur in the midst of thermokarst lakes (extant or extinct). Where summit collapse has occurs, the pingos may appear ring-like. Commonly, the mounds occur in consolidated networks of small-sized (~25-75 m in diameter) and unsorted polygonal patterned-ground. Sometimes, these polygons cross-cut the mounds

Pingo origin (Earth): In the TC, a region characterised by continuous and ice-rich permafrost, pingo genesis is tied closely to the loss of water by drainage or evaporation in thermokarst lakes [1]. As a thermokarst lake loses its water, the exposure of saturated but previously unfrozen lake-floor sediments to new, colder boundary conditions induces these sediments to freeze (by permafrost aggradation); subsequently, the ground is deformed upwardly by means of hydrostatic pressure. Eventually, this forms a domed structure/mound underlain by an ice core. Although unrelated in origin, small-sized (thermal contraction) and unsorted polygonal patterned-ground is a commonplace characteristic of permafrost terrain where closed pingos occur [1]. Polygonal patterned-ground that is orthogonal in orientation may develop when the loss of water in a lake basin where a pingo forms is episodic [13].

Closed pingos in UP?: The Martian mounds approximate terrestrial closed-pingos (of the TC type) in size, shape, ring-like appearance (sometimes) and spatial association with unsorted and polygonal patterned-ground. Interestingly, the mounds show dense clustering that is similar to that of the closed pingos in the TC; also, they are located at or near the centre of impact-crater floors, precisely where one would expect them to be on the basis of the TC model.

Crater-based paleolakes: All but two of the mound craters are included in a recent survey of putative crater-based paleolakes [11]. The occurrence of these paleolakes is deduced from the polygon type found in these craters, which is consistent with a desiccation origin [11]. Our craters occur within a narrow band of these paleolakes around the polar cap (Fig. 3).

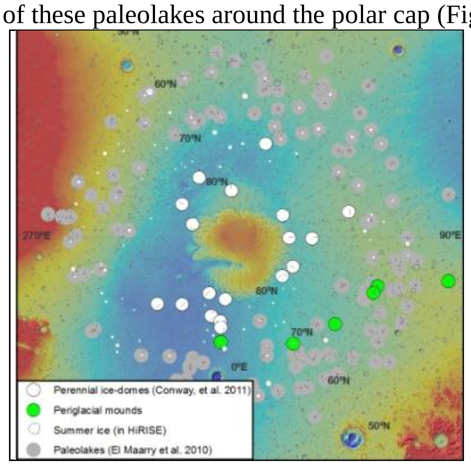

Figure 3: Map of different crater types, north polar region, Mars.

Periglacial mound origin: Since 2005, the possibility that closed pingos could have formed in UP late in the Amazonian Period has been widely discussed in the literature [3-9]. As noted above, the origin and development of closed pingos requires a) the occurrence of near-surface ice-rich regolith; and, b) pre-cursor boundary conditions above the triple point of water. The first criteria can be met as near-surface ground ice is thought to be ubiquitous throughout the high northern-latitudes [14-15]; the origin and/or recharge of ground-ice at these latitudes could be supplied by water-vapour laden winds that flow from the north pole [11]. Cold trapped by craters, this vapour might support the formation of perennial ice-domes, summer ice [11] and, possibly, of ice in those craters where our mounds occur (Fig. 3). Under past orbital solutions consistent with thaw processes [16], this crater-based ice could have thawed, forming paleolakes *in situ*; in turn, this might have triggered a series of periglacial events that led to the formation of closed pingos. Such conditions have been previously invoked to explain the enigmatic occurrence of gullies at these latitudes [17].

Alternative hypothesis #1: Central uplift complexes occur in Martian craters above ~8 km in diameter [18]. Using MOLA data we have created crater profiles to evaluate whether the crater-based mounds are central peaks that have been covered in sedimentary material [12]. By calculating the fill level in the mound craters, we have found that this is approximately equal to that of the surrounding plains [12]. This places the mounds well above the heights estimated for central peaks in these craters [18].

Alternative hypothesis #2: Impact-related hydrothermal activity [19] could be the progenitor of the crater-floor mounds. For example, amongst the geological traits observed at the Hesperian-aged Toro impact crater (17.0^0 E; 289.2^0 N) are mounds, polygonal fractures, veins and structural discontinuities that could be the result of volatile release and/or liquid flows [20-21]. Distinctive mineralogy and abundances of hydrated phases in and around the central uplift complex, perhaps associated with impact-melt bearing crater-fill deposits, also are consistent with a hydrothermal origin [20]. By contrast, the crater-fill in the UP mound craters post-dates the impact-formation of these craters and, thus, cannot be a product of impact-related hydrothermal processes. Moreover, were the mounds geological artefacts of impact-related processes, they would occur at or near the "true" crater floor and not at their current elevation datum.

Discussion: In terms of morphology, size, density of distribution and spatial association with small-sized polygons, the crater-floor mounds of northern UP approximate closed pingos such as those observed in the TC. Recent hypotheses linking a) crater-floor polygons to desiccated paleolakes; b) water-vapour laden winds to the accumulation of crater-based ice; and, c) thaw conditions rooted in past orbital solutions, bolster the viability of this interpretation.

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