

quent freezing of the basin sediments also initiate the formation and growth of perennially frozen, ice-cored mounds (hydrostatic pingos) [10]. Pingo development ends when the ice core thaws, leaving the overburden unsupported, and the mound collapses. A raised rim comprised of slumped material often encircles the area of mound collapse [11]. It is not unusual for hydrostatic pingos to be crossed by thermal contraction polygons.

d. *Sub-circular to irregularly-shaped raised rim depressions* are widespread in this region [12]. They occur in clusters, often coalesce and are concentrated in areas of bright surface materials (possibly in topographic lows). The irregular shape of the depressions rules out an impact hypothesis as does the correlation with surface material. Small-sized polygonal patterned ground also is commonplace in the landscape, as are the thermokarst-like collapse features discussed above. Similar landforms occur in Athabaska Valles and have been identified as collapsed pingos [13].

e. *Near-rim gullies* that issue metres from the ejecta structure of impact craters (Fig. 3) are commonplace in this region [14]. The gullies appear to be geologically young, as they are incised sharply, relatively free of dust and are largely absent of superposed craters. The gullies can be cut by scalloped depressions, which also occur nearby in the ejecta structure as well as on the crater slopes and floors. If the ejecta depressions are alases, artifacts of thawed ice-rich regolith formed at high obliquity, then we suggest that they could be the source of gully-forming fluids.

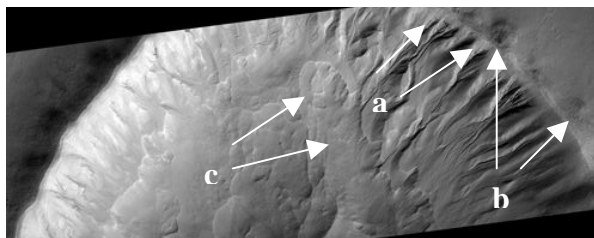


Fig. 3. (a). near-rim, crater-wall gullies; (b). nearby depressions on crater rim; (c). depressions on the crater wall and floor. (MOC-S)4-00681, 50.5°N 276°W, res. 3.29m/pixel). Image is ~9.1km across. North is to the left.

We do not discount the possibility that source fluids originate from clasts of thawed ice blocks in the ejecta structure, these having been incorporated into the ejecta during crater excavation. However, given the ubiquity of the alas-like features in many of the gullied craters and in the surrounding landscape, as well as the proximity of some depressions to the areas of gully issuance, we suggest that the evidence in favour of a thermokarst hypothesis is stronger than that which supports the ice-block melt hypothesis.

Discussion: Global climate models (GCMs) show that the obliquity-driven transportation of water from the north Martian pole to the middle latitudes of the northern plains could produce reasonably significant amounts of snow/ice surface accumulation over time [15][16]. We hypothesise that a large body of standing water was present intermittently in Utopia and western Elysium Planitia throughout the late Amazonian, in increments of time sufficient for the regolith to become saturated and, eventually, ice rich. Steady-state models based on simple atmospheric-regolith exchanges of water are inconsistent with the occurrence of near-surface ice-rich regolith in concentrations high enough or deep enough to induce the recent formation of thermokarst landforms, hydrostatic pingos or near-rim gullies in our target region [17]. Cryogenic suction also is incapable of producing ice-rich sediments below the uppermost metres of the regolith [18]

The broad spatial distribution of the putative periglacial features suggests that the formation processes associated with them were neither anomalous, trivial nor highly localised. Further GCM modeling is urged, in order to bridge the divide between the observed geological data and our understanding of Martian boundary conditions in the late and possibly recent Amazonian.

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