MARTIAN POLAR CRATERS: POSSIBLE POLAR MATERIALS APPARENT EFFECTS AND POST-IMPACT MODIFICATION BY APPARENT PERRENNIAL PERMAFROST MOUND (PINGO) FORMATION. S. E. H. Sakimoto\textsuperscript{1}, \textsuperscript{1}Department of Civil Engineering and Geological Sciences, 156 Fitzpatrick Hall, University of Notre Dame, Notre Dame, Indiana, 46556, email: ssakimoto@nd.edu.

Introduction: On Mars, as elsewhere, impact craters reveal both target effects as well as post-impact modification processes. The cavity morphology and central peaks or mounds of martian impact craters are key indicators in determining these target properties and processes. The martian polar regions (particularly the northern polar region) display significant departures from the global trends \cite{1,2,3} in both crater morphology presumed to be a result of target effects and central deposits presumed to be a result of post-formation processes \cite{e.g. 1,2,3}.

Data and approach for central deposits: The typical central peak topography for martian impact craters has been well-defined \cite{e.g. 1, 2}. Recent work in the equatorial region of Mars has suggested that there is evidence for pingo-like or small perennial permafrost mounds in the Athabascan, Valles region \cite{4,5} that may be tapping sources of water related to the proposed late Amazonian floods in the region \cite{e.g. 6}. Previous results from this study \cite{3} suggest that some of the polar impact crater central mounds are plausible candidates as perennial permafrost deposits (in whole or in part) that may be tapping polar aquifers. In the polar regions, these central mounds cover much of the crater floor \cite{e.g. figure 1}, with a north-south slope asymmetry \cite{steepers towards the equator} that suggests a significant volatile component lost through solar-driven sublimation \cite{see figure 2}. Several of the northernmost examples retain bright frost cover throughout the north polar summer season, but regardless of such apparent surface frost, the topographic signature for polar region craters frequently includes these gentle central mounds, which are frequently difficult to detect in images due to their subdued topography and probable dust cover \cite{3}. While these mounds could be cold trap-derived accumulated frost deposits, we suggest \cite{e.g. [3]} that hydraulic pingo formation \cite{e.g. [6]} typical of open system aquifers and topographically-driven water flow may well provide the hydraulic head and permafrost disruption to initiate pingo formation. Long periods of climate stability on Mars \cite{relative to Earth} could then explain their relatively larger sizes. The modeling effort: uses MOLA topography to provide cavity and final central mound constraints, assumes decreasing porosity with depth, assumes a basal thermal flux \cite{thermal gradient}, rotational symmetry \cite{ambient surface pressure and temperature}, and for the martian polar regions, imposes a phase relationship \cite{to govern the depth of the ice/water phase transition}, and uses both global average cavity shapes as well as local polar average cavity shapes as starting points. Initial modeling \cite{[3, and this study]} suggests that martian hydraulic pingo formation is not difficult to reproduce in model domains for plausible parameter values.

Data and approach for target effects: The polar craters have a noticeably more u-shaped cavity function and simple to complex transition than is observed in equatorial craters as well as the global crater trends \cite{e.g. [2]}. This work further supports this observation with specific crater comparisons between polar and equatorial examples with similar diameters, but for selected geologic units after the example of \cite{1}. There are some hints of a latitude dependence \cite{for these properties}, suggesting not only a unit-based dependence, but also a volatile-based dependent target property of sufficient magnitude that the cavity formation process as a whole is sensitive to it.

Conclusions: We support prior observational results \cite{1,2,3} showing the following differences for polar impact craters: 1) a simple-to-complex transition \cite{at larger diameters}, 2) generally higher eject ramparts, and more pronounced near-rim moats, 3) cavity shapes that are more u-shaped \cite{and v-shaped}, and very common central mound-like deposits. There may be a small latitude dependence \cite{for the apparent target effects}, suggesting a volatile-based dependent target property of sufficient magnitude that the cavity formation process \cite{as a whole} is sensitive to it.

We find that topography data \cite{is key in morphol} key in morphology analyses for these features, because of generally poor polar viewing conditions \cite{dust and ice and frost-associated albedo variations}. We find that these mound-like deposits are well-modeled as hydraulic pingoes \cite{3} particularly in the 65\degree-80\degree N and S regions \cite{for impact craters > 8 km or so in diameter}. These areas are generally higher \cite{in mapped water-equivalent hydrogen [7, 8] and thus presumed near-surface ground ice \cite{permafrost} that would be required for a permafrost “cap” necessary for
hydraulic pingo formation. The apparent approximately 8 km size minimum for substantial central mound formation tends to support pingo formation rather than simple accumulation of frost deposits, as the associated crater depths (1-2 km) must be sufficient to tap into the local aquifers for pingo formation and growth. If these pingos are still active, tapping into one would produce artesian water flow. Inactive pingoes may well include substantial residual permafrost deposits.


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Figure 1. Showing a MOLA topography profile for a polar crater compared to a typical cavity model fit for an equatorial impact crater. The central deposits are substantial, and the cavity wall slopes are significantly shallower, as is typical for most polar craters.