MARS NORTH POLAR SPIRAL TROUGH MIGRATION PATHS VARIATIONS REVEALED BY 3D RADAR MAPPING. K. L. Laferriere[1], A. M. Bramson[1], I. B. Smith[2], [1]Purdue University, West Lafayette, IN 47907 (klaferri@purdue.edu), [2]York University, Toronto, Ontario CA

Introduction: The north polar region of Mars features a mostly pure water ice [1] cap called the North Polar Layered Deposits (NPLD, Figure 1), which contain iconic spiral-patterned troughs. The troughs are sub-kilometer deep elongated depressions revealing the upper fine-scale visible layers of the NPLD. The NPLD are a series of stratigraphically continuous, sub-horizontal layers of ice with variable fractions of dust [2] that provide a record of Mars' climate variations [3].

The Shallow Radar (SHARAD) instrument onboard the Mars Reconnaissance Orbiter (MRO) reveals similar laterally continuous reflectors in the NPLD subsurface due to changes in dielectric constant, interpreted as changes of dust content [2].Discontinuities are observed in the upper ~500 m, beginning at the bottoms of current troughs and extending downwards into the subsurface stratigraphy. These features have been interpreted as bounding surfaces, recording the erosional and depositional history of ice at troughs during their migration, referred to as Trough Migration Paths (TMPs) [5, 6].

The stratigraphically-oldest troughs have migrated ~100 km during the accumulation of up to 1 km of ice [6]. Three interconnected mechanisms are suggested to lead to the migration of these troughs [7]: atmospheric deposition of ices, insolation-induced sublimation, and the transfer of ice by wind. Mars' katabatic winds contribute to the formation of the troughs' spiral pattern due to deflection from the Coriolis forces and also contribute to sublimation on the upwind trough sides [7, 8]. The TMPs vary in slope with depth within the subsurface radar stratigraphy, signaling changes in the ratio of mass balance forces over time [9, 10. Thus, the troughs respond to climatic forcing [7, 9, 11], and initial modeling of ice accumulation and ablation [11] shows that recreation of TMP shape provides constraints on Mars' paleoclimate and its dependency on orbital forcing. The TMPs therefore record information about Mars' climate variability during the Late Amazonian.

Methods: [12] and [14] compiled a 3D SHARAD radargram from ~2300 orbital tracks. The use of this data volume provides clarification of the subsurface layering and reduces the effects of viewing geometry. Mapping in this 3D dataset therefore provides important spatial context for TMPs. Radar delay times were converted to depth by assuming the real component of the dielectric constant to be pure water ice (ε′ ~ 3.15), consistent with previous measurements of the NPLD's bulk dielectric constant [1]. The pixel size of the 3D depth-corrected dataset is ~20 m vertically and 475 m horizontally. The updated version from [14] provides better removal of ionospheric distortions resulting in improved vertical resolution of the layering. We use the Seisware geophysics interpretation software to map the unconformities in the subsurface reflectors as TMPs.

Results: We find that TMPs have recorded generally poleward migration over the past ~500 meters of deposition of the NPLD (Fig. 1a). We have mapped 30 TMPs across 41 surface troughs and defined a set of 7 regions based on the observed TMPs (Fig. 1b).

Each trough is unique, but regional patterns are discernable. The majority of the TMPs (e.g., Fig. 2) become observable around the same (pink) reflector, including the marginal troughs. TMP12 (Fig. 2a) is potentially younger but the presence of TMP11 underneath may prevent the formation of a mappable migration path. TMP 36 (Fig. 2f) however, is noticeably younger, originating from above the pink reflector. The shape of TMPs across these radargrams, despite the general similarity in formation depth, is quite variable.

Troughs near the polar margins have migration paths that are near horizontal, suggesting they undergo more erosion than deposition and are affected by their initiation surfaces that may be less erodible. Trough 24 shows a migration path originating at the pink reflector (Fig. 2a), similar to the high latitude troughs. Additionally, this trough appears to have eroded into the basal unit (BU). Despite originating at a similar age (reflector) as other troughs from this radargram, TMP24 is nearly horizontal likely due to higher erosion than deposition and construction on a resistant surface. A nearly horizontal path is also observed for TMP 20 and 36, although neither eroded into the BU.

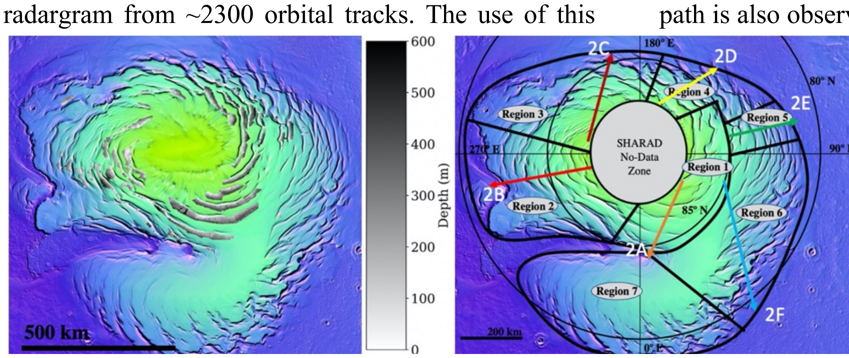

Figure 1: (Left) Planar view of mapped TMP depth (grayscale) over MOLA topography basemap. (Right) Regions based on our observations (black outlines) overlying MOLA topography basemap. Colored radargram tracks correspond to the locations of the panels shown in Figure 2 (arrow points to right).

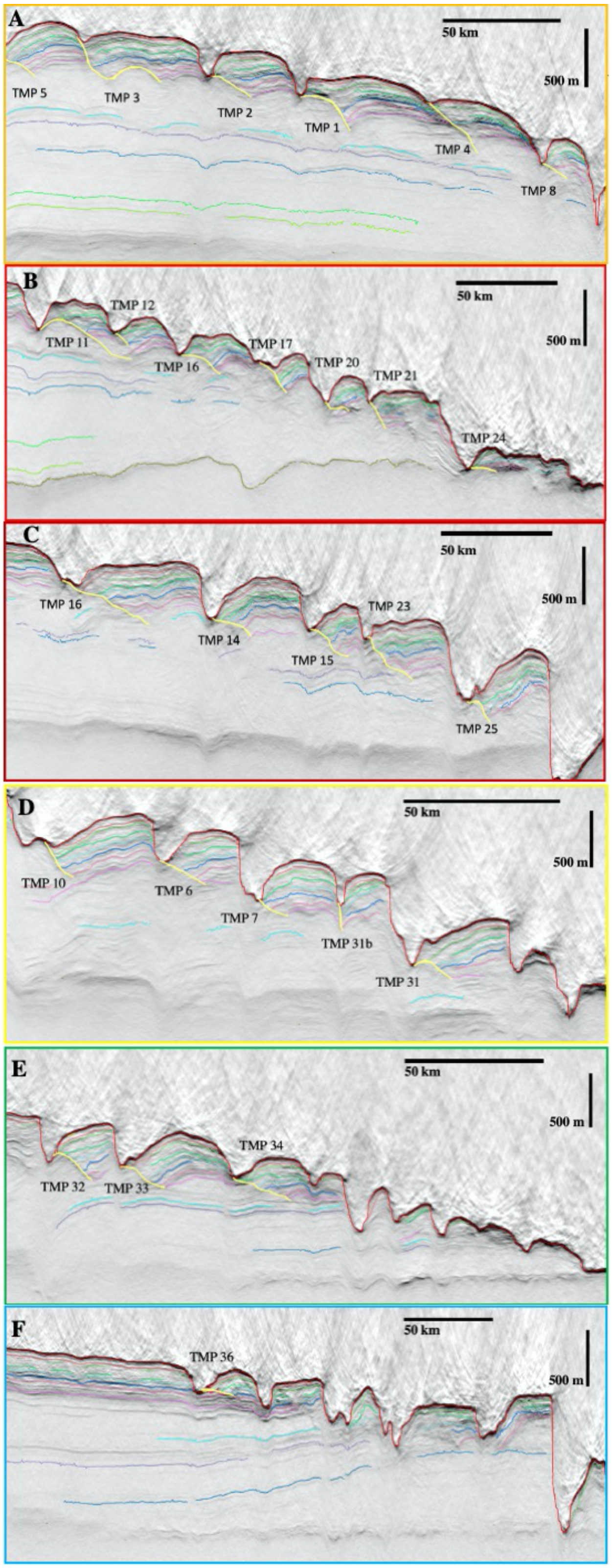

Figure 2: Sample radargrams with our interpreted subsurface layers marked as sub-horizontal colored lines and TMPs displayed in yellow. Panel outline colors match Figure 1 tracks. Panels A–F show Regions 1–6.

Similar to [6], we define Region 1 as providing the most classical view of migration paths (Fig. 2b). None of these TMPs are observed to be entirely horizontal or vertical, nor do any troughs erode into the basal unit.

Region 2 is defined by undulations present in both the surface and subsurface, making observations of TMP16 difficult to discern, At the margins, troughs have eroded into the BU. Overlaying a known large scarp in the BU [13], the second layer packet (~1 km depth) is eroded as well. Region 2 contains TMPs that vary from horizontal to vertical, suggesting localized, processes strongly affect migration here.

Region 3 is similar to Region 1 in that the TMPs are classical with a notable stepping pattern potentially connected to orbital forcing of climate [10]. Towards the margins, there is some erosion into the second packet of reflections, but not the BU. Region 4 is also similar to Regions 1 and 3, but towards the margins the oldest packets of reflectors are not observed.

Region 5 is characterized by TMPs in the most northern portion, with the marginal regions showing erosion into the second packet of layers with no signs of migration paths. Region 5 and 6, have previously been noted to have undergone massive erosional loss of ice prior to trough formation [6]. Region 6 contains a single TMP, shallow and young, on the border of Region 1. Towards the margins, there is a clear sign of massive erosion as the layers between the lowest blue and the upper ~500 m packet have been entirely removed.

Future work: We will use these 3D maps to determine the ice accumulation and retreat rates to provide constraints on Mars' paleoclimate, exploring a dependence on both obliquity and insolation as outlined in [11, see also new preliminary work in 15].

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