NORTH POLAR SPIRAL TROUGH IN-SITU FORMATION AS A WATER-ICE SOURCE TO LOWER LATITUDE GLACIAL AND PERIGLACIAL ENVIRONMENTS ON MARS. J.A.P. Rodriguez[1,2], A.G. Fairén[3,4], H. Miyamoto[5], Virgina Gulick[2,6], Natalie Glines[2,6], Francois Costard[7], Thomas Platz[1,8], Stephan van Gasselt[8]. [1]Planetary Science Institute, Tucson, AZ; alexis@psi.edu; [2]NASA Ames Research Center, Moffett Field, CA; [3]Centro de Astrobiología, Madrid, Spain; [4] Department of Astronomy, Cornell University, Ithaca, NY; [5]The University Museum, University of Tokyo, 113-0033, Japan, [6]SETI Institute, Mountain View, CA, [7]Université Paris Sud-CNRS Orsay, France, [8]Freie Universität Berlin, 12249 Berlin, Germany.

Introduction: The Martian north polar plateau, Planum Boreum (PB), comprises a domical water-ice rich layered deposit dissected by prominent spiraling troughs (Fig. 1A). Some investigations suggest that the troughs are highly dynamic geologic features, which have (and are still) undergoing poleward migration as a consequence of volatile removal from their equator-facing slopes and redeposition on their pole-facing slopes [e.g., 1, 2]. However, an alternative view, so far largely based on localized geologic investigations [e.g., 3, 4], suggests that following their formation by in-situ erosion, the troughs did not experience significant migration.

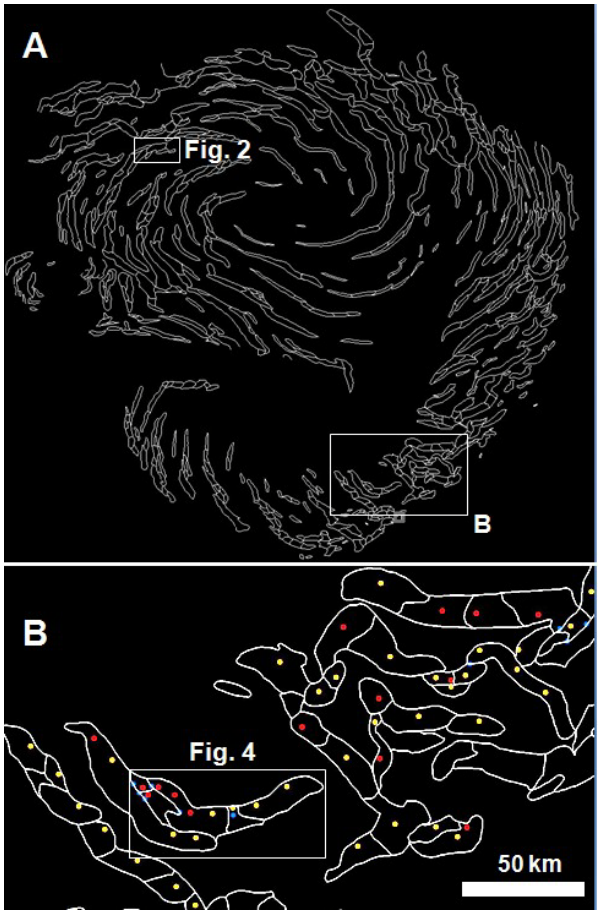

Fig. 1 (A) View on the north polar spiral troughs including internal topographic divisions (outlined in white). Mapping was produced using high-resolution (~6 m/pixel) Mars Reconnaissance Orbiter Context Camera (CTX) mosaicked image data in combination with a Mars Orbiter Laser Altimeter (MOLA) digital elevation mosaic (~115 m/pixel). **(B)** Example of spiral troughs showing internal topographic divisions (outlined by white line) and orientation of exposed stratigraphy at multiple locations along their flanks. (Red and blue: depressions and promontories, respectively, with exposed both equator and pole-facing strata. Yellow: trough scarps with only equator-facing strata exposures).

Each of these geologic scenarios carries important, yet highly divergent, implications regarding the recent history of water-ice mobility on Mars. For example, trough migration would have redistributed (but not removed) enormous volumes of water-ice within the confines of the polar plateau. On the other hand, widespread in-situ trough formation without migration would have resulted in a significant mass loss from PB.

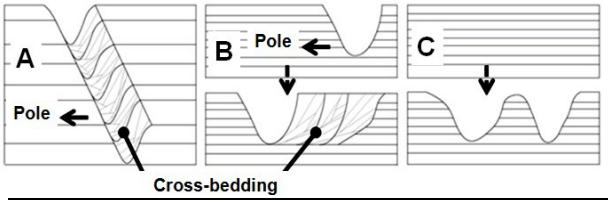

Fig. 2 Sketches showing the polar plateau stratigraphy expected to result from various styles of trough development. Strata geometries resulting from **(A)** trough poleward migration occurring during polar strata accumulation, **(B)** post-polar strata emplacement trough poleward migration, **(C)** trough formation by in-situ PLD erosion.

Exposed stratigraphic record of non-migratory troughs in PB: Trough poleward migration would have emplaced sediments over the pre-existing inclined surfaces of their pole-facing slopes. Consequently, exposed stratigraphy along these locations would have likely included cross-bedded deposits (Fig. 2A, B). Our topographic characterization of the PB spiral troughs reveals widespread interior compartmentalization (Fig. 1A) into systems of aligned, or parallel, depressions and

promontories (Fig. 3A). At numerous locations these depressions and promontories exhibit layers that can be continuously traced along both their equator and pole-facing slopes (e.g., Figs. 1B, 3). These stratigraphic relationships are consistent with in-situ trough formation without a subsequent migrational history (Fig. 2C). This hypothesis is also supported by the distribution of (1) trough exposures that only show equator-facing layers relative to (2) those including both exposed pole- and equator-facing layers (Fig. 1B).

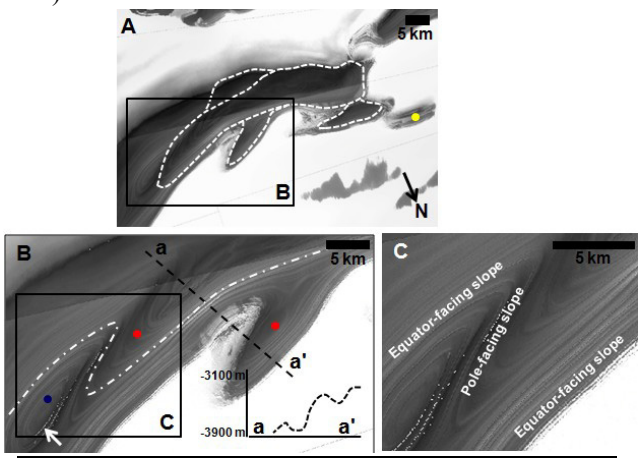

Fig. 3 (A) Section of a north polar trough. White lines trace the outlines of individual compartments, which include part of the trough's margins and interior ridges. Part of a CTX mosaic, centered at 85° 10' N., 110° 59' W., 6 m/pixel. **(B)** Close-up view on panel (A). Troughs of typically a few hundred meters in relief (elevation profile a-a'). Dashed line traces a layer continuously exposed along the equator-facing and pole-facing slopes of a promontory, as well as along the equator-facing slopes of two compartments. **(C)** Close-up view on panel (B). Layers exposed from the summit of the ridge to the deepest zones of the adjacent compartment, showing that horizontally extensive, nearly flat strata characterize the excavated stratigraphy of PB in the region.

Some identified spatial relationships include:

- Spatial concurrence within a single trough of exposures that (1) show both pole and equator-facing layers, and (2) others with only equator-facing layers (Fig. 4, numbers 1-7). In this example, the upper layers of the scarp are continuously traceable within the field of view showing that all the equator-facing exposures expose the same sets of layers.
- Closely-spaced equator-facing scarps in two parallel troughs (Fig. 4, numbers 4 and 8). Migration of scarp (4) should have reworked the materials into which scarp (8) is incised into cross-bedded deposits. However, both scarps show sections of the same stratigraphic sequences.
- The widespread distribution of locations interpreted as having been produced by in-situ erosion, which limits any potential migration to the discrete spatial domains of enclosed inter-trough plains.

Reconciling these results with radar-derived stratigraphy: We propose that Martian north polar troughs are not migratory features and that their locations represent the sites where they were originally excavated. However, we do not exclude trough migration as a key process in polar trough development, but we suggest that the relevant radar-based stratigraphic reconstructions [e.g., 4] likely describe much older migrational structures that were produced during stages of polar plateau construction.

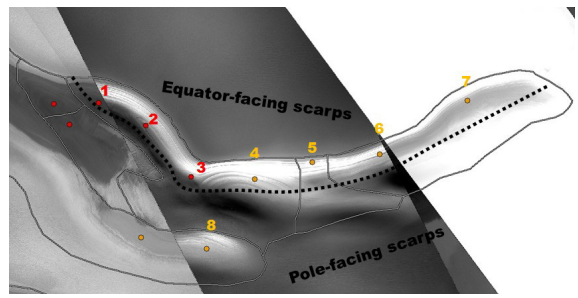

Fig. 4 View scarp zones that were likely produced by in-situ erosion (1-3) and their continuity with those that, without a regional context, could be interpreted as produced by poleward migration (4-7). The dotted black line traces the axis of the longest trough in view.

Paleoclimatic implications: We estimate that ~4 × 10^4 km^3 water-ice would have been removed from the polar plateau if trough formation was dominated by in-situ dissection, which is significant enough to have been an important contributor to the generation of widespread lower latitude glacial and periglacial environments. During period(s) of high obliquity, ice becomes stable at lower latitudes [e.g., 5].

References: [1] Howard A. (1978) Icarus 34, 581-599. [2] Smith I.B. and Holt J.W. (2010) Nature 465, 450-453.[3] Rodriguez, J.A.P. et al. (2007) Mars 3, 29–41. [4] Tanaka, K. L. et al. (2008) Icarus 196, 318–358. [5] Searls et al (2008) LPSC #2376.

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