TEMPORAL AND SPATIAL EVOLUTION OF SPIRAL TROUGHS ON PLANUM BOREUM, MARS FROM DETAILED STRATIGRAPHIC MAPPING: IMPLICATIONS FOR LOCAL ATMOSPHERIC PROCESSES. I. B. Smith[1] and J. W. Holt[1], [1]University of Texas Institute for Geophysics, Jackson School of Geosciences, University of Texas, Austin, TX 78758 isaac@ig.utexas.edu; jack@ig.utexas.edu.

Introduction: The spiral troughs of the North Polar Layered Deposits (NPLD) are unique features that contain stratigraphic information that provides specific constraints on the Martian atmospheric conditions, both current and in the recent (~5 Ma) past. Recent results from orbital radar investigations have shown the troughs to have initiated after approximately 1500 m of the ~2000 m of the NPLD was deposited [1]. They evolved quickly to an equilibrium state and consistently migrated poleward through subsequent deposition and erosion.

Recent detailed radar stratigraphic studies [1, 2] have been accomplished by 3-dimensional mapping of reflectors and discontinuities from the Shallow Radar instrument, SHARAD, onboard Mars Reconnaissance Orbiter (MRO) [3]. SHARAD operates with a 10 MHz bandwidth centered on 20 MHz allowing a theoretical vertical resolution of ~9 m in water ice. This resolution is sufficient to interpret thicknesses of ice that would incorporate many annual cycles, probably on the order of 20,000 years based on estimated rates of accumulation [4].

The late, but not recent, onset of troughs implies that something in the atmosphere and or climate changed at or just before the time of their formation. Additionally, the stratigraphy inherent to the troughs, and in particular the discontinuity resulting from offset layers at the trough itself, records information about three basic parameters, possibly more, governed by climate: transport by wind, atmospheric deposition, and solar induced ablation; each of which may have played a dominant role at some point in NPLD and trough history. The oldest spiral troughs began to form after ~1500 m of ice was deposited at the north pole [1]. This surface, on which they formed, we term the Trough Initiation Surface (TIS). Notably, the troughs initiated with approximately the same wavelength as can be measured today.

Processes: The most important process controlling trough formation and migration is likely to be katabatic winds. Katabatic winds permeate the NPLD and follow a sub-radial path outward from the polar high, rotating clockwise as they descend to the lower plains. Mapped wind streaks demonstrate that the spiral troughs align nearly perpendicular to the wind paths and support the conclusion that the troughs are both created and modified by wind [5]. Reflectors mapped in radar also support this conclusion, and quantitative measurements of slope relating to the location of deposited ice have been made [6]. Those results proposed that as winds accelerate downward, away from the pole, they remove material from the surface and carry that material until they reach an uphill climb, where the material, likely ice and dust, is dropped. This explains trough migration and may hold clues to trough formation. Additional evidence for winds acting on the NPLD to create large features comes from stratigraphy near Chasma Boreale [2].

Another important factor in NPLD and spiral trough growth is atmospheric deposition, which causes

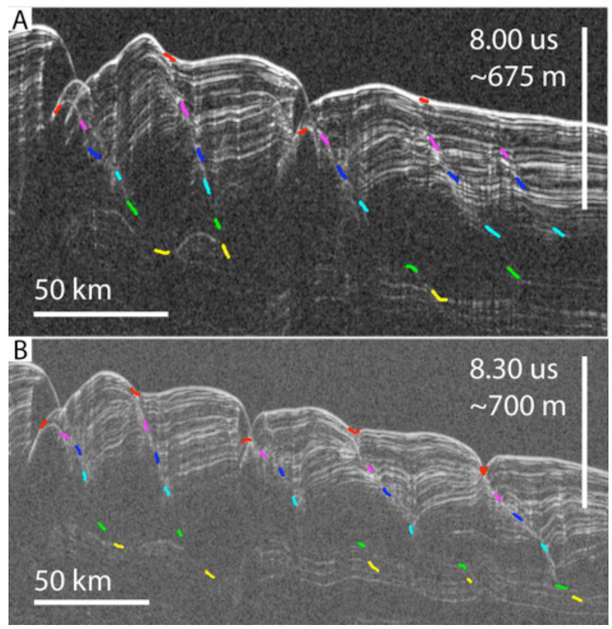

Figure 1: Radar observations 706402 (A) and 933202 (B) showing six points chosen along TMP. Colors indicate specific stratigraphic levels common between troughs and in plan view (Fig 2). Locations in Figure 2.

the NPLD to grow and the troughs to migrate upward [aside from the upslope migration from winds alone]. Variations in accumulation, on the order of tens to hundreds of meters, have been shown to exist in different locations around the pole and also near spiral troughs.

Lastly, evidence for solar induced ablation comes from mapping radar reflectors. Large-scale erosion is

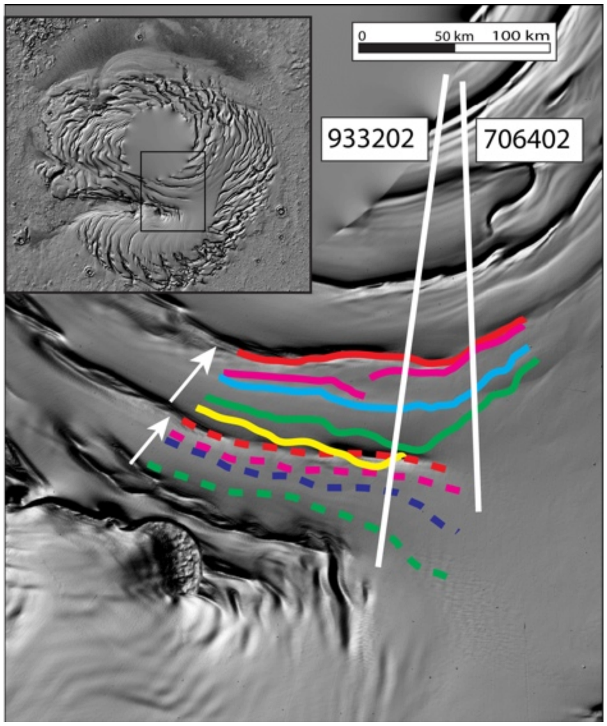

Figure 2: Paleo-locations of two troughs the subsurface based on mapping (Fig. 1). Arrows show direction of migration. Dashed lines indicate southernmost trough north of Chasma Boreale, and solid lines indicate next trough to the north. Colors match those of Figure 1. Inset shows location.

detectable at truncated reflectors, while smaller scale ablation is likely a part of what causes thickness variations near troughs [6].

Methods: The spatial and temporal migration of spiral troughs was evaluated by mapping trough migration paths (TMPs) for multiple troughs. The TMP determines where a trough was located through time, as noted by [1]. We mapped six stratigraphic levels for each TMP: the current location at the surface, the initiation point of each trough, and 4 distinct levels between. This gives sequential locations for each trough. The points at specific reflectors were chosen for being recognizable and repeatable in radar and can be seen in Figure 1.

The area bounded by Chasma Boreale to the south, the polar "hole" in data coverage beginning at 81°N, and the area between 0° E and 30° E was chosen because of the consistently clear radar stratigraphy at all levels, and the fact that this area contains only the oldest troughs. With these maps, the ratio of upward to northward migration is determined for many locations in the NPLD demonstrating some spatial variability, Figure 2. We are currently expanding the mapping area to include a much larger portion of the NPLD that includes the younger troughs surrounding 90° E.

Results: Preliminary mapping shows that the spiral troughs do not migrate at the same rate in even within a single trough. Lateral variations in upwind migration rate appear to be functions of both atmospheric conditions and topographic effects, namely regional slope. Therefore the current surface does not contain an exact northward version of former troughs, and instead the troughs have each evolved with unique histories, not unlike sand dunes on earth.

One would expect that during a time of erosion in other parts of the NPLD, the troughs would show an increase in ratio of northward to upward migration. First order results do not confirm this. In the oldest troughs, which have persisted during the time of younger trough formation, no stark change in TMP exists at the stratigraphic level that coincides with the erosion before onset of the younger.

Discussion: The TMP slope, and thus ratio of *upwind* to *upward* migration, reflects the relative amount of three parameters driven by the atmosphere and orbital forcing: deposition, transport, and erosion. Ongoing efforts to quantify the amount of sublimation between reflectors, and thus relative amount of loss to atmosphere and deposition will constrain these rates giving a better understanding of both global circulation and regional accumulation models.

Efforts to use quantified local accumulation near troughs (accumulation variation on differing slopes) and trough migration path slopes to create a 2D model are beginning. The eventual goal of this project is to reproduce inter-trough stratigraphy and make strong predictions of rates of deposition, transport, and sublimation based on measurable trough features such as wavelength, amplitude, and migration.

Local variations of trough migration make the trough model more complex than previously believed [1]. Two dimensional studies will not be sufficient to accurately depict cap-wide events due to large local influences, and more detailed mapping than is currently done will be necessary to understand the full story. Understanding individual troughs is becoming critical to gaining insight into the grander picture.

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