QUANTITATIVE RADAR STRATIGRAPHY OF THE UPPERMOST NORTH POLAR LAYERED DEPOSITS, MARS, AND PROCESSES CONTROLLING SPIRAL TROUGH MIGRATION.

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Introduction: Stratigraphic mapping is the key tool to understanding the morphodynamic evolution of sedimentary systems on Earth. This equally true for systems on Mars, including the North Polar Layered Deposits (NPLD). Outcrops, until recently, have been our only guides to understanding subsurface geometry. Quantifying the 3-dimensional stratigraphy, especially layer thickness variation over large areas, has been elusive until now.

The SHAllow RADar (SHARAD) instrument onboard Mars Reconnaissance Orbiter (MRO) is capable of observing reflectors beneath the NPLD surface at depths greater than 2 km [1, 2]. SHARAD's theoretical resolution is ~10 m in water ice [1], which comprises the bulk of the NPLD [3]. SHARAD detects tens of layers in the NPLD, the most and brightest being within the upper 500 m.

Generally, the layers in the NPLD are subhorizontal and continuous in the lowermost 1500 m of imaged deposits. Stratigraphic anomalies, determined to be discontinuities, dominate the uppermost 500 m of section. These discontinuities are associated with trough migration and are shown to be bounding surface s where ice deposits on-lap the eroded south-facing slopes of spiral troughs [4].

Proposed processes of trough migration are few, including: solar induced ablation, atmospheric deposition, and aeolian transport. By investigating subsurface stratigraphy we can begin to constrain the role and relative importance of each process.

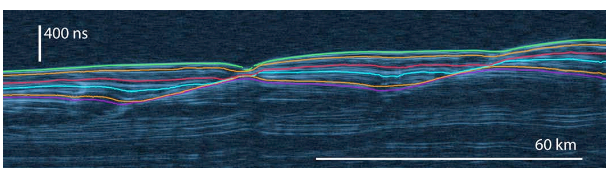

Figure 1: Mapped horizons on SHARAD observation 519201 (black line in Fig. 2). Five subsurface reflectors and the surface were mapped in 80 lines and resulting reflector elevations gridded. 400 ns is approximately 350 m in water ice.

Methods: 80 SHARAD observations (Figures 1 and 2) in a region between 15° and 55° E and 82° and 86° N on the NPLD were used to reconstruct paleosurfaces within the NPLD. Commercial seismic software, GeoFrame, was used to interpret horizons on each observation. A total of 6 horizons, all within the uppermost 500 m and including the surface horizon, were used (Fig. 1). The extracted time data were then geospatially referenced and imported into ArcGIS software to create surfaces by interpolation. ArcGIS was then used to create slope maps of each horizon and to calculate the accumulation between pairs of horizons by subtracting the elevations of each.

We geospatially referenced reflections in two steps. First, we locate the point of the earliest radar reflection in the data on Mars' surface. Due to cross-track slopes, the surface return and subsurface reflectors, are not always from nadir. Knowing this location is critical for obtaining accurate subsurface reflector geometries. Second, we correct for depth by assuming a velocity of radar waves consistent with that in water ice [3].

Once the six horizons were mapped, profiles oriented approximately perpendicular to the spiral troughs or following current surface wind direction were selected to investigate accumulation patterns. The

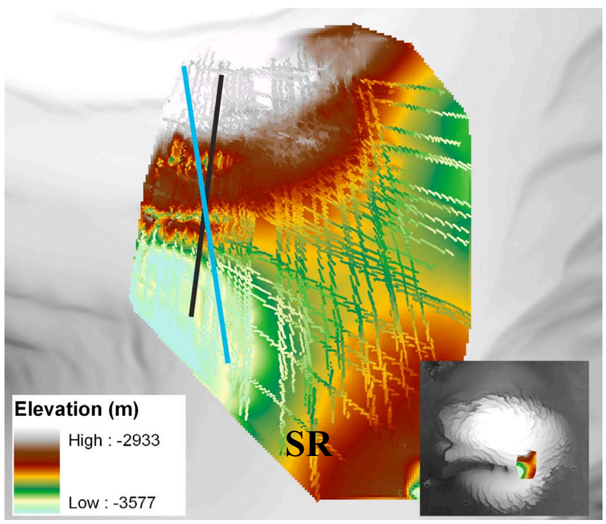

Figure 2: Basemap and data locations. 80 SHARAD orbits overlay a gridded interpolation of a paleosurface. Elevations are referenced to the MOLA aeroid. Black line is orbit track of observation 519201, Fig. 1. Blue line is location of Fig. 3's profile. Inset: Planum Boreum with gridded surface for location.

spacecraft orbit rarely follows either, so creating this grid allows for more flexibility in choosing useful profiles. An area of 30,000 km^2, roughly the size of Maryland, covering two main-lobe troughs and the Saddle Region (SR) between the Main Lobe and Gemina Lingula, was mapped (Fig. 2).

Observations: Deposits near the spiral troughs showed wide variation in thickness, between 0 and ~1.4 times that observed at the SR. Longitudinal variation is also observed; the westernmost profiles, those directly north of Chasma Boreale, had more variation than those farther east and north of the SR where regional topography is much less variable.

Plots of thickness show no systematic change with elevation (Fig. 3b). However, thickness plotted against slope illustrates a clear relationship: positive, south-facing slopes, are anti-correlated with thickness, while negative, north-facing slopes, have increasingly thicker packages (Fig. 3c).

Interpretations: It has been thought that solar induced ablation could account for the entirety of trough migration, but several arguments contradict this idea. First, the surface slopes on either side of the trough are not equal: the south-facing slopes being 75% steeper than the north-facing slopes. Calculations show that at this latitude, the total energy received from sunlight on each slope throughout a Martian year is approximately equal [5], so this strong discrepancy should not exist. Second, preferential sublimation of the south-facing slopes cannot account for the thickness variations seen.

We interpret the new data to demonstrate that katabatic winds descending from the polar high entrain material from an upwind slope and transport it to a downwind slope across a trough. This interpretation accounts for the layer thickness variation and agrees well with previous interpretations based on optical images from earlier missions [6, 7].

Conclusions: Accelerating winds remove material from the upwind slopes (usually south-facing) within a trough and carry said material to the downwind or north-facing slope. Plots of thickness vs. slope support this conclusion and demonstrate that accumulation is not uniform across a spiral trough. Therefore, interior trough slope played a major role in accumulation.

In the SR, we observe near constant package thickness as a result of very low slopes and near constant elevation. Thus accumulation is more uniform than near the troughs and acts as a control to estimate pre-transport accumulation.

We note that the regional slope is and was steeper north of Chasma Boreale likely producing greater wind speeds and energy to transport material. This results in greater variation of ice deposit thicknesses than in the relatively flatter regions, thereby growing steeper trough walls than in other locations.

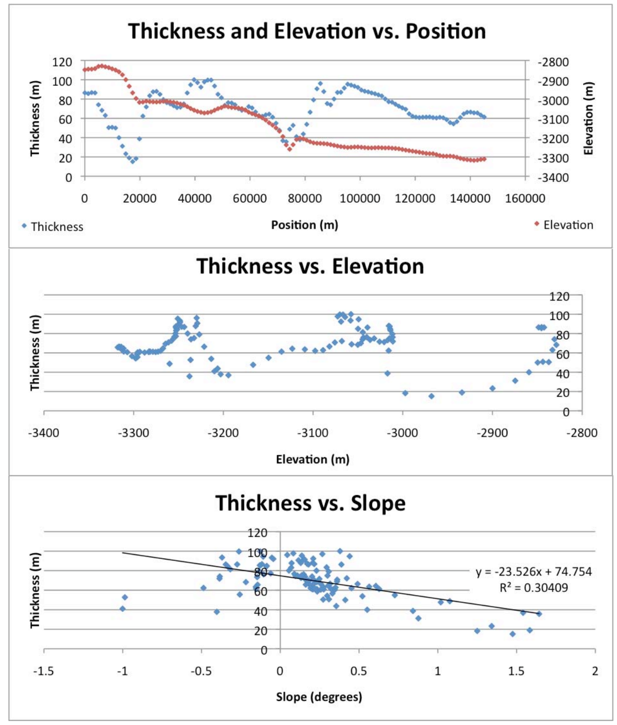

Figure 3: An example of package thickness (blue) plotted against local position, elevation, and surface slope along with elevation profile (red; location indicated by blue line in Fig. 2). Negative slopes indicate pole-facing surfaces and positive slopes indicate equator-facing surfaces. Elevation varies by ~ 500 m with no systematic change in thickness. Surface slope and deposit thickness are correlated.

There are two possibilities for creating the layer thickness variations: one, sediment was deposited uniformly and later preferentially remobilized, or two, concurrent winds moved accumulating ice during deposition. Both possibilities give rise to trough migration but don't explain how they initiated. Continuing studies will attempt to answer this question and find the relative amount of material sublimated during accumulation based on the average layer thickness in the SR.

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