EVIDENCE FOR SPIRAL TROUGH MIGRATION AND EVOLUTION FROM SHARAD RADAR OBSERVATIONS OF STRATIGRAPHY WITHIN THE NORTHERN POLAR LAYERED DEPOSITS, MARS.

I. B. Smith[1], J. W. Holt[1], S. W. Christian[2], A. Safaeinili[3]. [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; [2]Bryn Mawr College, Bryn Mawr, Pennsylvania 19010; [2]Jet Propulsion Laboratory, Caltech, Pasadena, CA 91109.

Introduction: The spiral troughs of the Martian Polar Layered Deposits (PLD) remain enigmatic features. They may result from radiational ablation of layered deposits, and they may undergo migration toward the center of the PLD due to katabatic winds eroding northern slopes and deposit further south on the pole facing slope [1,2,]. An increase in elevation has been hypothesized [1] if rates of new layer deposition are greater than ablational erosion.

Stratigraphic studies are one way to constrain hypotheses for trough formation and evolution. Surface exposures of layers within some troughs show steep dips, contrasting with the flat-lying layers generally observed elsewhere in the northern PLD (NPLD) [3]. Modeling of surface slopes in Gemini Lingula indicates that troughs are late-stage features, predicting that troughs in that region should crosscut layers at steep angles [4].

Exposures of layer morphology within troughs are limited; however, orbital radar sounding observations reveal stratigraphic anomalies beneath the surface of the NPLD that may shed important light on trough formation and evolution. Other anomalies observed may be related or indicate processes that have not yet been documented.

Methods: The SHAllow RADar (SHARAD) instrument on mars Reconnaissance Orbiter is an orbital, chirped radar on MRO, operating at 20 MHz center frequency (15 meters free-space wavelength) with 10 MHz bandwidth and 85 ms pulse duration [5,6]. Pulse compression yields a theoretical vertical resolution of ~8 m in water ice. Horizontal resolution is 0.3 – 1km along-track and 3-6 km across track. All but the Basal Unit (BU) of the NPLD is reliably penetrated by SHARAD [7].

Stratigraphic horizons and discontinuities can be identified and tracked in radargrams using commercially available seismic data analysis software. With many orbits to make a network of crossing observations we can map the three-dimensional structure of these features to constrain their spatial extent: Figure 2.

Radar Stratigraphy: In the radargrams many bright layers can be traced for long distances across the NPLD, especially in the central, thicker region. They vary in brightness and thickness and capture a long history of polar deposition.

Beyond Stratigraphic layers we have identified and tracked anomalies where layering is horizontally discontinuous, causing near-vertical and sloping features in the radargrams. These are tracked over multiple lines in the data to determine their overall shape in three dimensions. They are then projected onto the surface in map view to determine relationships to large scale surface features such at the troughs.

Observations: In the quadrant of 90E to 0E near the pole, orbital observations were made of subsurface anomalies. Two main types of unconformities are found, one being more prominent than the other; here we call them sloping and V-shaped unconformities. Six sloped and three V-shaped can be traced in this space; Figure 1 shows examples of each.

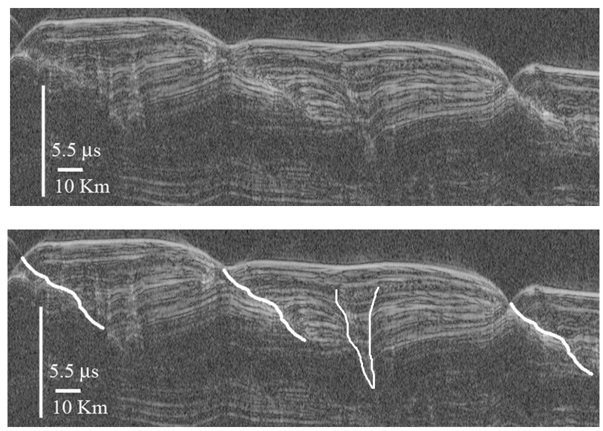

Figure 1. *Clip of Orbit 6247 (see figure 2 inset for location): Radar imagery in the upper portion of the NPLD. Among the stratigraphic layers unconformities appear as V-shapes and slopes. Upper: At the base of each trough begins an unconformity that slopes down and to the south. Lower: traces of slope and V-shaped unconformities. The same trace was overlaid on all three slopes. Middle and right are almost identical.*

The V-shape, center of figure 1, is found midway between two spiral troughs interrupting the layered deposits on both sides. The deposits dip noticeably from the north and south but are continuous up to the point of the unconformity. Across the discontinuity on either side different layers are present. These unconformities never reach the surface; instead they are buried beneath younger layers of ice. Since it appears younger and to incise the surrounding ice, this V may be an example of a buried version of [4]'s fast acting trough. It is too early to make that determination.

A second unconformity, the sloping type, is found to the left of the V and goes beneath the layered deposit directly adjacent. Eventually it reaches the base of a spiral trough. They do not show evidence of fine structure or fracture; rather they are quite diffuse. Across the boundary of the slope the layered deposits are unconformable.

Three examples of this slope unconformity are seen in Figure 1. The three have similarly varying slopes that change equally throughout their paths, while their initial and final elevations are different. This observation is consistent with thicker deposits at the pole and less deep ones at lower latitudes.

Images of the same unconformities in adjacent orbits show similar structure and vary in slope only slightly. Moving to the west the V-shape becomes wider eventually disappearing into the layered deposits. And to the east the acute angle of the triangle closes: the last visible remnant being a blip in the layers. Of the three most prominent examples, the longest one's full spatial extent is approximately 125 kilometers.

The sloping unconformities also change with longitude but do so over a much greater distance and to a lesser extent than the V-shapes. To the east and west the longest unconformities can be traced nearly 400 kilometers.

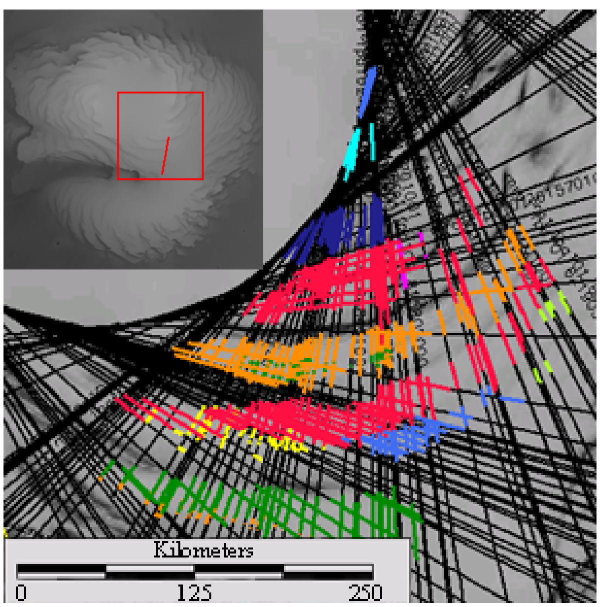

Figure 2. *Portion of NPLD with SHARAD orbital tracks and the upward projection of the stratigraphic anomalies. Colors indicate individual anomalies that can be traced hundreds of kilometers. Bright yellow and lower orange represent V-Shaped unconformities that are not as laterally extensive. Inset: NPLD showing orbit 6247 and area of Figure 2.*

Both types of unconformity can be mapped by plotting adjacent orbit lines over a basemap. All are given a color, and from above one can see the spiral pattern between troughs. The result is Figure 2.

We interpret these anomalies to represent the position of troughs over time. Since in all cases, slope anomalies appear farther from the pole deeper into the section, the trough position is required to move to the north as deposition continues.

Our evidence supports the trough migration theory of [1,2] who proposed that northerly katabatic winds remove ice deposits from the north slope (that facing the equator) and re-deposit it further south. Concurrent atmospheric deposition continues causing all parts to rise in elevation as they move northward, giving an up and north slope [1]. This creates an diffuse unconformity at the base of the trough that also rises with time. [8] models that troughs migrating will leave behind wavy discontinuities. The sloped unconformity seen in Figure 1 displays such a morphology.

Over the cross section of one discontinuity the slope varies. Slope is affected by rate of deposition and northerly winds that compete with each other [1]. Steep slopes, seen lower in the section, signify rapid deposit and thus accelerated elevation increase. And shallower slopes nearer the top formed during times of less deposition where wind had more influence.

Conclusions: SHARAD observations of stratigraphic anomalies sharing the spiral shape and a connection to spiral troughs indicate that the troughs migrated both north and upward as wind and atmospheric deposition took place. Katabatic winds from the north blew loose ice to the south leaving an unconformity at the points of ablation and deposition [1,9]. Upward motion took place as climate induced deposition filled and covered the contemporary surface.[1,9]

Understanding the V-shaped unconformities will require more study. It is evident however that they formed while the troughs migrated due to their shape and location. One idea is that they are remnants of steep, fast growing troughs [4] that were later buried.

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