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Early geomorphological evolution of the North Polar Layered Deposits, Mars, from SHARAD radar-facies mapping

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The north polar layered deposits (NPLD) are the largest accumulation of water ice in the northern hemisphere of Mars. Since their discovery, they are thought to hold a valuable record of recent climate change within their stratigraphy (Murray et al., Icarus, 1972; Cutts, JGR, 1973b), yet little is known about their age and accumulation history. Due to exposures in trough walls, detailed stratigraphy of the uppermost layers and their evolution have been studied extensively since the first Mariner 9 images of the NPLD (e.g. Soderblom et al., JGR, 1973). However, large portions of the polar cap are still unmapped and no detailed studies of the lowermost layered deposits have been performed to date, primarily due to a general lack of visible exposures.

Correlation of reflectors within radargrams acquired by the Shallow Radar (SHARAD) (Seu et al., Planet. Space Sci., 2004) onboard Mars Reconnaissance Orbiter makes a detailed stratigraphic reconstruction of the NPLD possible. An extensive set of radargrams is available over Planum Boreum and individual reflectors can be traced over hundreds of kilometers (Seu et al., JGR, 2007a; Putzig et al., Icarus, 2009; Holt et al., Nature, 2010) with a theoretical vertical resolution of ∼9 m in water ice (Seu et al., JGR, 2007a). In this study, we present a highly-detailed stratigraphic reconstruction of the first ∼500 m of the NPLD at a scale down to the single reflector. A set of 8 horizons was tracked across 700+ radargrams, and thicknesses were calculated for each stratigraphic interval assuming a bulk composition of water ice. Along with the quantitative analysis of derived isopach maps, this study is based on the qualitative comparison of "radar facies" in different locations of Planum Boreum with techniques borrowed from traditional sequence stratigraphy.

In general, the NPLD is characterized by uniform layering. However, important layer extent and thickness variations are observed within the lowermost sequence. Limited lateral extent and pinch-outs in the two lowermost layers suggests restricted water ice stability areas, shifts in water ice depocenters or active erosion along scarps, possibly due to increased solar incidence and reworking/transportation by katabatic winds. Two additional pinch-outs in the middle part of the sequence suggest a simple poleward retreat of ice deposition. The rest of the sequence, instead, is characterized by an increased lateral extent of layers. The observed stratigraphic patterns are likely related to climate variations, which, in turn, may be due to orbital forcing. We also found evidence of topographic control over layer deposition. Layers are thicker at higher elevations and where topographic lows were present. Steep, equator facing slopes likely induced increased sublimation due to higher insolation and water ice reworking and transportation by katabatic winds.

Future modelling of climatic variations due to orbital forcing must take into account the complex stratigraphic patterns and frequent hiatuses present within the lowermost NPLD. Methods traditionally used in sequence stratigraphy analysis on Earth, such as stacking patterns and trajectory tracing, can be borrowed and adapted to icy deposits on Mars to obtain more complete and straightforward interpretations.