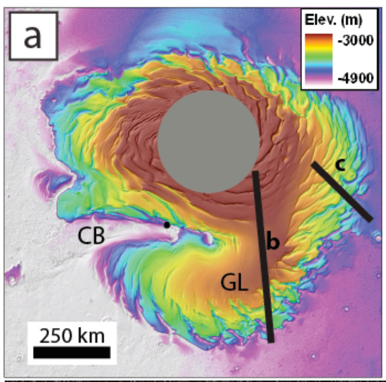
THE LONG-TERM EVOLUTION OF PLANUM BOREUM, MARS: A SYNTHESIS OF RECENT OBSERVATIONS AND MODELING. J.W. Holt, Institute for Geophysics, Jackson School of Geosciences, The University of Texas at Austin, Austin, TX (jack@ig.utexas.edu)

Introduction: Longstanding questions regarding the polar regions of Mars [1] can be addressed in a new way due to the advent of orbital radar sounding. In particular, a new perspective on the long-term evolution of Planum Boreum (PB) has emerged from radar stratigraphy obtained by the Shallow Radar (SHARAD) [2] on Mars Reconnaissance Orbiter, especially when combined with new modeling efforts.

This evolution includes a highly nonuniform, erosional basal unit (BU) surface, the early formation of Chasma Boreale, the complete infilling of a similarly-sized chasma, the relatively late onset and subsequent migration of spiral troughs, and a series of growth/retreat events that have left their imprint on the modern surface. Furthermore, the stratigraphic evidence indicates that processes observed operating today can explain all of the major features of PB. Finally, the mapped sequence of growth and retreat has provided a means to test global climate models that predict ice growth and retreat as a function of orbital parameters (e.g., [3]).



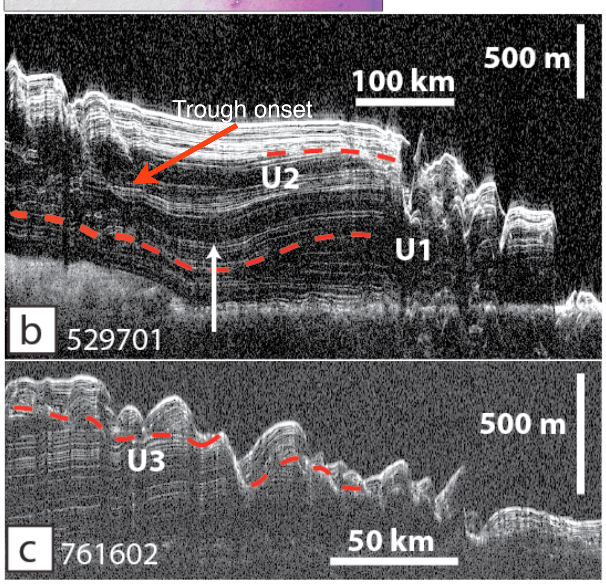


***Figure 1.** (a) Planum Boreum surface. (b) Portion of SHARAD 529701 showing stratigraphic sequences bounded by erosional unconformities (U1 and U2). (c) Portion of SHARAD 761602. Past margin retreat indicated by large-scale truncation at unconformity U3.*

Radar Sounding: SHARAD has acquired over 2000 PB observations [2] enabling the mapping of the uppermost surface of the basal unit (BU) [4,5]. PB has been revealed to be highly nonuniform and asymmetric about the pole (Fig. 2), while perfectly contiguous with Olympia Undae. SHARAD also provides critical information about the internal structure and stratigraphy of the overlying NPLD [4,6]. While bulk composition of the NPLD has been constrained by radar to be ~95% water ice [4,7], radar reflectors are assumed to arise from variations in dust content that modulate the dielectric properties of the layers [6,8].

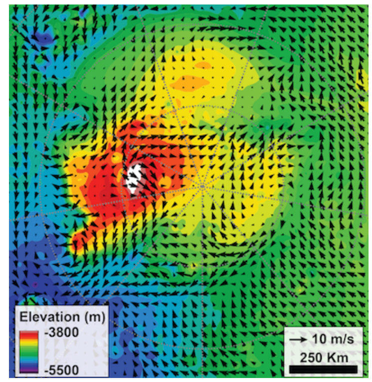


***Figure 2.** Basal Unit topography with wind vectors from meso-scale wind model. Courtesy Aymeric Spiga.*

Dominant Processes: Although ice flow has previously been proposed as a significant factor in shaping the gross morphology of Gemina Lingula (GL; Fig. 1a) [9-11], the analysis of internal radar stratigraphy including a 3-dimensional flow model [12] does not support that interpretation, nor does the presence of buried troughs within GL. This is in contrast to mid-latitude glacial features which exhibit viscous flow morphologies [13-15] and are estimated to be at least 100 Myr old and have therefore experienced more extreme variations in obliquity [16].

Likewise, there is no evidence yet identified in radar stratigraphy to support basal melting of NPLD from enhanced geothermal flux, or brittle deformation on large scales. Furthermore, sedimentary structures indicate that aeolian processes have played a major role throughout PB's history. This is clearly a dominant force at work both within the basal unit [17] and in the uppermost NPLD during the onset and evolution of the spiral troughs [18-20].

Spiral Troughs: Starting more than halfway through the NPLD, stratigraphic structures indicate the appearance of spiral troughs and their subsequent migration concurrent with new deposition ([18], Fig. 1b). This finding and the unique inter-trough stratigraphy supports an origin with katabatic winds as a critical driver [19]. All major characteristics of the troughs can be explained in the context of repeating katabatic jumps, otherwise known as cyclic steps [20], wherein lateral transport of material is an important process.

Accumulation History: Stratigraphy within the NPLD indicates the dominance of processes that are sedimentary in nature; therefore we use large-scale stratigraphic unconformities to define the major depositional sequence boundaries. At least three large-scale depositional sequences are preserved (Figs. 1b, 1c), each of which is bounded by an erosional event. The lower of these depositional units was mapped across Planum Boreum to reveal the early appearance of Chasma Boreale [21]. A higher unconformity found in the saddle region east of Chasma Boreale indicates a later period of regional erosion (Fig. 1b). In both instances, the lateral extension of reflectors bounding these unconformities are conformal under the main lobe of Planum Boreum, indicating that these erosional epochs may have been relatively short-lived and limited in extent.

Evidence does, however, exist for significant retreat of the NPLD margin in the region of Gemini Scopuli prior to the most recent episode of deposition. This may be coeval with the erosional event that created the uppermost unconformity (Fig. 1c).

Overall, the stratigraphy indicates a relatively simple accumulation history, with continuous deposition in the center of the deposits and either two or three large-scale (but relatively brief) hiatuses interrupting deposition and creating erosional surfaces in the lower latitudes of Planum Boreum. The youngest spiral troughs initiated above the upper unconformity, but some are older, indicating that conditions required for trough formation are not necessarily connected to net deposition or erosion.

Climate Modeling: Paleoclimate modeling can link changes in orbital parameters to atmospheric conditions and surface temperatures in order to predict the temporal and spatial patterns of ice accumulation.

One such model, (MAIC-2; [3]), estimates global surface-ice mass balance for the past 10 Myr. This model uses as input the periodic changes in insolation derived from predictions of Mars' orbital parameters [16].

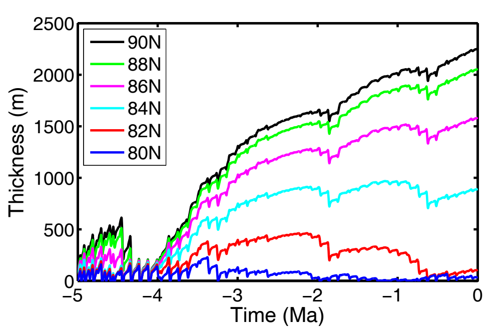


Figure 3. *Modeled growth of north polar ice after 4 Ma. Note presence of erosional events at ~3.2, 1.9 and 0.7 Ma, at obliquity peaks. Courtesy Ralf Greve.*

Due to mean obliquities higher than ~35° prior to ~5 Ma, large polar ice deposits do not accumulate prior to ~4 Ma in this model. The model was modified to include only the volume of NPLD as mapped using SHARAD data. Resulting ice sheet thicknesses for the past 5 Myr are shown in Fig. 3 for latitudes of 80°N and above. Significantly, the model predicts two or three large-scale erosional events that interrupt relatively continuous accumulation in the past 4 Ma (Fig. 3), largely consistent with the accumulation and erosional events observed in the radar stratigraphy.

Mesoscale Modeling: Paleosurfaces mapped with radar enable new studies using atmospheric modeling. The mesoscale atmospheric model of the Laboratoire de Météorologie Dynamique (LMD) [22] has been employed to evaluate feedbacks between topography, deposition and winds (Fig. 2). This uses paleotopography mapped by SHARAD as an input, and helped determine that Abalos Mensa, an isolated mound bounded by channel-like features, was a depositional construct that grew contemporaneous with the NPLD [23]. This also may help explain the persistence of Chasma Boreale throughout NPLD accumulation.

Conclusions: The internal radar stratigraphy of Planum Boreum contains a rich record of deposition, erosion, aeolian processes and compositional variations. Significant challenges remain to fully link the observations to climate modeling, but the observed radar stratigraphy is consistent with a simple model predicting northern polar ice growth since 4 Ma.

The dynamics of dust entrainment, transport, and deposition are important areas of future work to further refine the correlation between modeled ice deposition and observed layer stratigraphy at the outcrop level [24]. Accumulation patterns and layer dielectric properties observed with radar can provide further constraints for such modeling.

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