STRATIGRAPHY OF NORTH POLAR DEPOSITS ON MARS: MAJOR NEW FINDINGS.

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Introduction: We have begun detailed photogeologic analyses of parts of the north polar region on Mars that expose key geologic elements and relationships. Our goal is to better understand the interplay of local stratigraphy, H_2O ice and CO_2 frost, climate, and insolation and eolian processes in the development and modification of north polar stratigraphy and geomorphology. At present, extensive data sets for the north polar region include a MOLA DEM at 115 m/pixel resolution and thousands of THEMIS VIS and IR, HRSC, and MOC wide- and narrow-angle images acquired at various times. TES and THEMIS data provide useful albedo and thermophysical information.

The Rupes Tenuis unit: Much of the basal part of Planum Boreum within and west of Chasma Boreale consists of neary horizontally bedded strata of possibly Early Amazonian age [1] exposed on the floor of Chasma Boreale and along and above parts of Rupes Tenuis [1]. This prominent scarp runs from the southwest margin of Chasma Boreale westward to ~240º E. and rises hundreds to ~1000 m above Vastitas Borealis and ~600 m above the floor of Chasma Boreale. We name the basal strata of Planum Boreum the Rupes Tenuis (RT) unit.

Along Rupes Tenuis, the RT unit forms most of the thickness of Planum Boreum but is partly buried by younger layered deposits and mantle material that obscures its morphology (THEMIS V05209008). RT is crowned at 287ºE. by two massive layers having a combined thickness of ~100 m and whose eroded margins include circular to elongate knobs mostly <1 km across. The massive layers appear to dip gently westward. Below these, about 20 layers (and/or layer sequences) totaling <850 m can be discriminated in better exposures, but they generally cannot be traced continously for more than several kilometers. These beds appear to have somewhat uneven thicknesses. Locally, scarps cut across the beds and may result from faulting. The unit thins westward and cannot be traced with certainty west of ~242ºE.

For the Chasma Boreale floor platform, the RT unit is reduced to ~10 layers totalling 200 to 350 m in thickness [2]. MOC images (e.g., R2300500 and S0100879) indicate minor faulting, tilting, and fracturing and local burial by thin layered material.

None of these better exposures of the RT unit display dunes emanating from them and thus the unit does not make up part of the dark platy deposit described as forming the base of the Olympia Undae unit below. Rather, the RT unit may result from erosion and redeposition of materials generated by mud volcanism from the Scandia Tholi, Cavi, and Colles region, covering ~1.5 x 10^6 km^2 of surrounding plains and averaging ~100 m in thickness [2]. This reworking may have involved the adherence of fine-grained particles to polar surface ice. Rapid erosion of the RT unit ensued, perhaps resulting in much of the present form of the deposits. Subsequent stabilization of these deposits permitted the accumulation of the presently observed Early Amazonian crater population.

Amazonian craterforms—Implications for paleomantles: Based primarily on MOLA data, >1800 craterforms have been identified in the northern plains characterized by elevated interior floors and high-standing, horizontal to gently sloping, modified ejecta blankets [1, 3]. The observed craterforms may be indicative of impact-armored mantle material, which was subsequently removed where unarmored, leaving a perched (pedestal) crater. The distribution of these craterforms throughout the northern plains suggests that mantles were often present and in flux following formation of the Vastitas Borealis units [1]. Pedestal craterforms are also evident on the RT unit where exposed on Planum Boreum, including within Chasma Boreale, indicating that thick, Planum Boreum-centered layered deposits like the PB1 unit described below have been absent during much of the Amazonian [2]. Here, we refer to these inferred lowland mantles as the Vastitas Borealis paleomantle (VBP) unit.

The Olympia Undae unit: The dark north polar ergs of Olympia, Abalos, and Hyperboreae Undae mapped as the Olympia Undae (OU) unit [1] consist of dunes tens to hundreds of meters wide of varied form and areal coverage. The dunes are generally superposed on a moderately dark surface marked locally by fine ripples (>15 m in wavelength; e.g., MOC R0100086), which are oriented perpendicular to the wind direction indicated by barchan dune orientations. Locally, the dark surface includes broader undulations ~100 to 300 m in wavelength. The dunes emerge from beneath layered sequences mapped as Planum Boreum unit 1 (PB1) [1] where an uneven dark layer is locally detected (e.g., MOC E0201976). The dark layer may be buried dune material. The dunes are also partly buried by thin, bright deposits, mapped as the PB2 unit, as well as by young mantle deposits. The interdune ripples may be similar in age to the dunes, postdating the dark undulating material in places (e.g., MOC S0100668). In scalloped depressions along the margin of Planum Boreum, the dark material underlying the dunes and PB1 unit has a layered, platy appearance [4] and is locally buried by patches of possibly PB2 unit (e.g., MOC R0100728). Thus the OU unit consists of (1) a moderately dark, platy, locally basal member, (2) a very dark, uneven, probably sandy member locally made up of dunes discontinuously overlying the platy member, and (3) dark dunes and less-dark ripples that discontinuously overlie the eroded surface of the platy unit. The platy and dark members formed after the RT and VBP units and prior to PB1 unit. The dark dunes may include both exhumed dunes of the dark member [5] and younger dunes resulting from erosion of the platy and dark members prior to deposition of PB2 and mid-latitude mantle (MLM) [6] units. The interdune ripples may be made up of a non-saltating sand component. A 19-km-diameter crater at 81.7ºN, 190.1ºE within Olympia Undae likely formed in the midst of the platy unit sequence; the ejecta rests on the Olympia lobe and the crater contains some dark platy layers and dunes.

Formerly, Olympia Undae was interpreted to be underlain by PB1-equivalent layered deposits due to its domical regional shape [7]. However, we see only evidence for the opposite relationship (e.g., MOC E0201976). Overall, it may be that each platy layer, where not cross-bedded, represents an epoch of sand-sea migration and accumulation. These deposits then became subdued and modestly indurated during quiescent periods that may have included accumulation of icy layered deposits, which are locally observed in eroded scarps as bright interlayers (e.g., MOC E0201209). The dark upper layer may be the youngest of the sand-sea layers, but for some reason did not become indurated. The upper dune and ripple member is in close spatial association with the platy and dark members, indicating that the dunes have not migrated significantly since erosion of the PB1 unit and the platy and dune members. Also, dunes generally appear not to have migrated since emplacement of the PB2 unit.

Planum Boreum 1 unit. The lower part of this unit locally appears to be dark and may represent lag deposits, whereas upper parts appear to include cyclic albedo sequences [8]. We observe that the lower dark zone begins with darker, thicker beds at the base. We suggest that this may be due to inclusion of higher proportions of wind-blown fines derived from erosion of paleomantles (VDP unit) and materials of the OU unit. Ground-penetrating MARSIS radar echoes across accumulating ice layers of Planum Boreum east of Chasma Boreale suggest low-loss material such as a pure, cold ice [9]. This part of the PB units is farthest from exposures of the OU unit and thus likely freer from reworked OU material. Lower parts of PB1 unit include numerous unconformities, which may result in part from early episodes of trough insolation-controlled deepening perhaps associated with eolian removal and transfer of dark fines disaggregated from dark layers within the unit [10, 11].

Planum Boreum 2 unit: This unit consists of several alternating dark and bright layers and rests unconformably over PB1 and OU units and is potentially stratigraphically equivalent to the mid-latitude mantle (MLM). In troughs of Planum Boreum, it displays a basal dark layer that may be preferentially eroded from the troughs [10]. The surface of the PB2 unit appears rough in MOC images, and locally displays ripples similar in appearance to those associated with the OU unit (e.g., MOC M0000063).

Summary: Our north polar stratigraphic results are preliminary, and we likely will find additional stratigraphic units and relations with further study. However, some key findings are emerging, including: (1) much of Planum Boreum is long-lived, consisting of the evenly layered, moderately deformed and cratered, and heavily eroded Rupes Tenuis unit; (2) the circum-polar dunes are derived from platy and dark materials that underlie layered deposits and appear to form sequences (a) underlying Olympia Undae, (b) surrounding parts of Planum Boreum south of Rupes Tenuis and north Olympia Undae, and (c) covering parts of the RT unit on the floor and walls of Chasma Boreale; (3) the Planum Boreum 2 and MLM units may be stratigraphically equivalent; (4) circum-polar dunes generally underlie the PB2 and MLM units and thus appear to be largely inactive; (5) dark veneers appear to be made up of fines eroded from the OU unit and dark layers within the PB units; (6) many PB1 unconformities may be due to episodes of trough lengthening; and (7) Chasma Boreale may largely be the result of katabatic winds along its northwestern marginal scarp, which formed long before the OU and PB units were emplaced above it.

References: [1] Tanaka K.L. et al. (2005) *USGS Map I-2888.* [2] Tanaka K.L. (2005) *Nature 437,* 991. [3] Skinner J.A., Jr., et al. (this volume). [4] Byrne S. and Murray B.C. (2002) *JGR 107,* 5044. [5] Mullins K.F. et al. (this volume). [6] Mustard J.F. et al. (2001) *Nature 412,* 411. [7] Fishbaugh K.E. and Head J.W. III (2000) *JGR 105,* 22,455. [8] Milkovich S.M. and Head J.W. (2005) *JGR 110,* doi:10.1029/2004JE002349. [9] Picardi G. et al. (2005) *Science.* [10] Rodriguez J.A.P. et al. (this volume). [11] Fortezzo C. and Tanaka K.L. (this volume).