CHARACTERISTICS OF THE MARS NORTH POLAR BASAL UNIT AND ITS ROLE IN THE GEOLOGIC HISTORY OF THE REGION

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Introduction: Beneath much of the northern polar layered deposits lies a dark, platy unit noted by a few authors [1,2] and described in detail by *Byrne and Murray* [3]. We have continued the investigation of this unit [4,5] by examining MOC images and MOLA data (looking forward to the release of spring/summer THEMIS data) of the polar cap and of the features interpreted by *Fishbaugh and Head* [6, 7] as polar material remnants and glacial retreat features. While *Kolb and Tanaka* describe this unit as consisting of early north polar deposits, *Byrne and Murray* suggest that such a significant change in deposition style has taken place that the unit must represent a period in time when there was no polar cap. They believe that the basal unit (as it will hereafter be named in this abstract) consists of ice-rich paleoerg deposits that migrated to the low elevation plains underlying the current polar deposits. In addition to these possibilities, we suggest that the unit may have initially been deposited by outflow channels and/or a paleo-ocean.

Fishbaugh and Head [6-8] have shown that the north polar deposits may once have been larger, extending to about 75°N. Still unknown are the timing and cause of this retreat as well as how many times advance and retreat have occurred. The basal unit has yet to be placed conclusively in this history. However, the stratigraphic position of the basal unit below the polar cap places it in the transitional period between the Late Hesperian Vastitas Borealis Formation (VBF) and the polar cap (whose surface has a Late Amazonian crater age) [9]. The distribution of the unit (being associated exclusively with the cap and the Olympia Lobe) suggests that it may now comprise a basal ice portion of the ice cap (such as the distinctive lower deposits common in terrestrial ice sheets) [10-15].

Observations: *Characteristics.* The main features of this unit have been initially described by *Byrne and Murray* [3]. The contact between the polar layered deposits (PLD) and the basal unit is quite sharp, exhibiting a stark contrast in albedo (Fig. 1). Commonly, the contact is associated with a break in slope, and in some places is manifested as a protruding step. The basal unit also has a platy appearance. Further investigation of this unit for this study reveals that the unit is internally layered in many places, and the layers are distributed laterally throughout the unit. Layering in the basal unit is more irregular than in the PLD but can be on as fine a scale as the PLD (Fig. 1). There also appear to be lenses of material in the basal layers and pinching-out of many of the layers. In one outcrop examined in detail (Fig. 1), there are alternating thin, bright layers and thicker (35-40 m), darker layers with evidence of exhumed eolian erosion (yardangs) in the lower basal layers. In some places, thin, very dark layers exist within the PLD just above the basal unit which may be dune material sources. The PLD unconformably overlie the basal unit, and there is at least one location where the contact comprises an angular unconformity.

Contrasts in compositional and mechanical properties between the PLD and the basal unit have resulted in differential erosion between the two units. Erosion of the basal unit is typically characterized by pitting, residual mesas, ridges, grooves, and depressions exposing deeper layers (Fig. 2). Yardangs are visible in a few images of eroding layers. Individual layers within the basal unit also erode at different rates. Evidence of mass wasting, in the form of relatively bright streaks and masses of dark material lying at the base of the basal unit, is apparent but not common. The best exposures of differential erosion and mass wasting lie within trough walls near and extending into the Olympia Lobe (OL).

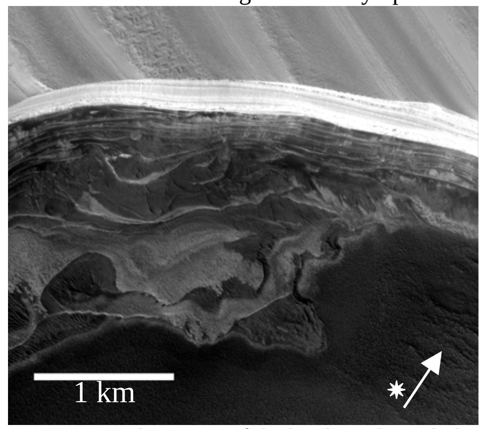

Fig. 1. Example outcrop of the basal unit beneath the PLD. Notice the sharp contact with the PLD, complex layering, and evidence of eolian erosion in the lower layers. The steeper parts of the basal unit in this image have a slope of about 40° and a thickness of about 300m. Portion of MOC image E02/01209, centered at 237.80°W, 83.85°N.

We have also found small-scale (100 m width) waviness lying primarily within trough walls all along the OL-cap boundary, rather than clumping in any particular locations. Further investigation should reveal whether these are deformational folds or an erosional effect. Even if they are folds, the possible evidence of deformation is rare and therefore minor.

Small, (≤ about 200 m diameter) circular pits have been found in a few MOC images of the basal unit. Since craters are rare in association with the polar cap and since the pits lie within the small exposed surface area of the basal unit, it is unlikely that they are impact craters. Stratigraphic relationships date the basal unit as being older than the PLD but younger than the VBF. Since so little of the unit has been exposed, it is unknown how many craters may yet be buried.

Dunes are closely associated with the basal unit, leading *Byrne and Murray* [3] to conclude that it is an icy sand-rich deposit and is the source for the large circumpolar ergs [16]. Where no dunes are present, there exists a dark mantle of material which has presumably eroded from the basal unit (Fig. 1). While a few lie within troughs, the locations where dunes are close enough to the basal unit to lie within a MOC image length of it cluster around arcuate scarps near the OL/cap boundary and around 180°W a place where scarps are nearest to the existing dune field. This provides circumstancial evidence that the dunes covering the OL are eroding from the basal unit. Further investigation should reveal the detailed relationships between OL dunes possibly eroding from the basal unit and other dunes stratigraphically overlying the VBF [17].

Occurrence. The basal unit crops out in troughs near and extending into the Olympia Lobe (elevations ranging from -4400 m to -4200m) and within the walls of Chasma Boreale [3] (Fig. 3). *Byrne and Murray* suggest that the OL is an exposure of the basal unit. Some images within relatively-dune free portions of the OL exhibit characteristics reminiscent of the basal unit, but identification of the basal unit using the described characteristics is more difficult here than where it is exposed in cross-section (e.g. in trough walls). Since the basal unit appears to have a mostly gradational contact with the OL deposits and is commonly associated with dunes, it is plausible that the OL consists partly or wholly of the basal unit.

The unit likely pinches out near Chasma Boreale. Preliminary analysis of images in this region show exposure of the unit within the western wall but not the eastern. Does the lobe extending from the mouth of Chasma Boreale and the cratered mesa ~140 km beyond partially or wholly consist of basal unit material? We find this to be unlikely since the erosional mechanism which carved the Chasma [18] would likely have preferentially eroded the basal unit in this area rather than preserve it. In addition, the mesa is about 1 km high, much thicker than the basal unit. It is possible that the cratered mesa is instead a remnant of polar material (like those seen just south of the OL [6,8]) that has been protected from sublimation by impact ejecta.

Thus far, we have found evidence for the existence of the basal unit beneath the current polar deposits and possibly in the form of the OL. Examination of MOC images of the polar material remnants south of the OL [6,8] has revealed no evidence for the unit. While there are isolated patches of dunes outside of the OL dunes, they may have migrated away form the OL over time or may consist of VBF or mantle material [17]. If the basal layer did exist elsewhere, it has since been significantly eroded.

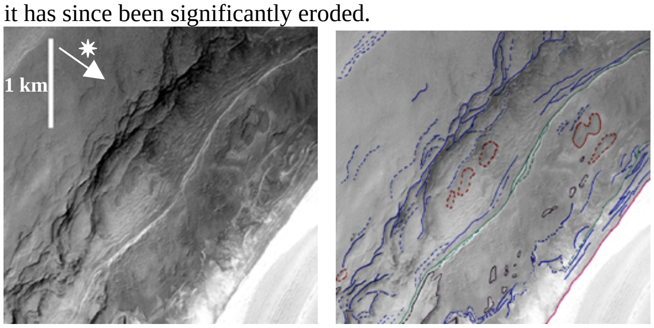

Fig 2. Example of differential erosion within the basal unit. The PLD are in the lower right corner. Portion of MOC image E03/00270, centered at 208.26°W, 85.03°N. Sketch map outlines PLD/basal unit contact (red), basal unit layers (blue), major breaks in slope (green), mesas (black), and pits (orange).

Discussion and Conclusions: The basal unit has had a complex depositional history. Our analyses have outlined the following characteristics of the basal unit internal layers which must be explained by any theory of origin: 1) various manifestations of differential erosion, 2) differing amounts of eolian reworking, 3) pinching-out, 4) alternating relatively high/low albedos, and 5) possible small-scale deformation in very few places. The basal unit/PLD contact is also complex, exhibiting unconformities and possibly being the source of the north polar dunes. Although its lower contact is not readily identifiable, this unit may represent the transition between deposition of the Vastitas Borealis Formation and the polar cap deposits and therefore provides important clues to the history of the north polar region.

If the unit is the main source of dune material and is composed partially of sand (and a cementing agent, possibly water ice), then it is unlikely that it was originally deposited by atmospheric means. The atmosphere is not dense enough to transport sand-sized particles other than by saltation [19]. This would decrease the probability that the unit is a paleo-polar cap deposit [1]. A paleo-erg origin for the unit requires a means of sand transport, either by dune migration or by outflow channel/oceanic sedimentation [3]. We have found no conclusive evidence thus far (such as eolian cross-bedding) for the unit having originally been a dune sea. The complex layering within the unit suggests changes in depositional style throughout its history.

Regardless of the origin of the material within the basal unit, it may currently behave as basal ice as seen in terrestrial ice sheets [10-15] and therefore may need to be taken into account when examining the rheology of the polar cap. On Earth, some glaciers and ice sheets have one or more layers of basal ice which can range in thickness from a few millimeters to tens of meters. Basal ice can have up to greater than 50% sediment by volume and has structural, chemical, and isotopic characteristics distinct from the overlying purer ice layers [10]. The contact between the basal ice and overlying ice is often quite distinct.

Basal ice can form by one or more of the following means [10,11]: 1) Regelation or congelation, 2) net adfreezing, 3) entrainment of pre-existing ice, or 4) mixing and crevassing. The various means of creating basal ice require some amount of meltwater. Meltwater could have come from the formation of Chasma Boreale [18]. The fact that the unit pinches out in the vicinity of Chasma Boreale suggests that it may have influenced chasma formation and that it may have even served as a reservoir for the meltwater [3], later freezing and creating basal ice. The creation of the basal unit as basal ice also would probably require longer time scales than the creation of terrestrial basal ice which at its thickest is an order of magnitude thinner than the martian basal unit.

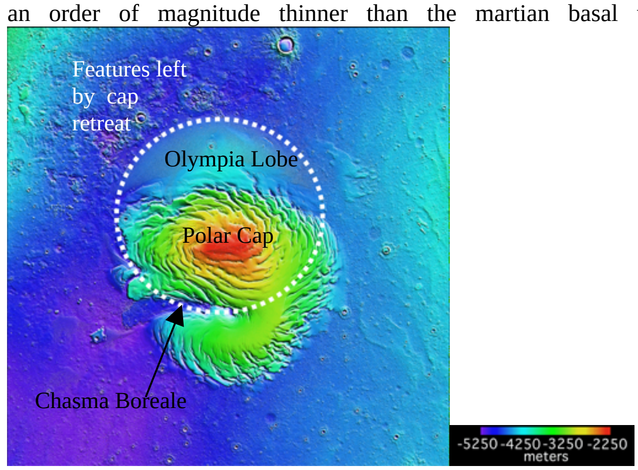

Fig 3. MOLA shaded relief map of north polar region (72°-90°N). Dotted line shows approximate extent of basal unit. 1°lat 60km.

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