CHARACTERISTICS AND DISTRIBUTION OF THE MARS NORTH POLAR BASAL UNIT Kathryn E. Fishbaugh[1] and James W. Head III[1], [1]Brown University, Dept. Geol. Sci., Box 1846, Providence, RI 02912, kathryn_fishbaugh@brown.edu, james_head_III@brown.edu

Introduction: Beneath much of the northern polar layered deposits lies a dark, platy unit (Fig. 1) noted by a few authors [1,2] and described in detail by *Byrne and Murray* [3] and *Edgett et al.* [4]. We have continued the investigation of this unit [5-7] 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* [8-10] as polar material remnants and glacial retreat features. Here we discuss the broad characteristics, two example outcrops, and the distribution of the BU. In another abstract in this volume, we examine possible origins and modifications of the BU.

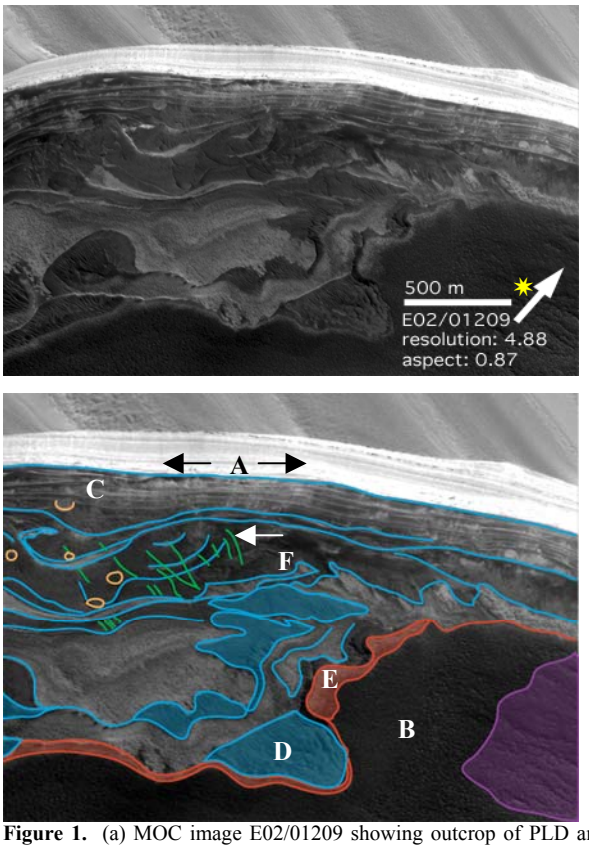

Figure 1. (a) MOC image E02/01209 showing outcrop of PLD and eroding layers of BU. (b) Sketch map of MOC image. Purple region shows ridges within dark mantle. Red outlines bright halo at base of BU, blue outlines major layers, with the shaded areas showing evidence of eolian erosion. Green outlines small, erosional ridges, and orange outlines pits whose impact origin is uncertain. Letters are explained in the text. Location of image is marked in Fig. 4.

Broad Characteristics: The main features of this unit have been described by *Byrne and Murray* [3] and *Edgett et al.* [4]. There is a stark contrast in albedo between the PLD and the BU (Fig. 1). Sometimes, the BU/PLD contact is associated with a break in slope and in some places is manifested as a protruding step. The BU also has a platy appearance. Further investigation of the unit for this study using MOC images and MOLA profiles reveals that the unit is internally layered in many places. Layering in the BU is more irregular than but can be as fine scale as the PLD. Nearly all basal layers pinch-out within the width of one MOC image.

The contrast in properties between the PLD and the BU has resulted in differential erosion. Erosion of the BU is typically characterized by pitting, residual mesas, ridges, and anomalous grooves. Yardangs are visible in a few images of eroding layers. Individual layers within the BU also erode at different rates. Evidence of mass wasting is apparent but not common. Small pits (diameter = <300 m) can be found in a few MOC images of the BU where erosion has exposed the surface of some layers; an impact origin for these features is uncertain. Since so little of the unit has been exposed, it is unknown how many impact craters may yet be buried.

The BU/PLD contact warrants further detailed discussion. In places (e.g., *A* in Fig. 1), the contact appears distinct and sharp. However, closer examination reveals more complexity. While *Edgett et al.* [4] note that the "waviness" of the contact in some locations (e.g., *A* in Fig. 2) is a post-formation erosional effect, there are few if no locations where a single BU layer can be traced along the entire contact, thus erosion must have occurred between formation of the basal unit and formation of the PLD. Direct evidence of some erosion during this time is apparent in MOC image E02/01056 wherein pitting within the upper layers of the basal unit is exposed and has resulted in undulations in the lower layers of the overlying PLD.

Erosion of the BU and abrupt subsequent deposition of the PLD may not necessarily characterize the entire BU/PLD contact. Instead, the transition may have been more gradual. In several images there exist dark layers within the lower PLD (*Edgett et al.* [4] noted dark lenses in one MOC image). These layers (*A* in Fig. 3) are as dark as the dunes in the north polar erg (*B* in Fig. 3). Either the dark material of the BU was gradually being deposited in smaller quantities along with the newly forming PLD until it finally ceased to be deposited, or, as discussed below, erosion of the BU freed material which was transported by wind and included into the lower PLD.

Dunes are closely associated with the BU, leading some [3,4] to conclude that it is an icy, sand-rich deposit and is the source for the large circumpolar ergs [11]. According to our observations, dunes are visible in many but not all MOC images of the unit. *Thomas and Weitz* [12] have proposed that the north polar erg source

was the PLD. With these new observations of the BU, it seems likely that the BU is actually providing a large portion of the sand-sized particles. Where no dunes are present, there sometimes exists a dark mantle of material which has presumably eroded from the BU (e.g., *B* in Fig. 1 & *E* in Fig. 2). However, dunes may also be eroding from PLD layers just above the BU/PLD contact. Figure 3 shows dark lenses of material (*A*) within the PLD which have albedos similar to that of the dunes (*B*). Dark lenses are not visible in every image which contains both the BU and dunes, and not all images with dark lenses have dunes (although the dunes may have migrated away); thus, the dark lenses cannot be the sole source of dune material. Instead, we suggest that material may have eroded from the BU and migrated as dunes onto the young, still-forming PLD, leaving dark material within the lower layers of the PLD; this may currently be happening in Chasma Boreale (e.g., MOC image E03/01735) and is also hypothesized to have occurred in Antarctica [13].

Example Outcrops: *Olympia Planitia.* We have created detailed sketch maps of BU outcrops in MOC images. As illustrated by Fig. 1, the layering within the unit is complex, with no single layer extending across the entire image (a distance of about 3.3 km). The outcrop exhibits 3 main sequences. At the bottom of the image, lying stratigraphically at the base, is a rough textured, dark mantle (*B*). This texture could be a result of the presence of hummocks, boulders, or small dunes. Above this lie alternating bands of bright and dark material, and above this are the brighter PLD.

Within the alternating light and dark bands of the BU is a section (*C*) just below the PLD with steeper slopes (about 40°) than the more exposed basal layers below it. There are about eight dark layers in this 300 m thick section; therefore, each dark layer is about 35 - 40 m thick. As explained below, the lighter layers are much thinner than the darker. Within this section, no particular layers extend across the entire image. The PLD unconformably overlie the BU as illustrated by the fact that the top BU layers do not extend uniformly across the image but are instead eroded in some places.

The lowest BU layer is characterized by a relatively low albedo and by lineations likely of eolian origin which may either be yardangs or longitudinal dunes (*D*). Darker layers stratigraphically above and the dark mantle below this show no such evidence of eolian reworking. It is thus assumed that the eolian features are not currently forming but have been exhumed by erosion of overlying layers. While ridges of unknown origin (*F*) appear in a few of the upper dark layers, they are for the most part featureless.

Between the dark mantle (*B*) and the lowest BU layer, there exists a narrow, bright halo of material (*E*). Either this represents 1) a very thin layer or 2) material which has mass wasted from above and collected here. Since the texture of the darker layers shows through in the lighter layers, it can be assumed that the darker layers are thicker. This same relationship is apparent throughout the BU in this outcrop. The bright halo may consist of material eroded from the brighter layers. Note its diffuse, irregular nature. Bright streaks cross-cut many of the layers just below the PLD, and there is little to no evidence of mass wasting of the darker material. Therefore, the brighter material is interpreted to be thinner and more mobile than the darker.

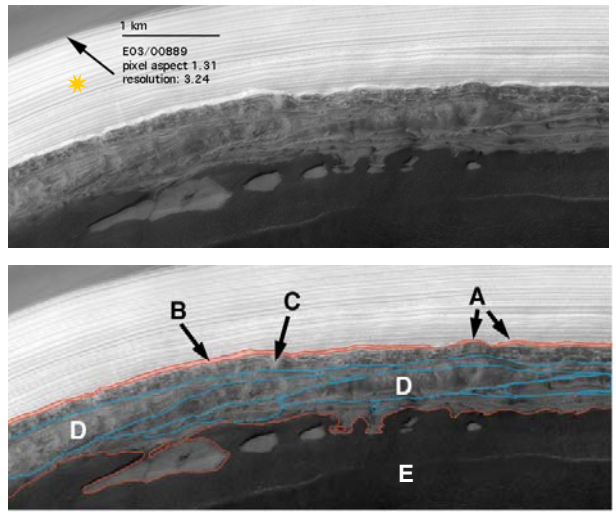

Figure 2. MOC image E03/00889 showing outcrop of PLD and the darker BU below them with dark mantle at the base. Sketch map outlines boundaries of exposed BU in red and major layers in blue. The red shaded area shows the transition zone between the BU and PLD at the contact. What look to be large lenses of material or massive beds in the BU (*D*) are actually just thinner layers exposed on a shallow slope. Letters are explained in the text. Location of image is marked in Fig. 4.

Chasma Boreale. The best exposures of the basal unit in Chasma Boreale (e.g. Fig. 2) lie within the two arcuate scarps at the chasma head region (Fig. 4). Alternating light and dark layers are evident in this region, as in Olympia Planitia. There exists a transitional zone in the PLD just above the contact (*B* in Fig. 2) which may consist of talus [4]; indeed light streaks of material emanate from this transitional zone (*C*). To allow talus to accumulate, there must be a small break in slope at the contact, too small to be discernable in MOLA profile data. Assuming that the talus was eroded from the PLD, the question then becomes, "Of what is this talus composed?" If it is dust, then why is it much lighter even than the darker PLD layers (which presumably contain dust [14]) in full sunlight on the left of the image? Instead, this transitional zone may be the uppermost layer of the BU with light streaks emanating from it as observed in the lighter layers of the BU in Olympia Planitia (Fig. 1).

Near the center of the BU in this outcrop are what appear to be massive beds or large lenses of material

(*D*), leading *Edgett et al.* [15] to conclude that the BU may consist of several different units. However, MOLA data reveal this to be a slope effect. The lenses are just layers exposed at shallower slopes than the other layers, again indicating differential erosion within the BU.

While no dunes appear in this image, the dark mantle at the base of the BU slope (*E*) may have eroded from the BU and not yet been worked into dunes.

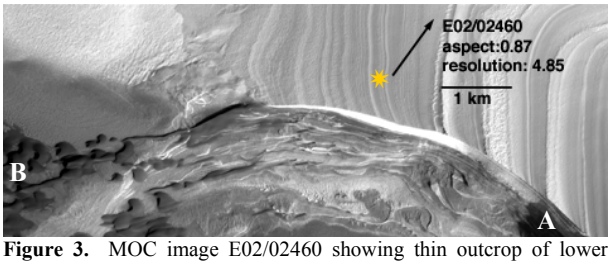

Figure 3. MOC image E02/02460 showing thin outcrop of lower PLD layers with the darker BU below. This image partially overlaps that of Fig. 1. Notice dark layers in PLD in lower right corner (*A*) and the dark dunes in the lower left corner (*B*) which may eroded from these dark layers. Location of image is marked in Fig. 4.

Distribution: The BU crops out in troughs near and extending into Olympia Planitia (elevation of BU/PLD contact at about –4330 ± 110 m) and within the walls of Chasma Boreale (elevation at about –4520 ± 80 m) [3,4] (Fig. 4). *Byrne and Murray* [3] suggest that Olympia Planitia is an exposure of the BU on the 180°W side. While few MOC images of the cap in the longitude range 270-70°W were available at the time of their study, further analysis of newer MOC images shows that the BU does not appear in the troughs within this region. Thus, the layer pinches-out beneath the cap somewhere between Chasma Boreale and the cap margin or has been eroded back to this location (Fig. 4b). Another possibility is that the BU exists only at the edges of the polar deposits in the locations observed and not beneath the center.

We have continued the investigation into the occurrence of this unit by examining the currently available MOC images of the features interpreted as polar material remnants and glacial retreat features [8-10]. While there are associated patches of dunes, there is no obvious exposure of the BU within these features. The possible polar remnant near 230°W is another story. Some images (e.g., MOC image M18/00121) show evidence of dark, eroding material which is possibly the BU. Without images of the contact with PLD, this cannot be uniquely determined.

Examination of images of the polar remnant near the small chasmata to the west of Chasma Boreale and of the mesa near the mouth of Chasma Boreale leads again to inconclusive determination of the existence of the BU. Dune fields lie near these features, but there is no immediately apparent PLD/BU contact, and the mesa and remnant scarps are frost-covered in most images.

Kolb and Tanaka [1] have suggested that the lobe extending from the mouth of Chasma Boreale is a remnant of this BU, and *Edgett et al.* [4] claim that the chasma floor consist of the BU. Unfortunately, there are no images of the lobe scarp which would allow a cross-sectional view. Our preliminary interpretation of these lobate deposits is that they represent a combination of lower BU layers exhumed by outflow [16] and by katabatic winds [17] and deposition of material from the outflow.

If one cannot assume that the presence of dunes necessarily indicates the presence of the BU, it must be concluded that the BU does not exist anywhere except beneath the main polar cap (and in the form of Olympia Planitia). Otherwise, if it did exist elsewhere, it has since been significantly eroded and is the source for isolated patches of dunes.

Summary: 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) almost no evidence of deformation. The BU/PLD contact is also complex, exhibiting unconformities and possibly being a 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 (see *Fishbaugh and Head*, abstract in this volume).

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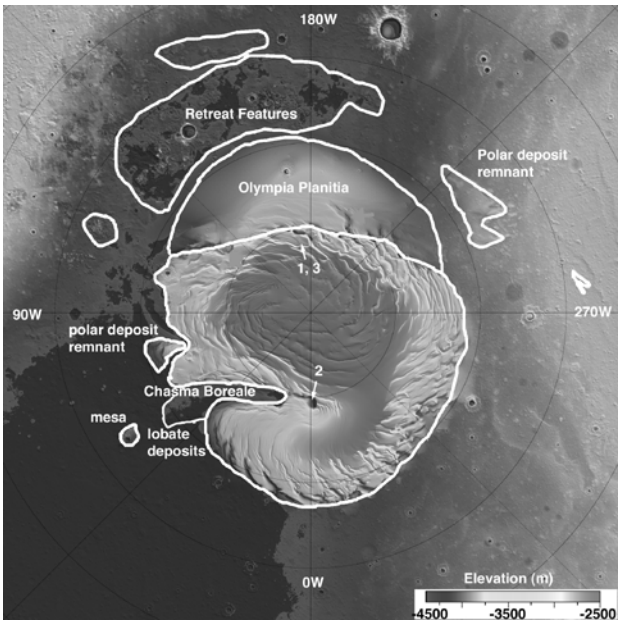

Figure 4a. MOLA shaded relief map of north polar region outlining major features discussed in text. Numbers indicate position of MOC images shown in Figs. 1, 2, & 3.

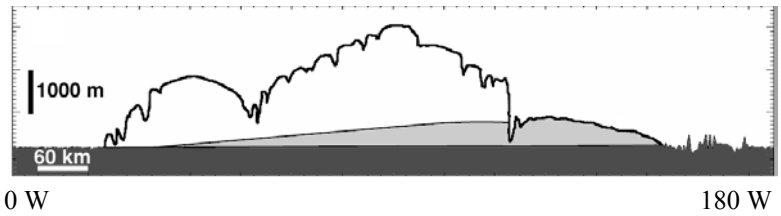

Figure 4b. Approximate profile of the basal unit (shaded grey) beneath the current polar layered deposits. From *Byrne and Murray* [3] (Fig. 11).