STRATIGRAPHY AND LANDSCAPE EVOLUTION OF CHASMA BOREALE, MARS. K. L. Tanaka[1] and M. C. Bourke[2], [1]Astrogeology Team, U.S. Geological Survey, Flagstaff, AZ 86001, ktanaka@usgs.gov, [2]Planetary Science Institute, Tucson, AZ.

Introduction: Chasma Boreale forms a broad, arcuate valley cut into Planum Boreum, the north polar plateau of Mars. Proposed origins for this feature include: (1) erosion by subglacial floods (jökulhlaups), perhaps induced by pressure melting or magmatism [e.g., 1-2], and (2) eolian erosion, including topographic control [e.g., 3-4]. Each of these interpretations reflects on whether or not Planum Boreum has experienced glacial flow. New high-resolution image data acquired for parts of Chasma Boreale, including Mars Reconnaissance Orbiter HiRISE and CTX images as well as ongoing geologic mapping results, further elucidate the eolian history of this feature.

Topography: Planum Boreum forms a subcircular plateau ~1000 km across and upwards of 2500 m thick that is dissected by many spiral troughs 10s of km wide and 100s of km long. Chasma Boreale itself forms a huge trough oriented tangential to the north pole. However, its floor is made up of a low plateau, Hyperborea Lingula ~200 to 350 m above the adjacent plain of Vastitas Borealis. Two partly enclosed arcuate depressions, Boreum and Tenuis Cavi (easternmost), mark the head area of Chasma Boreale.

Stratigraphy: Recent mapping results [4-5] along with investigation of newer data sets (reported here) reflect greater complexity in the stratigraphy of Planum Boreum than previously recognized. The surrounding plain is covered by the Early Amazonian Vastitas Borealis interior unit (ABv$_i$), which may be earlier outflow discharges that were subsequently massively reworked, perhaps by periglacial-like processes [6]. Thickly-layered materials that make up Hyperborea Lingula, Rupes Tenuis, and the lower parts of the northern walls of Chasma Boreale are mapped as the Early Amazonian Rupes Tenuis unit (ABt), which may be the result of locally reworked unit ABv$_i$ materials. Unit ABt retains a significant density of superposed impact craters, many of which have what appear to be pedestal ejecta forms indicative of ejecta armoring a mantle. The mantle may be remnants of ephemeral deposits that perhaps were emplaced and removed repeatedly throughout much of the Amazonian [4].

Following what may have been a considerable hiatus, dark unconsolidated material interbedded with bright, fractured layers were deposited, perhaps only locally. We call this the Olympia Cavi unit (ABoc), which may be Late Amazonian given its paucity of craters. HiRISE images show cross-bedding in the layers, which are darker in color near the base of the unit. Finely layered materials of the Planum Boreum 1-3 units (ABb$_{1-3}$), also known as polar layered deposits (units 1 and 2) and residual ice (unit 3), bury all the aforementioned units. However, unit ABoc apparently was emplaced only locally, and its relatively bright layers may be comparable to bright basal layers of unit ABb$_1$ exposed elsewhere. HiRISE images (e.g., PSP_001334_2645) show that units ABb$_{1-2}$ and ABoc are intensely fractured in places.

Bright, finely layered deposits covering the floor of Tenuis Cavus are partly covered by dunes and appear to embay the Olympia Cavi unit and to underlie unit ABb$_2$ (see CTX-8B). We have tentatively named these deposits the Chasma Boreale unit (ABcb). At present, the age of this unit relative to ABb$_1$ is uncertain and it either formed during or after deposition of unit ABb$_1$. This unit possibly includes layered deposits tens to a few hundred meters thick that extend from western Boreum Cavus southwestward across much of Chasma Boreale's floor.

Surficial materials: Dark dune fields occur in the cavi and as an elongated sand sea (Hyperboreae Undae) within Chasma Boreale. The dunes appear to source from the dark unconsolidated parts of the Olympia Cavi unit exposed in the steep, eastern scarps of Boreum and Tenuis Cavi. The surface of the dunes displays transverse ripples in HiRISE images; the profiles of these small ripples appear either symmetric or steeper on the sides facing the primary down-wind direction. Orientations are consistent with local dune-induced wind deflection. The dunes are bordered by sand sheet deposits that are rippled and have small barchans in the leeward cusps of the large barchans. The orientation of the smaller dunes indicates reversed wind transport in this location. In some places, these sand sheet deposits infill polygonal cracks. Large linear dunes have both rippled flanks and apparent active grain flow on flanks. These dune and ripple arrangements suggest multi-directional winds.

The dunes are mostly underlain by a rippled layer that may be a sand sheet; the ripples are inferred to be aligned perpendicular to the primary wind direction (down-chasma). Locally, MOC images show hollows in the sheet that appear to be former locations of dunes [7]. The ripples appear to be indurated. Similar ripples occur on the eastern scarp of Boreum Cavus; these are locally buried by blocky slide deposits shed from unit ABb$_1$. These indurated ripples have a degraded appearance in places, and do not show signs of reorientation in response to slide and dune features that override them. However, some dark, smooth ripples that occur on the cavi scarps have crests orientated in the downslope direction and appear related to cross-slope winds. They interact locally with boulders and thus may be active.

Brighter toned dunes, broad ridges, and apparent mantle material overlie part of the margins of Planum Boreum above the head scarp of Boreum Cavus. These may be unconsolidated dust and sand deposits eroded from the Planum Boreum units.

Dark veneers on Planum Boreum may be made up of dust eroded from older deposits, including a local dark layer at the base of unit ABb_2 [8]. Dark material also appears as a possible layer or lens in a pit along a graben wall within the residual ice (HiRISE PSP_001513_2650).

Erosional/degradational features: Surfaces of what may be the Rupes Tenuis unit (ABt) on the floor of Tenuis Cavus display subdued impact crater forms, including ejecta blankets. The surfaces are finely cracked (as seen in HiRISE) and may be highly modified and altered. On the margin of Hyperborea Lingula, unit ABt displays large polygonal troughs that include zones relatively resistant to erosion.

HiRISE and MOC images reveal fields of aligned troughs and grooves in surfaces of layers and unconsolidated dark deposits in the west-facing head scarps and plateaus above them of Boreum and Tenuis Cavi. They generally have smooth margins in the dark deposits and rugged margins in consolidated layers. They are oriented parallel to the primary, regional wind direction as indicated by dune forms; they also parallel broad troughs in Planum Boreum above the cavi head scarps. We interpret these features to be degraded yardangs. They do not follow the polygonal cracking orientations and thus may be relict features formed during accumulation of the unit.

Landscape evolution: Topography and stratigraphy appear to have exercised the greatest influence in the formation of Chasma Boreale, controlling erosional and depositional processes. During the Early Amazonian, emplacement of unit ABt formed a plateau that may have exceeded ~1300 m in thickness, perhaps extending south to ~65ºN. This unit may have been the result of reworking of Vastitas Borealis units by sedimentary diapirism and volcanism in the Scandia region, which may also be the origin of the Scandia unit that surrounds part of Planum Boreum [5-6].

As a result of erosion, the form of this early polar plateau became highly irregular, as represented largely by the present surface of unit ABt, much of which is buried beneath younger, finely layered units. Thus much of the early polar plateau's original outline and form are uncertain. Along the SW margin of Chasma Boreale, the relict surface of unit ABt consists of armored pedestals of impact craters, which suggests that unit ABt was easily eroded in earlier times. Also, some layers of unit ABt appear relatively thicker and more resistant. This indicates that such a layer may cap Hyperborea Lingula, which could account for the preservation of this plateau.

The crater pedestals appear to be important as topographic buttresses in the later accumulation and/or preservation of unit ABb_1 on the northwestern flank of Chasma Boreale. The southern flank of Chasma Boreale follows the exposed irregular but arcuate eastern margin of Hyperborea Lingula. The Hyperboreae Undae dune field extends from Boreum Cavus across the lingula, stepping across the exposed scarp connecting with and perhaps feeding extensive dune fields in the plain south of Chasma Boreale.

Unit ABoc appears to have been emplaced only locally around Planum Boreum, including in the eastern, southern, and northern rims of Boreum and Tenuis Cavi. It may be that these were areas where sand-rich material tended to collect between phases of bright layer accumulation produced by precipitation of ice and dust. The pre-existing northern scarp of Chasma Boreale likely served to channel katabatic winds across the chasma floor area, perhaps preventing significant accumulation of units ABb_{1-2}. Minor infilling of Chasma Boreale either coeval with unit ABb_1 or between units ABb_{1-2} produced the unit ABcb. This unit generally appears to be evenly layered, without cross-bedding and dark sandy layering as occurs in unit ABoc. Thus unit ABcb was emplaced during an episode in which dark sandy material was virtually absent in the cavi, perhaps as a consequence of low wind energy and/or coeval entrapment of dark sandy material in other locations.

Conclusions: Our observations of exposed stratigraphy and extant eolian landforms within Chasma Boreale indicate that the margins of an earlier plateau made up of the eroded Rupes Tenuis unit likely controlled winds patterns that prevented significant infilling of the chasma, while its flanks became overlain by finely layered deposits. This origin is similar to that proposed for Mars' south polar chasmata [9].

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