SUB-DIVIDING THE GEOLOGY OF VASTITAS BOREALIS, MARS: EVIDENCE FOR A VARIED RECORD OF AMAZONIAN DEPOSITION AND EROSION. J. A. Skinner, Jr. and K. L. Tanaka, Astrogeology Science Center, U. S. Geological Survey, 2255 North Gemini Drive, Flagstaff, AZ, 86001, jskinner@usgs.gov.

Introduction: The low-lying nature of the Martian northern plains and the contrasting character of the geologic materials that stand above and surround it strongly suggest that the region is a long-lived depocenter filled through time with rocks and sediment of diverse type, age, and provenance. However, despite its expanse and expected diversity, the observable surface of Vastitas Borealis (VB) is far more geomorphologically and stratigraphically similar than different. Different landforms have certainly been observed and different geologic histories proposed and evaluated (see summary of [1]). Yet, broadly consistent surface roughnesses, morphologic textures, and crater densities imply an elevated degree of evolutionary homogeneity. Geologic maps are testament; previous efforts to subdivide VB into discrete geologic units using Viking and post-Viking have foundered on its similarities. Consistently partitionable units and traceable contacts are rare, suggesting that primary (depositional) characteristics are largely absent [2]. Thus, we must focus on identifying the modifying geologic processes and their temporal and spatial interactions.

In conjunction with renewed characterizations of Mars' global stratigraphic framework [3], we are in the process of combining new observations of VB with the published topical investigations to help unravel its complex depositional and modificational history. Herein, we present evidence for existence of a previously unidentified geologic unit within VB and speculate about its formation, past extents, and role in the long-term evolution of VB.

Background: The Martian northern plains cover nearly one third of the planet and include multiple overlapping topographic basins likely formed through ancient impacts. Vastitas Borealis constitutes the expansive generally horizontal plains positioned between the highland-lowland boundary and the north polar plateau. The paucity of topographic features in VB coupled with its low elevation (<-3500 m) and thick overlying atmosphere complicated the early geologic characterization of VB. Viking Orbiter observations lead to the identification of the Vastitas Borealis Formation (VBF), a collection of four units delineated based on surface textures interpreted to be secondary features (grooved, knobby, mottled, and ridged) [4]. Observations made using post-Viking datasets prompted a re-evaluation of the VBF subdivision and lead to the re-gourping of VB materials into two units: an expansive "interior" unit and a narrow, discontinuous "marginal" unit [1]. Despite these efforts, differentiating between primary (depositional) and secondary (modificational) processes and their interactions remains a major complicating factor in subdividing the VB.

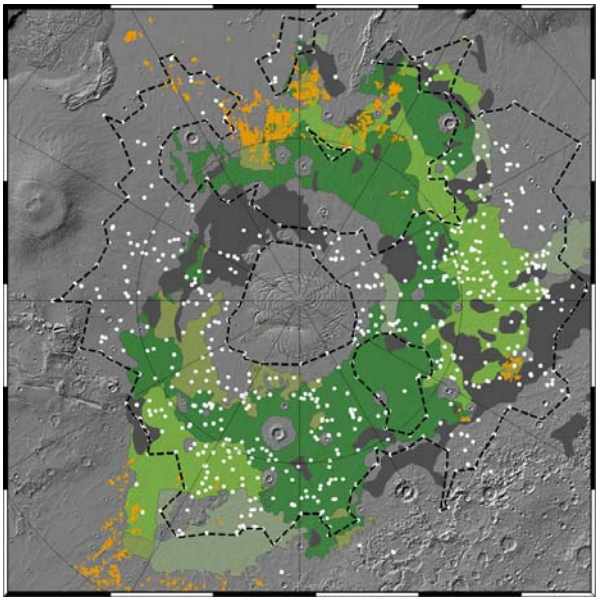

Figure 1. Polar stereographic view of the northern plains, centered on the pole. The dark outcrops represent the current mapped extent of unit Avu. White dots show the occurrence of topographically elevated crater forms. Orange lines are individual ridges within thumbprint terrain. Dashed lines represent the inferred previous extent of unit Avu.

Observations: We observe multiple lines of evidence that collectively point to the existence of unique outcrops of materials that superpose previously mapped Early Amazonian geologic units [1,4]. Our observations include consistent surface characteristics and conspicuous landform associations.

Surface character. The outcrops are delineated by their smoothness (relative to surrounding terrains), which is subtly apparent in MOLA DEM and derived slope maps as well as in THEMIS VIS images. Median high-pass filters of MOLA data show subtle lobes located at the margins of some of the outcrop surfaces, though many grade laterally into the distributed fields of knobs common the lowland plains. The albedo of the outcrops vary widely, though dark, linear windstreaks are common. We mapped 35 outcrops of this material between 29° and 80°N latitude. They occur along the highland-lowland boundary of NiloSyrtis

Mensae, north of Lyot crater, within the Scandia region, and circumferential to Utopia Planitia. Outcrops range from 180,000 to >$1x10^6$ km^2, covering $3.3x10^6$ km^2 total (**Fig. 1**). Spot measurements of the MOLA DEM spaced ~10 km along the periphery of each outcrop indicates the unit ranges from 0 to 224 m thick (mean of 32 m). In most areas, the unit appears to superpose the materials previously mapped as Vastitas Borealis materials [1,4].

Landform associations. Despite identification and delineation based on subtle morphologic and cross-cutting clues, we find that the outcrops are most notable in their consistent absence of certain landforms, including topographically elevated craterforms and thumbprint terrains (**Fig. 1**). Topographically elevated craterforms are conical features that have interior floors at or above the surrounding terrain. These are interpreted to be impact craters whose rims and ejecta have been severely degraded and interiors have been filled. Of the ~750 craterforms identified within VB, only 11% (n=85) are located within the boundaries of the mapped outcrops. Based on past analysis, craterform heights range from 31 to 162 m (mean of 40 m). Thumbprint terrains are arcuate ridges, many composed of pitted cones 100s of meters in diameter, that are concentrically nested and outwardly oriented. Though widely occurring in VB, these features have unclear origin and may be recessional moraines-like landforms, vents associated with subsurface devolatilization, or liquefaction fronts. Of the ~3200 thumbprint ridges identified within VB, only 2% (n=57) are located within the boundaries of the mapped outcrops.

Interpretation: We interpret that the outcrops we have mapped represent a discrete and previously unrecognized geologic unit. Because of its general confinement to the Martian northern plains and apparent superposition of the Early Amazonian landforms associated with this region, we refer herein to the unit as the Vastitas Borealis, upper member (unit Avu). The occurrence and concentration of topographically elevated craterforms and thumbprint terrains between the mapped outcrops of unit Avu implies that the features formed by the lateral contraction of the unit to their current extent. We interpret unit Avu as vestiges of an Amazonian-age mantle deposit that is tens of meters thick, correlative to the heights of both the outcrops and interspersed craterforms. This unit may have been emplaced as loess, perhaps sourced from degradation of the polar plateau, volcanic eruption, and/or surface impact. In this scenario, unit Avu is inferred to have covered a much larger area than currently represented. We speculate this previous extent by linking the occurrences of topographically elevated craterforms and thumbprint terrains (**Fig. 1**). This results in a unit that is ~$21.6x10^6$ km^2, covering 54% of the surface area contained within the highland-lowland boundary scarp.

The character of the transition from one geologic unit to another provides some insight into the units' formation. The margins of Vastitas Borealis have been mapped out and inferred to be a separate geologic unit [1], characterized by upslope-facing lobate margins and thumbprint terrains. However, we obsrve multiple examples where the low latitude margins of unit Avu contain undulations, surface cracks, and rugged hillocks, perhaps suggesting that they formed as the result of disturbance during the emplacement of adjacent units. This provides some stratigraphic information, as any interaction with adjacent units necessitates the existence unit Avu. For example, the Utopia channeled lobe that is sourced from Elysium Fossae is characteristically rugged, particularly along its northern margin. We interpret that the rugged hillocks may have formed when the floods were emplaced and interacted with the pre-existing unit Avu. Such interaction necessitates that unit Avu existed during the Early Amazonian. Other examples include undulating terrains in Galaxias Fossae, the exhumed domes of Scandia Colles, layering in materials in northern Amazonis Planitia, and pedestal-type craters in Chryse Planitia. These collectively suggest that the unit was present from the Early to Late Amazonian, though temporal continuity cannot be confidently constrained. These features all allude to the interaction of geologic processes with a pre-exising material that has been subsequently stipped away.

We perceive the spatial and temporal occurrence of unit Avu to be a context for understanding the evolutionary history of the Martian northern plains. Based on associations with unit Avu, we postulate that the previously identified VBF members may represent a maturation of the sedimntary mélange compose the northern plains. More detailed analysis of the unit's characteristics can lead to better understanding of the unit's formation.

References: [1] Tanaka, K.L. et al. (2005) USGS SIM 2888, 1:15M scale. [2] Tanaka, K. L. et al. (2003a) JGR, 108 (E4). [3] Tanaka, K.L. et al. (2009) LPSC abstract. [4] Scott, D.H., et al. (1986-87) USGS I-1802 A-C, 1:15M scale.