EVIDENCE FOR AND IMPLICATIONS OF LIQUEFACTION IN THE VASTITAS BOREALIS MARGINAL UNIT IN SOUTHERN UTOPIA PLANITIA, MARS. J. A. Skinner, Jr.[1], K. L. Tanaka[1], and R. L. Fergason[2], Astrogeology Team, U.S. Geological Survey, 2255 N. Gemini Dr., Flagstaff, AZ 86001 (jskinner@usgs.gov), [2]School of Earth and Space Exploration, Arizona State University, PO Box 876305, Tempe, AZ 85287-6305.

Introduction: The Vastitas Borealis (VB) units form the bulk of the Martian northern plains and are likely comprised of physically- and chemically-altered detritus of channel, mass-wasting, and atmospheric origins [1-3]. It is generally understood that widespread textural homogeneity, marginal onlap relationships, counts of kilometer-size impact craters, and periglacial-like morphologies of lowland deposits alludes to pervasive ice- and/or water-assisted resurfacing at the beginning of (and perhaps throughout) the Amazonian [2-4]. However, it remains unclear why, where, or how particular modificational processes occurred. Analysis of the marginal transition from VB units into older, geologically and stratigraphically discordant terrains holds hope for understanding not only lowland resurfacing processes but also the internal structural and stratigraphic characteristics of these units.

We present geomorphological and thermophysical observations of the southern Utopia Planitia highland-lowland boundary (HLB). Based on these observations, we infer that the currently-mapped VB margin in southern Utopia Planitia is modificational (not depositional) in origin and speculate that it formed through seismically-induced liquefaction.

Geologic setting: Utopia Planitia is bounded on the southwest by Isidis Planitia, the southeast by the Elysium volcanic rise, the north by a subtle topographic saddle, and the south by the HLB. Geologically, the southern Utopia HLB is comprised of the Late Hesperian Utopia Planitia 2 unit (HBu$_{2}$) of likely sedimentary mass-wasting, diapiric, and collapse origins [2, 5-6], onlapped by Early Amazonian Vastitas Borealis (VB) interior and marginal units (ABv$_{i}$ and ABv$_{m}$, respectively) of likely primary and/or modified outflow channel deposits [2-3, 5]. Unit ABv$_{m}$ forms a narrow (often less than 20-km-wide) set of outcrops of linear, lobate, and sinuous scarps and thumbprint-like surface textures. Unit ABv$_{m}$ transitions northward into unit ABv$_{i}$, which consists of vast hummocky, knobby, and smooth plains [1-3]. It is not clear whether unit ABv$_{m}$ coincides with or slightly post-dates the more widely-occurring unit ABv$_{i}$.

Observations: Geomorphologically, the southern Utopia VB margin is composed of overlapping, south-facing lobes (Fig. 1A). These lobes are sometimes accompanied by a tens-of-kilometers-long shallow, arcuate trough located between 2 and 3 km north of the VB margin. The lobe-forming VB margin in southern Utopia Planitia is traceable from the Arena Colles region (~90°E) to the base of the Elysium volcanic rise (~125°E), a distance of >2800 km. North of Arena Colles, the lobes become indistinct, perhaps due to burial by mid-latitude mantle deposits [2, 7]. The elevation of the VB margin within southern Utopia varies only slightly (–3569+/-318). The margin, including the thin fronts described above, commonly ramps onto or terminates against small knobs and plateaus tens of meters high. For <50 km north of the VB margin, the unit's surface is characterized by a series of arcuate ridges that are generally spaced ~1 km apart and pointed south, roughly parallel to the marginal lobes. The ridges are themselves composed of small (<80-m-wide) pitted cones. Hummocks, knobs, and cones exist where the ridges intersect (Fig. 1A). We observe several topographically-subdued arcuate and pitted ridges south of the ABv$_{m}$/HBu$_{2}$ contact, though these are neither as continuous nor as distinct.

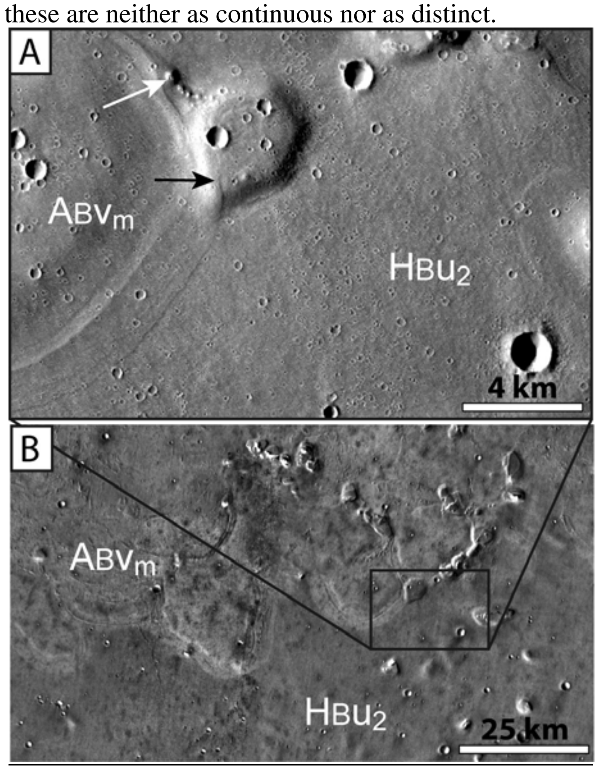

Figure 1. Geomorphologic and thermophysical characteristics of the southern Utopia VB margin. (A) Marginal lobes of unit ABv$_{m}$. Note hummocks (white arrow) and onlap of knob (black arrow). THEMIS V19691008. (B) ABv$_{m}$/HBu$_{2}$ contact as represented in THEMIS daytime IR images.

Thermophysically, the VB marginal unit in southern Utopia is bright in daytime THEMIS IR images relative to the adjacent, more southerly Utopia Planitia 2 unit (HBu_2) (Fig. 1B). The reverse is true for nighttime images. Qualitatively, the thermal expression of the VB marginal unit indicates that the unit has a lower thermal inertia than the adjacent Utopia Planitia 2 unit. This change in thermal properties may be a result of surface roughness and/or differences in surface lithology and particle size. Because the thermal contract is not apparent in visible range images, it is not likely to be caused by differing amounts of atmospheric dust on the surface, which would show contrasting albedo patterns. Similarly, the thermal discrepancy is not apparent in TES-derived thermal inertia maps [8], a likely relict of the large relative footprint of the TES compared THEMIS. These observations suggest that the ABv_m/HBu_2 margin may be defined by laterally-variable surface characteristics at decameter scales, including contrasting particle size, induration, and/or surface roughness, but is relatively homogenous over multi-kilometer scales.

The geomorphologic and thermophysical character of the ABv_m/HBu_2 geologic contact is spatially coincident and is confined to within <50 km north of the contact. North of this region, within the larger expanse of the VB, there are no observed arcuate, pitted ridges or associated distinct thermal contrasts.

Interpretation: Based on geomorphologic and thermophysical observations of the VB marginal unit (ABv_m) in southern Utopia Planitia, we suggest that the unit formed through deformation of pre-existing materials, perhaps through liquefaction of near surface materials. On Earth, sediment and soil liquefaction occurs when shear stresses are applied to saturated, cohensionless material. The build-up of pore-water pressures as particles compact produces an upward surge of pressure that results in fluidization of surface and near-surface (generally <10 m) materials. The most conspicuous evidence of subsurface liquefaction is observation of both surface deformation and sediment vented onto the ground surface [9-10]. Surface waves can cause periodically-spaced deformational landforms such as ridges, fractures, and sand blows [10].

In southern Utopia Planitia, the south-facing, upslope orientation of the VB marginal lobes indicate fluidized movement of surface materials rather than depositional or erosional processes (as would be expected for marginal marine features [11]). Also, mass-wasting (*e.g.*, gravity slumping or solifluction) would produce lobes oriented *downslope*, the opposite of what is observed. The onlap and abutment of lobate margins against and around higher-standing features indicates lateral propagation of a surface wave. We interpret hummocks and knobs as evidence of surface deformation at interfering wave fronts. Sharp thermal contrasts suggest the surface of unit ABv_m consists of greater proportions of fine-grained particles and/or meter-scale surface landforms than the adjacent (and underlying) HBu_2 unit. We interpret the gradual disappearance of observed geomorphologic and thermophysical characteristics toward the north as evidence that liquefaction was localized to the VB margin.

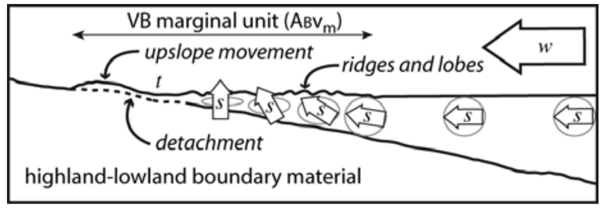

Figure 2. Schematic cross-section across ABv_m/HBu_2 contact. Circles depict shoaling of a laterally-propagating surface wave ("w") within unconsolidated VB material. "S" shows directional stresses as the wave crosses the ABv_m/HBu_2 contact, forming arcuate ridges and lobes. Deformation is focused at the unit margin due to variations in the subsurface. Marginal lobes form due to near surface detachment and upslope movement, resulting in marginal troughs ("t").

We hypothesize that the VB marginal unit represents the lateral propagation of a seismic wave that deformed pre-existing, unconsolidated materials of Vastitas Borealis (Fig. 2). We attribute the marginal unit to the manifestation of shoaling effects of the surface wave and the detachment and southward movement of a surface unit. This hypothesis implicates major variation in the near subsurface (within the uppermost tens of meters), perhaps due to grain size, lithification, and/or water or ice content. Topographically-subdued ridges and pitted cones observed in unit HBu_2 may be relicts of similarly-formed liquefaction features. Older surfaces may indicate higher stands of subsurface volatiles and/or different layers of liquefied lowland materials. We speculate that the source of the seismic energy was lowland impacts, whereby lowland material was conducive to wave propagation.

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