THE DEUTERONILUS CONTACT ON MARS: MORPHOLOGY, AGE, TOPOGRAPHY.

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Introduction: Vastitas Borealis Formation (VBF) is among the most widespread units on Mars that covers the majority of the northern plains [1-3]. Morphologically and stratigraphically similar unit covers the floor of Isidis Planitia [3]. The modes of VBF emplacement are debatable. In the framework of the northern ocean hypothesis [4-7], the VBF is considered as a residue of a large standing body of water [e.g., 8]. Alternatively, the VBF may represent deposits of sedimentary materials formed independently in different regions of Mars [9,10]. One of important and testable prediction of the ocean hypothesis is the topographic configuration of the VBF boundary: if the unit indeed marks the presence of an ocean, its boundary should occur near a specific topographic level that corresponds to a former equipotential surface [11]. Testing this prediction requires the knowledge of (1) the large-scale topography of Mars and (2) the exact position of the VBF boundary.

Previous studies: The topographic characteristics of Mars are well known after the MOLA experiment [12], whereas uncertainties in the location of the boundary remain. The map of the Deuteronilus contact, which was initially proposed as a possible shoreline of the putative ocean [4] and generally coincides with the previously mapped edge of the VBF [2], is based on images with relatively low resolution. As the result, it portrays the contact as short and discontinuous pieces [7]. In the geological map of the northern plains [3], two units, interior and marginal, show the extent of the VBF. Although edges of these units are generally close to the pieces of the Deuteronilus contact shown in [7], in many regions these boundaries diverge significantly. These uncertainties strongly limit the possibility to assess the topographic characteristics of the VBF edges [13].

In our study, we strictly followed the original definition of the Deuteronilus contact [4] and mapped it around the northern plains and in Isidis Planitia using the gapless THEMIS-IR day- and nighttime mosaic (version 12.0). In places where the location of the contact was unclear, we used high resolution, images (CTX) to map the boundary. The goals of our study were as follows: (1) trace and map the contact as continuously as possible, (2) assess the types of its relationships with the surrounding terrains, (3) estimate the absolute model ages of the surface of the VBF adjacent to the contact in different regions, and (4) collect the topographic data along the mapped boundary.

Morphology and extent of the contact: The Deuteronilus contact in both the northern plains and Isidis Planitia always consists of broad (a few tens of km) lobes oriented toward the highlands, away from the main body of the VBF. We have mapped this specific morphology of the contact in the following regions: (1) Tantalus Fossae (263.6-276.3E, 586 km), (2) Tempe Terra (303.6-318.6E, 2,260 km), (3) Chryse Planitia (320.4-332.1E, 2,495 km), (4) Acidalia Planitia (333.2-345.9E, 2,496 km), (5) Cydonia-Deuteronilus Mensae (0.3-23.9E, 3,926 km), (6) Nilosyrtis Mensae (63.4-95.1E, 3,874 km), (7) Utopia Planitia (96.7-124.6E, 2,851 km), (8) Elysium west (127.2-132.1E, 914 km), (9) east of Phlegra Montes (170.8-183.0E, 2,841 km), and (10) around the Isidis floor (3,570 km). The total length of the contact in the northern plains is ~24,000 km. In the gaps between the mapped segments, the morphological characteristics of the contact are not seen due to either superposition of younger materials or erosion of the specific contact morphology.

The typical feature of the lobes is that they embay, envelop and squeeze between the local obstacles. There is also evidence that local topographic lows control the distribution, extent, and orientation of the lobes. These characteristics suggest that the Deuteronilus contact formed due to emplacement of liquid or rather semi-liquid materials.

Ages: If the putative northern ocean formed by the catastrophic discharge of the outflow channels and the VBF is its residue, the surface of the VBF should show about the same age throughout the northern plains. In order to test this prediction, we have counted craters within the VBF occurrences using the THEMIS-IR daytime mosaics. The count areas were selected as close to the mapped sections of the contact as possible to ensure that the age estimates would characterize the unit that forms the contact. Within the northern plains, the surface of the VBF demonstrates the ages that vary from 3.61 (+0.05/-0.08, Tempe) to 3.53 (±0.03, Chryse) Ga; no correlation between the age estimates and location of the crater count areas was found. The age of the VBF-like unit within Isidis Planitia is estimated to be 3.46 (±0.01) Ga.

Topography: We used the 1/128 MOLA gridded topography to collect data on the elevation changes along the mapped segments of the Deuteronilus contact. Each segment occurs at specific topographic level with very small variations (±1σ in each case): Tantalus: -3,301±44 m; Tempe: -3,953±67m; Chryse: -3,897±64m; Acidalia: -3,936±89m; Cydonia-Deuteronilus: -3,901±61m; Nilosyrtis: -3514±65m; Utopia: -3,585±57m; Elysium west: -3,706±57m; Phlegra: -4,004±57m. Fig. 1 shows the entire topographic profile along the Deuteronilus contact within the northern plains. The profile shows that with the exception of the Tantalus Fossae, which was tectonically elevated, the contact occurs at two distinct topographic levels. The lower level (-3.92 to -4.00 km) characterizes the majority (~70% by length) of the contact from the Tempe to the Cydonia-Deuteronilus segments and the Phlegra segment. The higher level (-3.58 km) that characterizes the contact along the southern edge of the Utopia basin, the Nilosyrtis and Utopia segments.

The floor of Isidis basin is tilted in SW direction and segments of the Deuteronilus contact in this region occur at different topographic levels. The most elevated, NE, segment is at the mean elevation of -3,543±17m, which is very close to the elevations along the Nilosyrtis segment. The deepest, SW, segment occurs at the elevation of -3,814±21 m.

Utopia-Isidis connection: The eastern edge of the Nilosyrtis segment within the northern plains and the NE segment of the contact within Isidis Planitia occur on opposite sides of the lowest portion of the Isidis basin rim. Topographically, this area represents a divide between the lowlands of the northern plains and the Isidis basin. The Deuteronilus contact on both sides of the divide appears as very distinct feature in the THEMIS and CTX images. Our detail inspection of this region has revealed no evidence of possible connections between the VBF occurrences in the northern plains and the VBF-like materials in Isidis Planitia.

Discussion/conclusions: The Deuteronilus contact, which often coincides with the edge of either the interior or marginal units of the VBF, is a very prominent feature that can be traced continuously for thousands of kilometers around the northern plains and within Isidis Planitia. In these regions, the morphology of the contact suggests that materials that form the contact were liquid/semi-liquid upon their emplacement. The lack of the volcanic sources inside the occurrences of the VBF, the thermal properties of the unit [14], and evidence for mud volcanism in association with the VBF [15-18] exclude its volcanic origin and indicate its formation by deposition of wet sediments [e.g., 3]. Occurrences of the VBF in the northern plains and the VBF-like unit in Isidis Planitia are not connected suggesting that the sources of these materials in both regions were different.

The VBF shows little evidence for the presence of smaller subunits and appear as a homogenous unit (the interior unit) with edge facies (the marginal unit) that are prominent in places [3]. The estimates of the absolute model ages on the surface of the VBF suggest that its material was emplaced during a relatively short time interval. Both the homogeneity of the VBF and the small variations of its ages are consistent with the predictions of the ocean hypothesis.

The absolute majority of the mapped Deuteronilus contact in the northern plains (~98%) follows two distinct topographic levels, ~-3,900±70 m and ~-3,600±90 m. The lower level characterizes large contiguous regions around the possible water source (the outflow channels in Chryse Planitia) and in its diametrically opposite region (Phlegra). Such topographic configuration of ~ 17,000 km of the contact in these regions in combination with its morphology and the ages of the VBF suggest that a large fraction of the northern plains was covered by a mixture of water and sediments either at the Noachian/Hesperian transition [19] or during the Late Hesperian [20].

However, the noticeably higher (~300 m) position of the contact around the southern edge of the Utopia basin (~8,000 km) may contradict significantly to the hypothesis of a single ocean. The Nilosyrtis-Utopia sections of the Deuteronilus contact may suggest the existence of an independent water/sediment reservoir within Utopia Planitia. This explanation requires both an independent source(s) of water to fill Utopia and a topographic barrier that disconnected the Utopia lowland from the rest of the northern plains. The age estimates indicate that the possible reservoirs in Utopia and in the rest of the northern plains were formed simultaneously.

In the framework of the single northern ocean hypothesis, the different topographic levels of the VBF edges can be attributed to the long-wavelength topographic readjustments after the emplacement and evolution of the single body of water/sediment. The tilt of the Isidis floor is consistent with and may be suggestive of the long-scale topographic variations.

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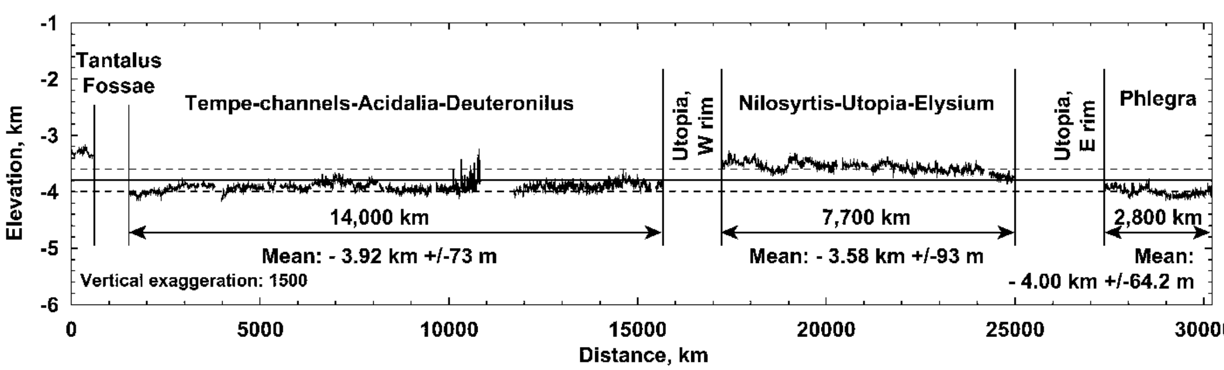

Fig. 1. Topographic profile along mapped segments of the Deuteronilus contact in the northern plains.