LAYERED MANTLE DEPOSITS IN NORTHEAST ARABIA TERRA, MARS: II. MODELS FOR NOACHIAN-HESPERIAN SEDIMENTATION, EROSION AND TERRAIN INVERSION.

C. I. Fassett and J. W. Head, Dept. of Geological Sciences, Brown University, Providence, RI. 02912 (Caleb_Fassett@brown.edu).

Introduction: The thick mantle material in the *etched unit* (Nple) and *dissected unit* (Npld) of in northeast Arabia Terra [1] presents an excellent study area for attempting to understand the processes of deposition and erosion on early Mars. In a companion abstract [4], we have described our new observations of these units using new data. Based on our craters counts, the mantle material was deposited during the Noachian or earliest Hesperian, and was subsequently eroded over a relatively short amount of time. This erosion removed hundreds of meters of material, which led to the formation of mesas and knobs, and the exhumation of underlying craters (Figs. 1,2,3).

On the basis of Viking data, hypotheses for the origin and modification of this deposit, summarized in [2,3], include: 1) pyroclastic (airfall or ignimbrites); 2) dust deposits; 3) water-laid ocean sediments; 4) lateral eolian transport; 5) fluvial erosion and sedimentation; 6) some combinaton of these.

Here we address the following questions: 1) what mechanism led to the areally-extensive deposition of the mantling material? 2) What processes have eroded the mantling unit, leading to terrain inversion? 3) What are the implications for understanding the geological history of Mars on the basis of remote sensing data?

Fill Material Emplacement Mechanisms: The material which formed a mantle in the etched unit appears to have been broadly draped over the terrain. On the basis of Viking data, the preferred hypotheses were that the fill material was either a pyroclastic deposit or an indurated aeolian dust deposit [3], though less favored possibilities included water-laid ocean sediments, surface volcanic flows, or fluvial sedimentation. The continuing attractiveness of the layered dust and/or ash explanation is that these can explain the draping nature of the deposit and its aerial extent. Also, Syrtis Major represents a plausible nearby source for volcanic eruptions that could have led to ash deposition during the Noachian, when we believe the mantling was deposited. A new date [5], shows that much of the latest surface of Syrtis Major is early Hesperian in age and that the broad structure of Syrtis is similar to other volcanic provinces thought to involve abundant pyroclastic volcanism.

Though dust and ash remain plausible explanations, and fit many of the deposit characteristics, new observations suggest that volatiles (mixed with dust or ash) could have been a significant component of the mantling material. This is motivated by four factors: (1) atmospheric deposition of ice/dust mixtures is known to occur on the Martian surface (in particular, at the poles [6] in the recent); (2) debris from this material can be preferentially concentrated in preexisting lows (crater and valleys) by known processes; (3) cyclic deposition and removal mediated by the climate and atmosphere, driven by orbital parameters [7], is consistent with the observed layering and areal extent, and (4) recent work has illustrated the importance of volatile (and debris) deposition in tropical and mid-latitude regions in more recent periods of Martian history [8-10].

Thus, we currently favor a model in which dust nucleated ice is deposited by atmospheric precipitation during periods of orbital parameter variation conducive to low-latitude snow and ice accumulation. A contribution from airborne pyroclastic tephra from late Noachian-early Hesperian eruptions (particularly Syrtis Major activity) may also have been important.

Model for Erosion: On the basis of Viking data, the preferred explanation for erosion, exhumation, and inversion in the etched and dissected units was aeolian [2,3]. However, the amount of erosion that is needed in northeast Arabia Terra is large (hundreds of meters, see, e.g. Figs. 1,2 and Figures in [4]), and occurred over an area of hundreds of thousands of km^2. If this erosion took place in a relatively short period of time (e.g., a few hundred million years), consistent with the crater counts [4], this would require erosion rates ($>10^3$ nm/yr) that are higher than typical for aeolian processes on Mars, at least in the recent [11]. Although aeolian weathering has undoubtedly modified the etched unit (Fig. 3), the extent of erosion and inversion which occurred at this location is difficult to explain by this process alone.

Invoking volatile loss to the atmosphere appears to be a more plausible way to explain the scale of erosion that is observed. It is also consistent with the observed morphologies, such as formation of cuspate margins (Fig. 1) and pits (Fig 5 in [4]) which could result from local loss of volatiles to the atmosphere at these locations.

Implications for Remote Measurements of the Martian Surface: Widespread, intense exhumation has taken place in NE Arabia Terra. Recent work [12,13,14] has suggested that if the extent of exhumation seen here is commonplace on other parts of the Martian surface, as has been suggested in other locations, this needs to be taken into account when attempting to decipher the history of early Mars. The etched terrain is mapped as Noachian based on its density of old, large craters, yet has almost no valley networks preserved, likely as a result of subsequent (Hesperian) processes which have altered its topography by hundreds of meters. The type of exhumation observed here may complicate the ability to draw straightforward inferences about surface processes on “valley network Mars” by largely removing the Noachian surface yet preserving a population of large-craters from the Noachian. Thus, exhumation needs to be considered [see also 12, 15] when interpreting derived crater counts of Martian surfaces or when interpreting the observed spatial distribution of valley networks.

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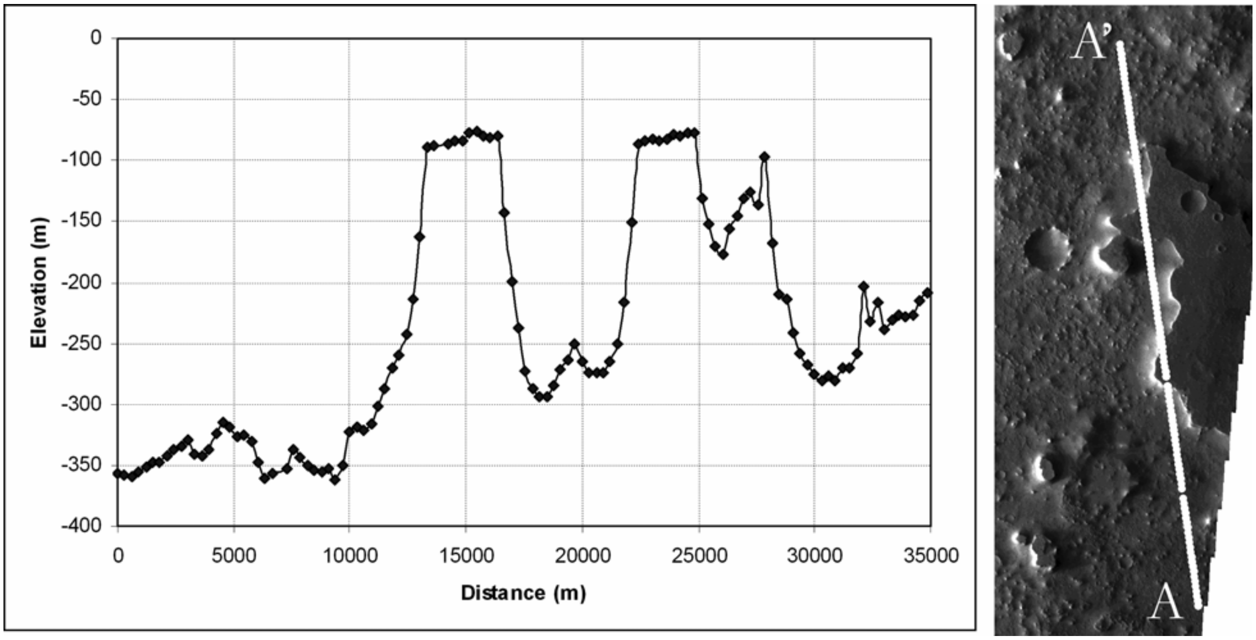
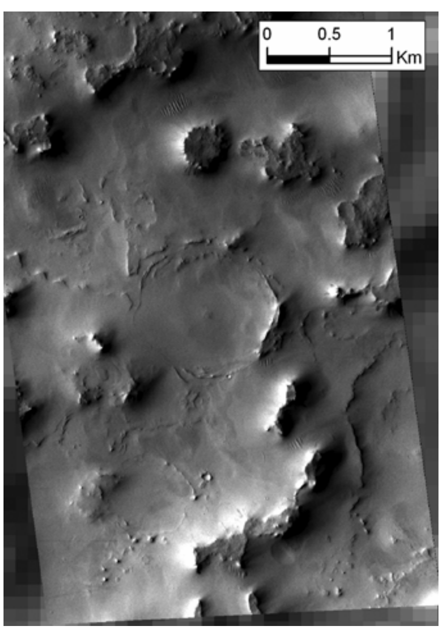


Figure 1. (top) Example profile across the fill unit in the etched terrain, showing the amount of erosion that must have occurred to produce these steep mesas. THEMIS VIS image V06402022 and MOLA orbit 11764.



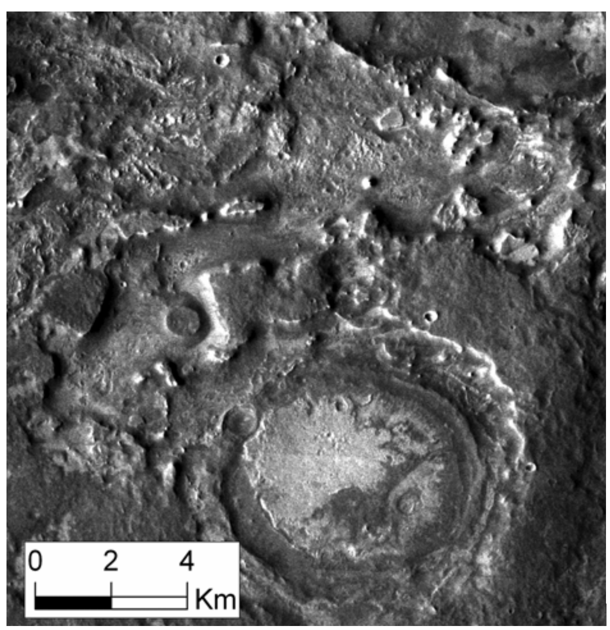


Figure 2. (left) MOC image E0200959. Inverted craters, knobs, and the faint outlines of a degraded 1-km crater (center).

Figure 3. (right) THEMIS VIS image V01571010. Where the mantling material has been eroded, old underlying craters are exhumed.