CYCLES OF EROSION AND DEPOSITION IN EASTERN ARABIA TERRA, MARS.

R. L. Fergason and P. R. Christensen, Mars Space Flight Facility, School of Earth and Space Exploration, Arizona State University, Tempe, Arizona, 85287-6305, robin.fergason@asu.edu.

Introduction: Low thermal inertia regions on Mars, such as Tharsis Montes, Arabia Terra, and Elysium Planitia, are interpreted to be surfaces mantled in dust, and cover about a third of the martian surface and the majority of the northern mid-latitudes. This dust mantle masks the underlying surface preventing the identification of composition or thermal inertia of distinctive surface morphologic features observed in these regions. However, eastern Arabia Terra contains morphologic features, such as layers exposed within craters, and evidence for fluvial and volcanic processes, that provide insight into the geologic history of this area. It is also the location of elevated elemental hydrogen abundances in data from the GRS/NS/HEND instrument suite, interpreted as the water content in the uppermost surface layer [1, 2, 3]. The relationship between the geologic processes that produced these features, the high water abundance, and the dust mantle offers insight into geologic environments and climates on Mars.

Method: To help better understand the geologic and dust cycle history in Arabia Terra, many datasets, including THEMIS daytime and nighttime infrared images, THEMIS and MOC visible images, TES and THEMIS thermal inertia, TES albedo, and MOLA were integrated to create a unit map of the study region. THEMIS day and night infrared images [4] were used to initially map unit locations based on morphology and thermophysical differences. Both THEMIS visible images and narrow angle MOC images were then analyzed to confirm unit boundaries and to identify detailed morphologic features. THEMIS-derived thermal inertia (100 m per pixel) [5] was used in conjunction with TES thermal inertia (3 x 6 km per pixel) [6, 7] to differentiate thermophysical units and quantitatively interpret the physical nature of each surface. An effective particle size was determined for surfaces with a thermal inertia below ~350 [8]. TES albedo [9] and the Dust Cover Index (DCI) [10] was used to identify the presence of surface dust, and MOLA topography [11] was used to measure the thickness of layers and unit materials. This unit map was used as a basis for determining the relative age and environmental relationships between surfaces, and fostered the interpretation of the geologic history of this area.

Observations: The study region was mapped into five units based on differences in the thermophysical and morphologic characteristics of the surface: (1) dust mantled; (2) intracrater mounds; (3) intracrater material; (4) wind streaks; and (5) cratered plains material. In this work, we have focused on determining the origin of the intracrater mounds unit and layers in the dust mantled unit, and identifying a possible formation relationship between these two materials.

Five craters in this region contain interior mound material that ranges in height from 300 to 2500 meters. These mounds erode in a fluted or yardang pattern that occurs on the slopes and often on all sides of the mounds (Figure 1). The mounds have variable THEMIS thermal inertia values. The majority of mounds have a low thermal inertia (40-140), indicating that they are mantled by a minimum of a few centimeters of dust or fine sand. However, one mound has a higher thermal inertia (400-435) and is either free of dust or the dust layer is too thin (tens of microns) to considerably lower the thermal inertia. Due to its proximity to likely active sand deposits, which would prevent the accumulation of air-fall dust on this surface, a thermal inertia of 400-435 may be more representative of the actual thermal inertia of the intracrater mound unit. All mounds, regardless of their thermal inertia, have an albedo similar to the surrounding dust-mantled surface. The thermal inertia of the mounds (40-140; 400-435) is lower than bedrock and suggests a less consolidated material, such as an ash flow tuff or weakly lithified dust, and in many cases is likely mantled in an unconsolidated dust layer to further lower the thermal inertia. The fluted or yardang-like erosional pattern of the intracrater mounds is suggestive of a weakly indurated material, and corroborates the observed thermal inertia values. Although these materials primarily occur within craters, there are materials north of Henry Crater that have similar erosional morphologic features and fine laminations, suggesting a more extensive deposit.

Layers are observed under the dust mantle and may be related to the intracrater mound unit (Figure 2). This material has a rough erosional boundary suggestive of weakly indurated material susceptible to erosion by wind. However, this material has a different erosional expression than the intracrater mound unit, as it is thinner and does not erode into yardangs or a flutted patter. Due to its location on the plains, rather than inside a crater, this material has likely experienced significantly different wind conditions than the intracrater mound material, and this difference in location is a possible cause of the variable erosional expressions observed. Assuming these layers are formed by the same processes as the intracrater material, the presence of layered material beneath the dust layer and intracrater mound remnants just north of Henry Crater are evidence that the deposition of this layered material occurred throughout the entire study region.

Discussion and Interpretation: From this analysis, the following geologic history of this material has been determined. Following a period of volcanic and channel-forming activity, there was deposition of consolidated material found in craters that forms the intracrater mound unit. This material is lithified, but is not as resistive to erosion as the material found on the surface beneath the dust layer and may have had a fundamentally different origin than this material. There are at least two possible scenarios for the origin of this material: (1) deposition of volcanic ash; and (2) lithification of air-fall dust. First, a pyroclastic deposit or volcanic ash may have occurred, and the erosional nature of the intracrater mound unit is distinctive and is similar to volcanic ash deposits found on Earth. Tharsis Montes may have experienced explosive eruptions in its history [e.g. 12, 13], and is a possible source for volcanic ash in this region. Alternatively, this material could be multiple layers of ancient dust that have been lithified by some process. This scenario implies that dust was deposited, possibly in a manner and environment similar to the current martian climate. Then dust became cemented, and these deposits were eroded into their present configuration. The entire study region may have been cemented, and then eroded. Alternatively, only portions of the dust may have been cemented, such as within crater by a lacustrian process [14], and the remaining unconsolidated material was removed by wind. The intracrater mounds consist of fine laminations at the resolution of MOC images, suggesting repeated cycles of deposition and cementation. In either case, it is likely that volcanic ash or dust was deposited over the entire study region and has been eroded from the surface beneath the dust layer with material in craters remaining.

Regardless of the formation mechanism responsible for these deposits, the geomorphology observed in this region indicates that multiple periods of deposition and then erosion have taken place. In addition, the detailed surface textures and morphologies observed through the dust mantle indicate that this layer can only be a few centimeters to 1-2 meters thick. A similar thickness was suggested and these deposits were determined to be less than 10^5 years old, based on estimates of average annual dust deposition from global dust storms (10 μm/year) and assuming a dust mantle thickness of 1 meter [15]. These results support these previous assumptions, and thus the hypothesis is consistent with these Viking-era results. It is plausible that multiple cycles of dust deposition have occurred in Arabia Terra, and the morphologic features in this region support this suggestion. The intracrater mounds may be multiple layers of lithified dust that represent an ancient climate similar to modern times. In this scenario, Arabia Terra is a region with low shear winds, and dust is unable to remain in suspension. This air-fall dust is deposited onto the surface. Some process then cements these dust particles together, and this process is repeated until multiple layers are formed. Alternatively, the accumulation of dust in this region could be a single event indicating a significant change in wind circulation patterns on Mars in the recent past. The observation of different surface morphologies, such as distinctive lava flow fronts and fluvial channel morphologies, indicates that there has been a change in surface environments over time in this region, and is conclusive evidence that this region has not been a continual region of dust accumulation throughout Martian history. It also is possible that some mechanism, such as dust devils, removes dust from these surfaces [16, 17]. Rather than dust accumulating in the low thermal inertia areas, these regions may instead be in equilibrium and the dust mantle remains a relatively constant thickness over time.

References: [1] Boynton et al. (2002) *Science, 297*, 81-84. [2] Feldman et al. (2002) *Science, 297*, 75-78. [3] Mitrofanov et al. (2002) *Science, 297*, 78-81. [4] Christensen P. R. et al. (2003) *Science, 300*(5628), 2056-2061. [5] Fergason R. L. et al. (2006) *JGR, 111*, E12004, doi:10.1029/2006JE002735. [6] Jakosky B. M. et al. (2000) *JGR, 105*, 9643-9652. [7] Mellon M. T. et al. (2000) *Icarus, 148*, 437-455. [8] Presley M. A. and Christensen P. R. (1997) *JGR, 102*(E3), 6551-6566. [9] Christensen P. R. et al. (2001) *JGR, 106*(E10), 23,823-23,871. [10] Ruff S. W. and Christensen P. R. (2002) *JGR, 107*(E12), 5127, doi:10.1029/2001JE001580. [11] Smith D. et al. (1999) *Science, 284*, 1495-1503. [12] Edgett K. S. (1997) *Icarus, 130*, 96-114. [13] Hynek B. M. et al. (2003) *JGR, 108*(E9), 5111, doi:10.1029/2003JE002062. [14] Malin, M. C. and Edgett K. S. (2000) *Science, 290*(5498),1927-1937. [15] Christensen P. R. (1986) *JGR, 91*(B3), 3533-3545. [16] Christensen P. R. (1982) *JGR, 87*(B12), 9985-9998. [17] Haberle R. M. et al. (2006) *GRL*, 33(L19S04), doi:10.1029/2006GL026188.

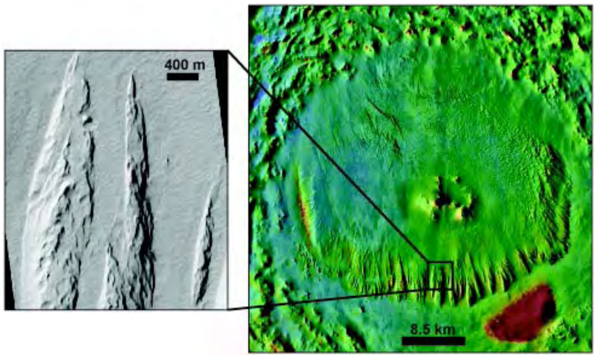

Figure 1. THEMIS nighttime IR mosic in color and overlaid onto daytime IR mosaic of interior mound material. Black/white image is a portion of MOC-NA visible image M2000102 (NASA/JPL/MSSS).

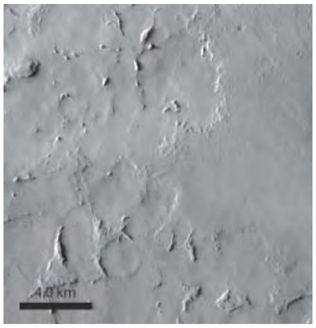

Figure 2. THEMIS visible image V05529007 of layered material in Arabia Terra that is mantled in air-fall dust.