EROSIONAL PROGRESSIONS IN THE MEDUSAE FOSSAE FORMATION, MARS. K. E. Mandt,[1] S. de Silva[2] and J. R. Zimbelman[3], [1] Space Science and Engineering Division, Southwest Research Institute (San Antonio, TX, kmandt@swri.edu), [2] Department of Geosciences, Oregon State University, (Corvallis, OR), [3]Center for Earth and Planetary Sciences, National Air and Space Museum, MRC 315, Smithsonian Institution, (Washington, DC).

Introduction: Erosional remnants on the surfaces of planetary bodies preserve a valuable record of past and present climate and geologic processes, and material properties of the formations in which they are found. On Mars yardangs and mesas are amongst the most prominent surface features and the abundant yardangs in the Medusae Fossae Formation (MFF) have been attributed to the mildly indurated nature of the MFF and the presence of strong unidirectional winds [1, 2, 3]. However, they have also been suggested to be moraines resulting from glaciers [4]. The mesas have been noted by few authors, with little insight provided as to their source or significance [5, 6].

As part of a comprehensive survey of the MFF we have examined the occurrence of mesas and yardangs in the MFF and have found evidence that shows the progressive development of these features through aeolian processes. The results of our analysis are that both mesas and yardangs are produced by a sequence of erosional stages. Their forms have implications for the material properties of the MFF and help constrain the climatic conditions that prevailed during their formation.

The MFF: The MFF is an enigmatic formation located along the equator, stretching between 120 and 190 degrees W. It is located within the Amazonis Planitia region and lies between the Tharsis and Elysium volcanic centers. In all places where they are in contact, the southern portion of the MFF overlies the mysterious dichotomy boundary: a great circle inclined 28 degrees to the equator that divides the northern lowlands from the southern cratered highlands [7]. The MFF is considered to be one of the youngest deposits on Mars based on stratigraphic relationships [7, 8, 9, 10].

A wide variety of hypotheses have been proposed for the geologic origin of the MFF: ignimbrite [3], aeolian deposit [7], paleopolar deposits [2], exhumed fault rocks [11], carbonate platform [12], rafted pumice deposits [13], lacustrine deposits [1], ash fall tuff [10, 14, 15], and subsurface aquifer [4]. Subsequent research has narrowed the possibilities down to ignimbrite, ash fall tuff and aeolian deposit.

Methodology: A total of 713 Mars Global Surveyor (MGS) Mars Orbiter Camera (MOC) images with average resolution of one to three meters per pixel were analyzed based on the features observed in the images. Though newer missions provide higher resolution images, MOC was chosen for its extensive coverage of the MFF. Each image was studied within the context of the Mars Odyssey Thermal Emission Imaging System (THEMIS) mosaic. Maps (Figure 1) were created identifying the locations of images showing mesas and yardangs within the MFF to highlight their extent throughout the formation.

Yardangs: Yardangs are linear features formed by aeolian erosion that tend to form in fine-grained material with some degree of induration and can be as large as a few kilometers in length and 100 m high [16]. Terrestrial yardangs in "ideal" form are well-streamlined, and have an aspect ratio of about 3:1 [17], although ratios as high as 50:1 are possible in well-indurated ignimbrites. A strong unidirectional wind eroding lithologically consistent material is required to form ideal yardangs. Properties such as jointing and layers with different degrees of induration can alter the morphology of a yardang. Terrestrial yardangs are seen individually and in "fields" with aerial extent of up to hundreds of square kilometers.

In the survey of MOC images, 78% of images showed yardangs in some form. Yardangs in their various forms and textures were evaluated using the MOC image survey and are described below.

Curvilinear Yardangs: Curvilinear yardangs are seen in 55% of the MOC images surveyed for this study and are mapped in Figure 1a. The texture of the curvilinear yardangs range from smooth (yellow on map) to rough (red on map); 54% are classified as smooth and 46% as rough. Possible explanations for the rough texture include fine-scale layering or heavier induration.

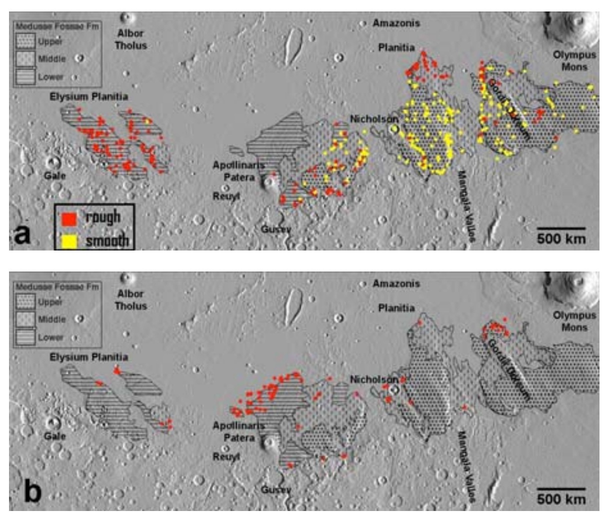

Figure 1 - Map of MFF showing locations of images with (a) Yardangs and (b) Collapse features and mesas

The curvilinear nature of the yardangs does not appear to be due to changes in wind orientation or related to topography, so some material property such as jointing or varying degrees of induration within the material is the best explanation for their morphology.

V-shaped Depressions: Many v-shaped depressions are observed throughout areas of the curvilinear yardangs. They have been interpreted to be deflation hollows caused by the removal of less resistant material [15]. The depth of these depressions ranges from 10 to 50 m.

When the v-shaped depressions are compared with many yardangs showing curvilinear morphology, a progression from depressions to yardangs can be seen as shown in Figure 2. The progression begins with a single v-shaped or half-v depression. The depressions will form in clusters and begin to elongate leaving a yardang in the center. Eventually the linear features will wipe out the v-shapes leaving curvilinear yardangs. Over time the yardangs will be completely eroded to show the underlying terrain. This progression from v-shaped depressions seems to correlate more with smooth-textured yardangs, but not exclusively.

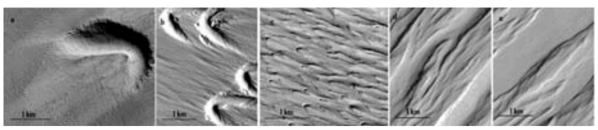

Figure 2 - Erosional progression from v-shaped depressions to curvilinear yardangs. (a) MOC e1000390 illuminated from the top of the image showing a single v-shaped depression. (b) MOC m0700371 illuminated from the right, showing a cluster of v-shaped depressions. (c) MOC m2101904 illuminated from the right, showing yardangs with remainders of v-shaped depressions at the tip. (d and e) MOC e0301400 illuminated from the right, showing fully formed curvilinear yardangs. Image (d) shows the remainder of an elongated v-shaped depression. The smooth underlying terrain is visible in image (e) between the yardangs.

Serrated or Feathered Scarps: Some curvilinear yardangs appear to originate from serrated or feathered scarps. Based on analogy with terrestrial examples, serrations or feathering will form through aeolian modification of re-entrants and headlands, produced by a prominent joint set or fluvial incision, that are progressively accentuated until the material is divided into yardangs. Serrated or feathered scarps are seen with both smooth and rough-textured curvilinear yardangs.

These two types of progressions could indicate different material properties. The v-shaped depressions seem to form around a knob of material that is more indurated than the surrounding material. If the surrounding material is at least partially indurated, then an elongated depression will form as the wind differentially erodes the material along the trough of the depression. Serrated or feathered scarps would be more likely to form in lithologically consistent material with prominent joint sets.

Collapse Features: A study of the lower member of the MFF with a specific focus on the region lacking yardangs [18] noted several chains of pits and interpreted them to be troughs created by subsurface collapse or movement. These features were observed on scales ranging from one to tens of kilometers.

We have found that there is a progression from these troughs to mesas that is clearly visible in MOC images (Figure 3) with erosional mesas of less-than-kilometer scale (Figure 3d) in 13% of the MOC images surveyed. The evolution of the mesas appears to be as follows. Chains of pits form, and are preferentially deepened and widened by the wind. Evidence for mass wasting is also apparent. Eventually only mesas remain and are then eroded by aeolian processes to reveal the underlying terrain. Evidence of this erosional progression has been located in Figure 1b. Mesas are primarily limited to the edges of the deposit where the apparent thickness is less than 250 m assuming the base material below the entire formation is relatively flat [19]. Mesas are spatially separated from yardangs.

Figure 3 - Erosional progression from troughs to mesas. All images are illuminated from the right. (a) MOC e0301084 showing chains of pits formed by probable subsurface collapse. (b) MOC e0502396 showing similar collapse features which have progressed to deeper trenches through a combination of aeolian erosion and mass wasting. (c) MOC e1001357 showing the development of individual mesas as the deepening of the trenches progresses. (d) MOC e0402348 showing a group of mesas resulting from this progression. (e) MOC e0501356 showing heavily eroded mesas at the final stages of this erosional progression

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