THE WESTERN MEDUSAE FOSSAE FORMATION, MARS: A POSSIBLE SOURCE OF DARK AEOLIAN SAND.
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Introduction: Dark dunes have been observed on Mars since the Mariner and Viking missions, occurring largely as polar sand seas (ergs), intracrater deposits, and other topographically confined bedforms [summarized in 1]. Most terrestrial sand is formed by comminution of granitic material into durable quartz grains, but Mars apparently lacks this parent material [e.g., 2]. Previous work has traced polar erg sand to the sediment-rich polar layered deposits [3], and sand dunes in Noachis Terra have been linked to local sedimentary units [4], but the ultimate origin(s) of those sand-rich units are not identified. Thus, while sand-sized sediments may be produced by a variety of processes [1], the particular process(es) and ultimate source(s) of sand-sized sediment on Mars has (have) not been discovered. One long-standing hypothesis for the origin of dark dune-forming sediments on Mars is as volcaniclastic sediments [5]. However, appropriate sediment pathways and other evidence supporting this hypothesis have been lacking.

Here we present an investigation into the origin of dark sediments in the western Medusae Fossae Formation (MFF). These sediments are interpreted as aeolian bedforms from a variety of evidence. A combination of evidence suggests that the western MFF itself may be the source of this sand-sized material.

MFF: The MFF is a dusty equatorial unit that stretches from 130^o to 240^o E [e.g., 6 and references therein]. The western MFF (Fig. 1) consists of two lobes stretching from the dichotomy boundary into the western Cerberus plains, and standing ~500-1000m higher than the lava plains. Yardangs are ubiquitous in the MFF [7,8], demonstrating both the particulate nature of the formation and the prevalence of aeolian sand transport.

Data: Morphologies, surface textures, and locations of dark sediment deposits in the western MFF were identified on visible-wavelength images at multiple scales. Grain sizes of the sediments were derived from thermal inertia estimates using THEMIS nighttime infrared images. Reflectance (I/F) near 0.65 µm was quantified using images from the High Resolution Imaging Science Experiment (HiRISE) [9]. Composition was investigated with data from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) processed using standard techniques [10]. Mesoscale regional atmospheric modeling [MRAMS; 11] provided input into the derivation of likely sediment transport directions.

Results: The deposits display multiple indications of aeolian emplacement, with mass wasting also influencing deposit locations.

Morphology and Surface Texture. Where their morphology is not controlled by surface depressions, these deposits commonly have barchanoid, domal, or otherwise aeolian dune-like forms. They often display troughs adjacent to flow obstacles [e.g, Fig. 2], consistent with an aeolian echo-dune morphology [1,12]. Deposits imaged by HiRISE show rippled surface textures, typical of Martian dunes [13].

Location/context. The dark deposits are found in relative topographic lows, such as within impact crates, between erosional remnants (e.g., yardangs), and in pits or other local surface depressions. Elsewhere, they are found at the bases of slopes. Numerous small deposits are distributed within the eastern of the two MFF lobes. Larger deposits cluster densely within a topographic trench at the southern end of the MFF (Fig. 1).

Thermal inertia. These dark sediments are bright in both day and night THEMIS infrared images. We interpret this “IR-bright” behavior as the effect of large grain sizes (warm at night) and low albedo (warm during the day). The dark dunes are higher in thermal inertia than most of the bright dust-covered MFF, but lower than adjacent exposures of indurated material (e.g., yardangs) or crater rims and peaks, consistent with a coarse-grained sedimentary composition.

Grain size. Thermal inertia calculations [using the approach in 14] yield a range of values, which when converted to effective particle sizes [using relationships in 15], yield inferred grain sizes from fine to coarse sand, sizes that are amenable to formation of dunes.

Reflectance. Sampling (~140 locations total) gives an average I/F value for the dark deposits of 0.052±0.011. In contrast, I/F of the adjacent bright indurated surfaces is 0.084$^{\pm}$0.020 An intermediate-toned material is also observed, with an average I/F of 0.063±0.016. This intermediate-tone material commonly occurs on slopes between bright upper surfaces and dark basal deposits, or on more horizontal surfaces it is transitional between dark sand and brighter surrounding plains (Fig. 2).

Composition. Two of the larger dark deposits are covered and resolvable in CRISM data. Analysis of spectra from the much larger deposit indicates enhancement of high-calcium pyroxene (HCP), consistent with the association of HCP with many dark areas, such as lava flows [16 and references therein]. In contrast, spectra from the much smaller deposit show a weak enhancement in olivine. The infrared spectral continua and visible-wavelength spectra of both deposits suggest that the dark sand grains are weakly altered or coated with dust.

Interpretation: Most evidence suggests that the source of the dark sand is within the MFF, although modeling and compositional data are inconclusive.

Morphology. For the strongly clustered dunes within the topographic trench at the southern end of the MFF (Fig. 1), most echo dune trough locations suggest sand emplacement by a northerly wind. Scour marks around flow obstacles and sand ramp orientations relative to local topography also suggest emplacement by a predominantly northerly wind.

Location/context. The numerous small deposits in the eastern MFF lobe often appear to be eroding from between strata. The relief of the MFF lobes likely presents some topographic barrier to more northern sand sources.

Brightness transitions. On slopes, the intermediate-toned material is hypothesized to be a mixture of dark sand and bright dust weathering together out of the MFF, from which the brighter material is winnowed away during mass wasting, leaving the darker sand as basal deposits. On dunes, intermediate-toned material (e.g., Fig. 2) is interpreted as atmospheric dust deposited on/not removed from atop dark sand.

Modeling. Modeling shows winds generally from the south and east, inconsistent with most morphological indicators. This apparent inconsistency may be due to the inferred effects of yardangs or other local topographic features. It is also possible that these deposits were emplaced during a different (prior) climatic era.

Composition. Sand deposits within the western MFF appear to vary in mafic mineral composition, The range of compositions suggested by infrared spectra are comparable to the compositional range of sand both on the northern Cerberus plains and on the southern highlands.

Conclusions/Implications: From the above evidence, the MFF itself is hypothesized as the most likely source for the dark sand. An alternative hypothesis is that sands within the MFF are externally sourced and intercalated with the highly friable ligher-toned material that dominates the MFF. Continued investigations will explore both hypotheses. Recent work has identified the MFF as volcaniclastic [e.g.,6,18]. If our first hypothesis is correct, these dark dunes would provide an example of a volcaniclastic origin for dark Martian dune sands.

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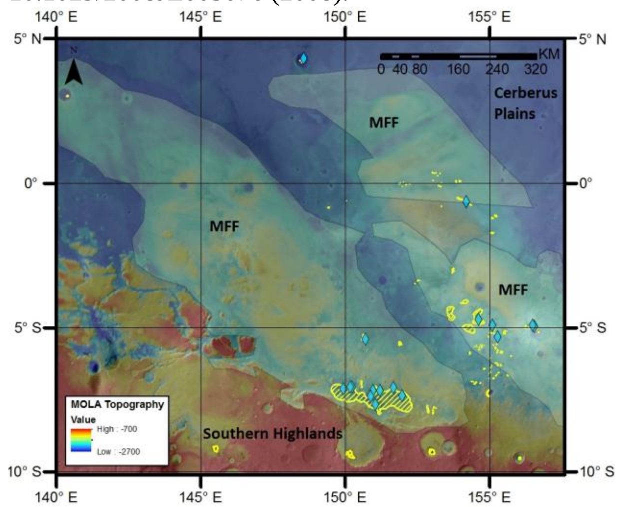

Fig. 1: Western MFF study area, showing the two MFF lobes stretching from the southern highlands on to the Cerberus plains. The locations of dark dunes (yellow hatching) and sites from which thermal inertia values were derived (blue diamonds) are indicated.

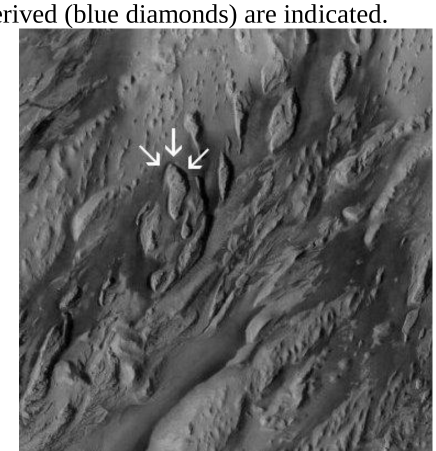

Fig. 2: CTX image P07_003769_1742_XN_05S209W near 5.5^{0}S 15.7^{0}E showing dark sediments with mounded/positive relief and echo-dune-like troughs (white arrows). From image center to lower left is an example of material intermediate in tone between the dark sands and brighter surrounding plains.