HiRISE OBSERVATIONS OF THE MEDUSAE FOSSAE FORMATION. L. Keszthelyi[1], W. L. Jaeger[1] and the HiRISE Team [1]USGS Astrogeology Team, 2255 N. Gemini Dr., Flagstaff, AZ 86001.

Introduction: The Medusae Fossae Formation (MFF) has puzzled Mars researchers for decades. It has been suggested to be volcanic ash, mudflows, eolian deposits, carbonate banks, ice-cap deposits, etc. [1-12]. The most striking morphologic characteristic is that the surface is covered with massive wind-eroded yardangs [1]. It is also closely associated with the radar "stealth" region [6, 13, 14]. Recent radio sounding measurements from MARSIS and SHARAD have provided further constraints on its bulk properties [15].

Previous Constraints: The fact that the MFF is readily eroded by the wind requires that it be composed of relatively weak material [1,12]. Since the MFF is not surrounded by large sand deposits, the particles formed by the wind erosion must be smaller than sand-sized. It is likely that the eolian erosion comes about primarily through abrasion by saltating grains of basaltic sand.

Photogeologic mapping shows that there are at least 3 distinct stratigraphic units within the MFF [2]. These appear to span the breadth of the Amazonian Period. However, the youngest portions have consistently revealed very low impact crater densities [1]. What is unclear is if these young model ages indicate that parts of the MFF formed during the most recent part of Mars' geologic history, or if erosion has erased the older craters.

Infrared observations (IRTM, TES, and THEMIS) show that the region has a low thermal inertia, with typical values ~100 J m^{-2} $s^{-1/2}$ K^{-1} [16]. These values do not have a unique interpretation, but are consistent with the upper tens of centimeters consisting of dust. The infrared spectrum is also consistent with at least a few microns of dust [17].

The Gamma Ray Spectrometer suite of instruments onboard the Mars Odyssey spacecraft provides estimates of some elemental abundances. The MFF is most notable for its high chlorine content [16]. Multivariate statistics point toward volcanic gasses as the source of the Cl in the MFF [16].

The first indication that the MFF has a physical make-up fundamentally different than most of Mars came from Earth-based radar. At 3.5 and 12.6 cm wavelengths, no radar energy is measured returning from a region that closely (but not perfectly) correlates with the mapped extent of the MFF [13,14]. This requires that the dialectric constants of the MFF (at these wavelengths) be remarkably similar to the atmosphere and that there be no scattering surfaces in the upper several meters.

Most recently, SHARAD has been able to constrain the electrical properties of the MFF by observing the strength of radar returns from the unit underneath the MFF. To allow the SHARAD signal to pass through as much as 3.5 km of material, the MFF must either (a) have properties similar to relatively clean ice or (b) be dry silicates with sufficient porosity to bring the average density below 1900 kg/m^3.

HiRISE Observations: HiRISE is providing ~26 cm/pixel views of the MFF in 3 colors. The preliminary results are presented in [18] and here we describe our continued investigation of the MFF.

Some features in HiRISE images only reinforce what was known from Viking and MOC data. For example, the morphology of the ridges are indeed those of wind-carved yardangs, but HiRISE shows more details on how the material is faceted by the wind. These ridges do not have the soft curves and striations of glacial drumlins nor are they found in channels as expected for fluvial streamlined forms. The criss-crossing erosion patterns show evidence for variable wind directions – sometimes inconsistent with wind streaks that identify the current wind patterns. As many other studies have previously concluded, we find that the only plausible hypotheses for the formation of the MFF are either dust or pryoclastics deposited from the atmosphere.

HiRISE does provide a better understanding of the stratigraphy within and around the MFF. Given the slopes of the scarps, horizontal layering at the 10-cm-scale should be resolved by HiRISE. Much of the "classical" MFF (especially the main parts of Gordii Dorsum, Eumenides Dorsum, Memnonia Sulci, and Zephyria Planum) appears to be massive. Most of what appeared to be layering at lower resolution is actually erosoional fluting. Where we find layering, it is quite subtle, being marked by small benches in eroding cliff faces. These layers are remarkably uniform in color (Fig. 1). This is a strong indicator that the MFF has great homogeneity through at least hundreds of meters vertically and several kilometers laterally.

There are some layers several meters thick that appear to be better indurated than the bulk of the MFF. These are most common in the west, especially within Aeolis Planum and Aeolis Mensae. Interestingly, these indurated layers appear to be often discontinuous on the kilometer scale. The uppermost surface often shows the most induration. This could be because it is resistant to erosion or because interaction with the atmosphere causes the induration. These harder layers commonly are jointed and have meter-scale blocks shedding from steep slopes [18]. Other than these blocks, boulders are essentially absent from the MFF. The ejecta from small impact craters are remarkably devoid of blocks resolvable by HiRISE.

Isolated buttes that appear identical to the MFF can be found over a much wider area than the mapped boundaries of the MFF. In Amazonis Planitia, these MFF outliers appear interbedded with flood lava flows [19]. Along the southern boundary of Cerberus Palus, the flood lava flows that coursed through Athabasca Valles are draped on top of MFF yardangs [19], but this same lava flow is being exhumed from under a thin mantling deposit that has been locally indurated by secondary impact crater ejecta [20].

Elaborating on the Volcanic Hypothesis: Overall, these observations are inconsistent with welded ashflows as predicted by the classic ignimbrite model. Instead, the MFF appears to be either volcanic or eolian airfall. Where indurated, the MFF does have more than a passing similarity to the polar layered deposits [21]. However, since ice is not stable at the equator today, we favor the low-density airfall model over the ice-rich hypothesis.

Given that the MFF appears to be interbedded with the flood lava flows, the source of the pyroclastics could be the same fissures that fed the flood lavas. These include the Cerberus Fossae to the north of the MFF and Memnonia Fossae to the south. While these plausible sources are closer to the MFF than the Tharsis shield volcanoes, it is still likely that the pyroclastics were redeposited by the wind, becoming trapped against the dichotomy boundary.

Mafic pyroclastics on Mars could either be small droplets (like on the Moon) or a frozen foam (like "reticulite" formed in terrestrial lava fountains). We use a simple compaction model [21] to test if either could produce an average density less than 1900 kg/m^3 assuming that the mafic glass has a density of 2700 kg/m^3. For reticulite with an initial porosity of 99% and a strength that is 1% of solid rock, we estimate that a thickness of up to 1.7 km could be supported. For glass beads with an initial porosity of 40% and a strength that is 10% of solid rock, a thickness of 1.0 km is allowed. This is substantially less than the 3.5 km maximum thickness of the MFF. However, simply doubling the strength value of reticulite (to 2% of solid rock) allows 3.5 km of this material to have an average density of 1900 kg/m^3.

An intriguing alternative possibility is that ice helps to keep the deep interior of the MFF from self-compacting. The water could have come from the atmosphere or the recent aqueous flood(s) in Elysium Planitia. However, underneath 3.5 km of highly insulating cover, water should not freeze [22]. Instead, there is unequivocal evidence for subsurface water flow in the region (e.g., the esker-like feature in PSP_006683_1740). We speculate that it was the MFF, rather than ice, that capped this underground river and the MFF has been subsequently eroded away by the wind.

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Figure 1. Color from PSP_006260_1745 at 5.5 °S, 182.4°E showing typical MFF as seen by HiRISE. Note the faceted yardang, isolated small blocks shed from the steepest slopes (arrows), and the uniformity in color despite enhancement in Adobe Photoshop (saturation +50).