CONSTRAINTS ON THE ORIGIN OF FINE LAYERS IN GANGES MENSA AND HEBES MENSA, MARS. Ross A. Beyer, Alfred S. McEwen, *Lunar and Planetary Lab, The University of Arizona, Tucson, AZ, 85721-0092, USA (rbeyer@lpl.arizona.edu)*.

Ganges Mensa is located near 311° E, 7.5° S, and has been studied ever since it was first resolved with the Mariner 9 spacecraft. Masursky [1] indicated that this was a finely layered deposit, and that those layers did not match the layering seen in the canyon slopes. Sharp [2] noted that the layers appeared near-horizontal. Hebes Mensa is located near 283° E, 1° S, and is within the entirely closed Hebes Chasma. Observations by the Viking spacecraft indicated that there were light and dark layers of uniform thickness within these mensae, and the similarity to other layered mesas and deposits in the Valles Marineris was noted [3]. However, Malin and Edgett [4] showed that some of the albedo patterns previously attributed to layering on Ganges Mensa were not bedrock layers, but topographic benches where dark toned aeolian material accumulated (their Fig. 26). Komatsu et al. [5] show a similar example of dark toned material collecting on a topographic bench on Hebes Mensa (their Fig. 11). Ganges and Hebes Mensae are indeed layered, but the layers are too thin to have been resolved by cameras before the Mars Orbital Camera (MOC) [4].

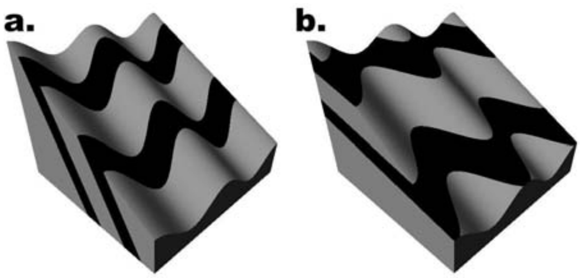

Figure 1: These cartoons show how layers with dips steeper (*a.*) and shallower (*b.*) than the overall slope are expressed when the surface has a fluted morphology.

Many hypotheses for the origin of structures like Ganges and Hebes Mensae have been discussed [see 6, for a review]. One of them, deposition in a low-energy lacustrine environment [7, 8], accounts for the thin, areally extensive, bedded layers that are observed. Layers deposited in this fashion should be horizontal unless they were tilted by tectonic activity.

More recently, Lucchitta et al. [9] noted that these mensae appeared to have steep sides, and suggested similarities to Icelandic tuya. Chapman and Tanaka [10] and Komatsu et al. [5] further explored the tuya analog for these mensae and other similar structures in the Valles Marineris. They found similarities in that the easily eroded flanks of tuya may be similar to the fluted flanks of the mensae. Chapman and Tanaka [10] indicated that Ganges and Hebes Mensae had an ideal tuya form and that the fine layers were dipping in a down-slope direction with horizontal to steep dips.

These studies were the first to raise the issue of these fine layers being non-horizontal. Many qualitative descriptions of the orientations of these fine layers have been made, but none have made quantitative measurements of the dip angle or dip direction. Unfortunately, measuring such characteristics on the flanks of the mensae is difficult. It can be accomplished in a few locations using data from the MOC and the Mars Orbital Laser Altimeter (MOLA). These measurements are difficult because the fine layers are not very distinct. If MOC images are separated even by just a few hundred meters, it is not clear which layers match between the two images. Morphological comparisons, shadow measurements, and individual MOLA tracks aligned with MOC images can help to narrow parameter space and constrain dip angle and direction.

Layer Dip Angles and Surface Slope Angles

A first order constraint on the dip angle of bedded units can be made from the overall angle of the slope on which they are observed and the surface features of that slope. A layered volume cut by a sloping, fluted surface might look like Fig. 1. This figure shows that beds which have a dip direction parallel to the dip direction of the overall surface slope have a different morphology when viewed from above if the beds are dipping more or less steeply than the overall slope.

Figure 2 shows thin layers exposed on the south face of Ganges Mensa that are exposed in this surface. The surface expression of the layers resembles Fig. 1b , not Fig. 1a, indicating that these layers are dipping less steeply than the overall surface slope. The slope in this area is about $25°$, so these layers must be dipping at an angle less than that.

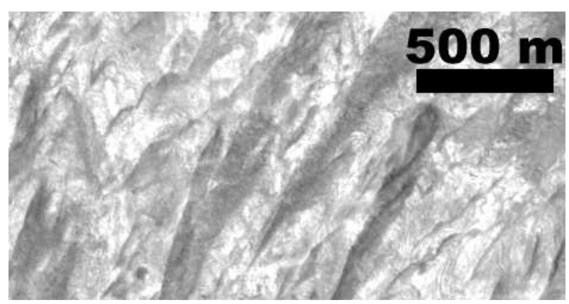

Figure 2: This is a portion of the MOC image M09/03505, it shows thin layers on the south face of Ganges Mensa that are exposed in the fluting that covers this surface. North is to the top of the image, and the downward slope is southwards.

Similarly, Fig. 3 shows thin layers exposed on the north face of Hebes Mensa. Again, the morphology that we observe is similar to Fig. 1a, indicating that these layers are also dipping at an angle less than the overall surface slope. That slope is 10 to $15°$ for the portion of M03/00648 in Fig. 3 .

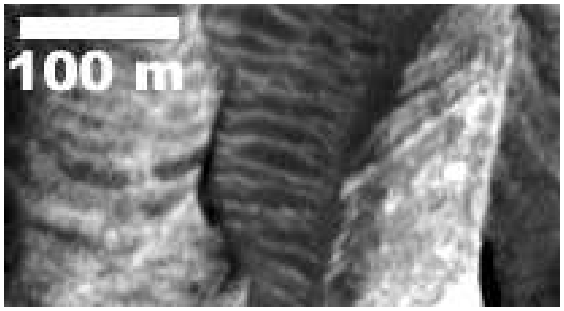

Figure 3: This is a portion of the MOC image M03/00648 on the north face of Hebes Mensa, it shows thin layers exposed in the fluting that covers this 10 to 15° slope, showing that those layers must be dipping at a shallow angle. North is to the top of the image and the downward slope is northwards.

Discussion

Allen [11] measured the overall slopes of five Icelandic tuya and found that the mean of the steepest slopes was $34^\circ \pm 4^\circ$.

This morphology is very common in MOC observations of the flanks of Ganges and Hebes Mensae. Since the slopes are generally less than 30°, we can make the generalization that most of the fine layers observed on the flanks of these mensae are dipping at angles of less than 30°. It is important to note that this observation would also be consistent with completely horizontal layers. Similarly, it would be consistent with layers that dip shallowly in a direction parallel to the overall slope (radially outwards from the mensae), or in a dip direction into the slope (radially inwards to the mensae).

Since we do not find widespread evidence of layering which dips steeply in a direction radially outwards from these mensae, then the layers can not be analogous to the steeply dipping foreset beds often observed in terrestrial tuya. Furthermore, the mensae have relatively shallow slopes overall which is inconsistent with the ideal tuya form that has been proposed for these mensae in the past. Even if steeply dipping foreset beds had been eroded into the slopes that we observe on these mensae then morphologies like that in Fig. 1a should be common on the shallow flank slopes that we observe.

These observations do not necessarily preclude the mensae from having formed in a manner broadly similar to terrestrial tuya. as these characteristics could be consistent with a more severely eroded tuya. The steeply dipping foreset beds may have been eroded away or be preserved in unimaged or buried locations, and the fine layering that is observed may be from the inner core of the tuya. Alternately, the mensae are many times the size of terrestrial tuya, and it is possible that subglacial edifices of this size do not have the steeply dipping foreset beds observed on terrestrial tuya. In this manner, the physical processes of volcanic construction of such a large edifice beneath and through many kilometers of ice on Mars may have fundamental differences from those of terrestrial tuya that we do not yet appreciate.

The finest layers in Ganges and Hebes Mensae are horizontal to shallowly dipping. Unfortunately, this does not particularly exclude any of the various hypotheses for the origins of these mensae. However, any formation hypothesis should take these measurements into account.

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