HiRISE Observations of Valles Marineris layering
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The High Resolution Imaging Science Experiment (HiRISE) camera on the Mars Reconnaissance Orbiter (MRO) is providing spectacular images of Mars resolving features at the sub-meter scale [1]. Color imaging and overlapping stereo images are also valuable for viewing topography and stratigraphy. We have used the HiRISE data to examine the layering observed in the chasma slopes, the interior mesas, the chasma floors, and layers observed on the surrounding plains. The high-resolution images show extensive layering with variable lithologies, and stunning new views of familiar landscapes.

Chasma Wall Layers

HiRISE resolution of layers in the chasmata walls provide better detail on the sub-meter texture of their outcrops. A talus cover dominates the low angle slopes and so layering is best observed on the spurs of the spur-and-gully morphology of the slopes and near the chasmata rims.

The layers identifiable in lower-resolution data as dark-toned units resolve into rubbly outcrops of meter-scale boulders (Figure 1). A previous study [2] reasoned that since these layers were dark-toned even on sunlit-facing slopes, that they must be inherently dark-toned material. HiRISE images show that while these layers may be slightly darker-toned than the talus, the major cause of the darker tones observed in the Mars Orbiter Camera (MOC) images are in fact due to sub-MOC-pixel length shadows cast by the meter-scale boulders that have eroded out of the layer. So the dark tone of this layer in MOC images is a result of roughness on a scale smaller than the image resolution [3].

However, the observation of these outcrops is still consistent with an interpretation of dense basalt flows which erode into boulders whose size is controlled by cooling joints in the flow. Although it is difficult to evaluate the character of the interstitial layers which do not crop out through the talus, the morphology and surface expression as observed in HiRISE images remains consistent with mechanically weaker layers composed of more friable material [2].

Figure 1: The north rim of Coprates Chasma showing more resistant layers cropping out and displaying a rubble texture (middle of frame and below). Portion of the red channel mosaic from PSP_002814_1665.

Light-Toned units within Chasma Interiors

Inside of Valles Marineris, massive blocky lithologies are frequently observed to be interbedded with meter-scale layered units (Figure 2), suggesting either different depositional environments or post-deposition modification of local areas. Folding is evident in West Candor Chasma near the contact with the chasma wall, indicating post-deposition disruption, perhaps associated with further extension in Valles Marineris.

Stereo images reveal tilting of layered beds in several locations. Fractures, joints, and faults are also commonly seen.
At the western end of Valles Marineris where Ius and Tithonium Chasmata transition into Noctis Labyrinthus, fractured layered units are observed in the central peak of Oudemans Crater (Figure 3). These dark and light-toned layers provide evidence of older deposits buried beneath the lava flows of the Hesperian plains, at least in western Valles Marineris.

Layering on Interior Mesas

Some of the interpretations of dark-toned units on various interior layered deposits have favored a volcanic origin [e.g. 4, 5]. HiRISE and MOC images indicate that some of the features previously interpreted as mafic dikes...
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Figure 5: This covers a flank of the largest light-toned mound in Juventae Chasma. It is highest in the southeast (bottom right) corner of the image and slopes down to the northwest. Portion of the red channel mosaic from PSP_002590_1765.

and volcanic ridges [6, 7] are simply linear remnants of an indurated dark-toned mantle that has acted as a temporary caprock on top of light-toned materials. An example on Ganges Mensa (Figure 4) shows the southern tip of a ∼9 km long dark ridge on the top of Ganges Mensa previously interpreted as a dark lava flow or a dike [6]. The dark-toned material of the ridge does not display any obvious lava flow textures, and is eroding into fine-grained talus, not meter-sized boulders. Similarly, this image gives a view of the underlying light-toned strata which do not appear to be faulted or disrupted, as the case would be if this were an intrusive dike.

Meter-scale layering is visible in many of the interior light-toned units at HiRISE resolutions. However, for some units on interior mesas where layering was expected, there is no coherent meter-scale layering visible. Similar to the way that MOC images showed that some previously-identified layers were simply topographic benches [8], figure 5 shows that the fine layering texture that was seen in some MOC images is a result of dark-toned granular material accumulating in the topographic grooves of this unit. The morphology and erosion along joints into semi-rounded boulders is consistent with a sedimentary interpretation [9].

Mesas in the central chasmata, which have been described to have massive lithologies display a scalloped texture in HiRISE images (Figure 6). At slightly larger scales, these units show evidence for intense aeolian modification, and these small scallops or facets may be sub-meter ventifacts. However, it is also possible that the rims of these scallops may be more resistant material that has undergone diagenesis along joints in the rock mass [e.g. 10] prior to the aeolian erosion.

Plateau Layering

The layers observed outside of Valles Marineris are concentrated near Ius, Melas, and Juventae Chasmata. These layered deposits have darker units interbedded with light-toned deposits, and other color variations are also visible. While the ages of the light-toned layered units inside Valles Marineris relative to the formation of the canyons are still under debate, those on the plains are stratigraphically above the Hesperian lavas and consequently represent a relatively younger period of emplacement.

Summary

Even at the highest resolution, there is a paucity of impact craters on the well-exposed light-toned layered and massive units, suggesting the units are friable in nature with a low crater retention age. This is consistent with HiRISE observations of other light-toned units on Mars which indicate that small craters may be a primary agent for beginning the disruption of light-toned units. These craters are preferentially eroded away, leaving the intercrater areas as mesas or hills, but otherwise leaving little trace of the craters themselves. Although rapid burial be-
neath dark mantle deposits and formerly overlying units may also explain why there are so few craters.

Observations of layered units along the chasma walls which erode into a rubbly mass of meter-scale boulders support their interpretation as volcanic flows. These units are a sharp contrast to the light-toned units which erode into sparse rounded boulders, but more frequently into finer particles.

Preliminary HiRISE observations of light-toned units do not support mafic volcanic origins, but sedimentary or other origins are not ruled out.

The variety of light-toned lithologies observed within Valles Marineris show some geographic clustering. However, why some light-toned units are present in some locations, but not others is a subject of ongoing investigation.

HiRISE images continue to display evidence for massive amounts of erosion on these layered units in and around Valles Marineris.

References


