**STRATIGRAPHY OF EASTERN COPRATES CHASMA, MARS.** R. A. Beyer, A. S. McEwen, *Department of Planetary Sciences, Lunar and Planetary Lab, The University of Arizona, Tucson AZ 85721-0092, USA, (rbeyer@lpl.arizona.edu).*

The Mars Orbital Camera (MOC) onboard the Mars Global Surveyor (MGS) spacecraft has observed extensive layering near the martian surface and in the Valles Marineris system [1]. Layering seen in the walls of terrestrial canyons is often sedimentary in nature, with new layers being put down by the slow process of deposition from rivers, lakes, or oceans. Alternately, volcanic processes with multiple episodes can deposit many layers of volcanic rocks and/or tephra, and intrusive magmatism can also create layered sequences at depth that are later revealed by erosion and uplift. The Valles Marineris is the only canyon that cuts deep into the martian crust. The origin of the layers is unknown, but there are hypotheses for both sedimentary [2] and volcanic origins [e.g. 1, 3]. Also relevant to the exposures that we see today are the formation processes of the giant chasma system itself [e.g. 4, 5, 6, 7] and what geologic changes the region has gone through since that time.

The synthesis of imaging datasets like MOC and the Thermal Emission Imaging System (THEMIS) with well-controlled topographic data from the Mars Orbital Laser Altimeter (MOLA) has allowed us to analyze the stratigraphy of the eastern portion of Coprates Chasma, in the Valles Marineris system.

**Stratigraphic Obervations**

Distinct competent layers are observed in the wall rock of eastern Coprates Chasma, part of the Valles Marineris system on Mars. These layers are visible in both MOC and THEMIS images of the north wall of the chasma, the free-standing massif in the middle of the chasma, and to a lesser extent on the chasma's south wall.

Our observations indicate that the stratigraphy of Coprates Chasma consists of alternating thin strong layers and thicker sequences of weak layers. The strong, competent layers act to maintain steeper slopes and play a major role in the overall slope and geomorphology of the chasma walls. The strong layers occur singly, or in thin sequences compared to the more massive sequences of intervening relatively weak layers. Furthermore, the competent layers are the source of meter-scale boulders that can be seen just downslope of some outcrops. The weaker layers must erode into fragments smaller than a few meters (less than current best camera resolution).

Our ability to confidently trace layers in the chasma decreases with decreasing elevation. Layers near the top of the stack are easy to identify because they are not covered by talus. The topmost competent layer in this area is well-preserved and easy to identify in outcrops in the northern wall of the chasma less than a hundred meters below the elevation of the plateau surface (Fig 1). The strength of this layer is most evident where it outcrops near the crest of the massif in Coprates Chasma (Fig 2). This massif is characterized by flat-topped areas at its crest which preserve pre-existing plains surface. The flat-topped areas of the massif owe their existance to the presence of this topmost strong layer which resists erosion. We have been able to identify this topmost strong layer in the northern wall of Coprates Chasma, but not in the southern wall.

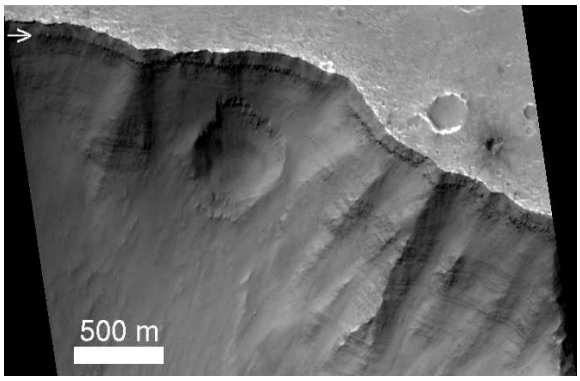


Figure 1: This is a portion of MOC image E03/02145 that covers the north wall of Coprates Chasma. The arrow marks the location of the topmost strong layer.

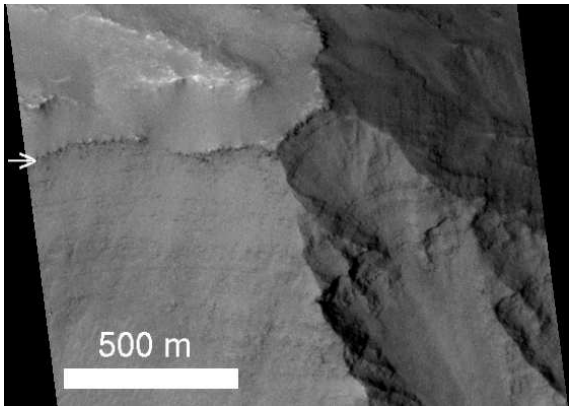


Figure 2: This is a portion of MOC image M08/05277 that crosses the crest of the massif. The arrow marks the location of the topmost strong layer here.

Given the dark tone and relatively high strength of these competent layers, we feel that their most likely composition is that of basalt. The topmost competent layer exhibits a morphology and extent that is comparable to terrestrial flood basalts. The other competent layers further down the stack are more difficult to characterize, and may be thin flows interbedded with tephra or other sediments, they may even be intrusive sills. A basaltic composition is indicated by Phobos ISM [8], TES [9] and THEMIS [10] measurements of martian surface composition. Given the footprint size of these instruments, they are probably sampling the intervening weak layers to a large extent, although the strong layers could have

stronger absorption bands, dominating the signal. The relatively weak layers are probably not thick basaltic lava flows, but could have a basaltic composition. It is expected that there is a much greater ratio of tephra to lava on Mars than on Earth [11]. However, given the overall strength of the wallslopes [12], they are probably not unconsolidated sediments.

**Layers as a Tectonic Marker**

The topmost strong layer can be identified in several places along the massif, and in the chasma wall to the north. The layer in the massif essentially has three segments from east to west as shown in Fig. 3. The westernmost segment has a dip of $0.39^\circ$ down to the west over a 20 km distance, the next segment has a dip of $0.09^\circ$ down to the west over a 78 km distance. The easternmost segment has a dip of $0.05^\circ$ down to the west or east over 23 km, due to the different elevation of outcrop on the north and south sides of the massif crest in M03/06302. The most extreme dip down to the south within the massif itself is in this same image which is $3.65^\circ$ over a 610 m distance. The layer also outcrops on both the north and south faces of the massif in AB1/08003 over the westernmost flat-topped area of the massif, but the difference in elevation is only a few meters over a much greater distance.

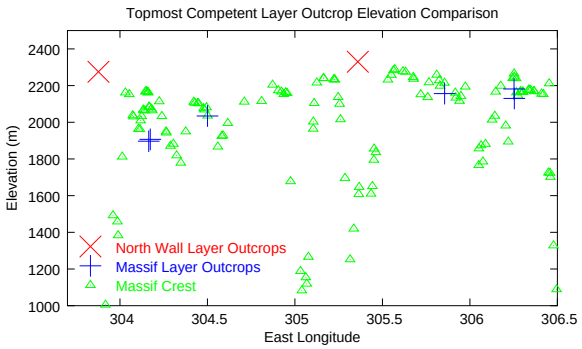


Figure 3: This shows the outcrop locations of the topmost strong layer both in the massif and in the north wall of E. Coprates Chasma. The elevations of the crest of the massif are also plotted to show the variability of the massif crest in relation to the layer outcrops.

Similarly, we can take a look at the two outcrops of this layer in the wall to the north of the Coprates massif, and we see that over the roughly 86 km that separates them, the elevation difference of the two outcrops is 60 m, indicating that the layer in the wall is flat-lying relative to the layer in the massif. We estimate that the thickness of the layer itself is probably about 10 m. In looking at the relative elevations of the outcrop in the north wall of Coprates and in the massif, the elevations of the outcrop in the massif are 150 m to 350 m lower than that in the chasma wall.

These measurements indicate that the massif has undergone some complicated tectonic motions resulting in a subsidence down to the west and south. It has long been thought that this portion of the Valles Marineris is a north-south extentional graben system [5,13], and these measurements indicate that the massif is indeed a horst block.

**Conclusions**

These observations of the layering in eastern Coprates Chasma indicate that the material into which the chasma is carved consists of alternating strong and weak layers. The presence and extent of the occasional strong layers has a large impact on chasma and wall slope morphology. Different combinations of strong and weak layers may have some impact into the varying morphologic character of chasmata within the Valles Marineris, as well as the location and size of landslides. This also explains the paucity of observed boulders on Valles Marineris wallslopes if the thin strong layers are the only source of greater than meter-sized boulders.

Understanding the stratigraphy has also led us to identify a strong layer near the top of the stack. This layer shows an elevation offset between its outcrops in the nothern chasma wall and its outcrops in the massif indicating subsidence of the massif, most likely due to extensional fault motion. There are several models for how the Valles Marineris formed, including different combinations of rifting, collapse, and mass wasting. These observations indicate that this portion of Coprates Chasma formed primarily by extensional fault motion.

**References:** [1] A. S. McEwen, M. C. Malin, M. H. Carr, and W. K. Hartmann. Voluminous volcanism on early Mars revealed in Valles Marineris. *Nature*, 397:584–586, 1999. [2] M. C. Malin and K. S. Edgett. Sedimentary Rocks of Early Mars. *Science*, 290:1927–1937, 2000. [3] J. Williams, D. A. Paige, and C. E. Manning. Layering in the wall rock of Valles Marineris: intrusive and extrusive magmatism. *GRL*, 30:25–1, 2003. [4] K. L. Tanaka and M. P. Golombek. Martian tension fractures and the formation of grabens and collapse features at Valles Marineris. In *LPSC*, p.383–396, 1989. [5] R. A. Schultz. Structural development of Coprates Chasma and western Ophir Planum, Valles Marineris Rift, Mars. *JGR*, 96:22777–22792, 1991. [6] B. K. Lucchitta, A. S. McEwen, G. D. Clow, P. E. Geissler, R. B. Singer, R. A. Schultz, and S. W. Squyres. The canyon system on Mars. In *Mars*, p.453–492, 1992. [7] J.-P. Peulvast, D. Mège, J. Chiciak, F. Costard , and P. L. Masson. Morphology, Evolution and Tectonics of Valles Marineris Wallslopes (Mars). *Geomorphology*, 37:329–352, 2001. [8] S. Murchie, L. Kirkland, S. Erard, J. Mustard, and M. Robinson. Near-Infrared Spectral Variations of Martian Surface Materials from ISM Imaging Spectrometer Data. *Icarus*, 147:444–471, 2000. [9] J. L. Bandfield, V. E. Hamilton, and P. R. Christensen. A Global View of Martian Surface Compositions from MGS-TES. *Science*, 287:1626–1630, 2000. [10] P. R. Christensen, et al. Early Results from the Odyssey THEMIS Investigation. In *LPSC*, #1519, 2003. [11] L. Wilson and J. W. Head. Mars: Review and analysis of volcanic eruption theory and relationships to observed landforms. *Reviews of Geophysics*, 32:221–263, 1994. [12] R. A. Schultz. Stability of rock slopes in Valles Marineris, Mars. *GRL*, 29:38–1, 2002. [13] R. A. Schultz. Multiple-process origin of Valles Marineris basins and troughs, Mars. *Plan. Sp. Sci.*, 46:827–834, 1998.