THE LAYERED UPPER CRUST OF MARS: AN UPDATE ON MGS MOC OBSERVATIONS AFTER TWO MARS YEARS IN THE MAPPING ORBIT. K. S. Edgett and M. C. Malin, Malin Space Science Systems, Inc., P.O. Box 910148, San Diego, California 92191-0148, USA.

Introduction: The upper crust of Mars is layered and geologically diverse. Burial and exhumation complicate the use of impact craters to determine the age of materials. Since September 1997, we have employed the Mars Global Surveyor (MGS) Mars Orbiter Camera (MOC) to test hypotheses regarding the nature of the layered crust [1, 2]. Here we summarize key observations and update earlier findings, based on new MOC images acquired in 2002 and early 2003.

North Polar Stratigraphy—A Third Unit: Two distinct stratigraphic units were recognized in the north polar layered materials from MOC images acquired 1999–2001: a lower, dark-toned layered unit and a younger, upper, lighter-toned layered unit [1, 3, 4]. The lower unit is a source for dune-forming sand [3, 4] and erosion of this unit by wind is proposed to cause the undermining that creates north polar arcuate scarps [4]. In a recent paper, we stated that there are no other stratigraphic units [4]. We were wrong. Late 2002 MOC images of the arcuate scarp at the end of Chasma Boreale show that there is a third unit, distinct from the other two, that underlies the dark-toned sand-producing unit (Fig. 1). Now that we know what the unit looks like, we find that it is readily recognized in earlier images. The north polar layers preserve a record of at least three major, distinct changes in sedimentary material and depositional pattern over time.

Athabasca Vallis Source is Buried: The channeled scabland of Athabasca Vallis and a similar valley system in east Cerberus were proposed to be young features that resulted from discharge of water from the Cerberus Fossae [5]. The main argument against this hypothesis for the fluid source has been evident since the early MGS mission: image SP2-53103 shows a large streamlined "island" in the wake of a crater that was cut by one of the Cerberus Fossae. The trough post-dates the crater and the streamlined landform. More importantly, the size and location of the streamlined landform indicates that the responsible fluid had sufficient volume and energy to create the "island" where it is found—thus the source must have been farther away, somewhere further up-slope, where there are no Cerberus Fossae troughs. Recent MOC images (e.g., Fig. 2) show that the scabland landforms emerge, fully-born, from beneath a plain in eastern Cerberus. Either the entire Athabasca Vallis system (and its eastern counterpart) were buried and are now being exhumed from beneath this plain, or the valley system headward of this location was buried by these plains-forming materials. In either case, the original source for Athabasca Vallis and its eastern counterpart may be the same: it is buried, and is probably located north of Cerberus on the Elysium rise.

Strata and Interbedded Craters of Sinus Meridiani and West Arabia Terra: North Sinus Meridiani presents a vast, Colorado Plateau-scale exposure of layered, sedimentary rock [2, 6]. We examined a region between 2°–9°N, 1°–8°W and found that light-toned, layered bedrock in northwest Sinus Meridiani can be traced into western Arabia Terra, where the materials are mantled by dust. The rock units are divided into four distinct stratigraphic units. Impact craters of diameters 30–60 km are interbedded with these ~200 m-thick units, attesting to their antiquity, revealing unconformities between units, and indicating that sediment deposition spanned considerable time. The crater at 8°N, 7°W, which contains spectacular repeated sedimentary layers (e.g., E05-00804), was once buried beneath > 600 m of material. The layers in this crater formed in a different environment than the layered material outside the crater. Details on these results were recently presented by Edgett and Malin [6].

Layers Beneath Lunae, Syria, and Sinai Plains are Exposed in Valles Marineris: The results from Sinus Meridiani demonstrate that the martian crust is a layered, cratered volume [6]. Observations of strata inside and outside the crater at 8°N, 7°W, show that craters interbedded with intercrater strata may contain layered materials of different physical attributes than those outside the crater [6]. An extension of these results applies to the Valles Marineris interior layered units, which most investigators consider to be lacustrine, eolian, or volcaniclastic materials deposited in the chasms after they formed. The Valles Marineris cut through portions of the Lunae, Syria, and Sinai plains. The earliest Mariner 9-based geologic maps of Mars, and all similar maps since then, acknowledge that, beneath these plains, there must lie older, heavily cratered terrain. Craters must have been filled and became buried beneath the plains, through which the Valles Marineris troughs were later cut by extension. The work in Sinus Meridiani [6] shows an example of what may lie beneath these plains—thick intercrater strata with large, interbedded impact craters, each with its own layered fill, each perhaps with a fill that is different from the strata outside the crater. Craters similar to and larger than the one at 8°N, 7°W, should have been buried beneath the plains through which the Valles

Marineris are cut. MOC images have been used to predictively test this hypothesis; they show examples of light-toned, layered outcrops in the walls of the Valles Marineris [1, 2] (Fig. 3). Light-toned outcrops are also exposed on plains above Ius Chasma (e.g., M21-01527), and some layers in walls of Ius and west Candor have similar thickness and repeated qualities as layers in southwest Candor Chasma.

Age of Light-toned Layered Outcrops: Some investigators propose that the light-toned, layered, sedimentary materials described by Malin and Edgett [2] are geologically young ("Amazonian") features [e.g., 7]. MOC images demonstrate otherwise—the materials are quite ancient ("Noachian" or "pre-Noachian"). For example, light-toned outcrops at the mouth of Mawrth Vallis were cut by the valley-forming process. Likewise, light-toned layered outcrops in south Holden Crater were cut by Uzboi Vallis. In both cases, the layered materials were lithified prior to being cut by a valley; they must date back to a time when it was still possible for such valleys to form. Our work in Sinus Meridiani demonstrates the interbedding of impact craters and the antiquity of these materials [6], and light-toned layered material exposed in the walls of the Valles Marineris likewise indicate an extremely ancient setting for deposition of those materials.

References: [1] Malin M. C. and Edgett K. S. (2001) *JGR, 106(E10),* 23429–23570. [2] Malin M. C. and Edgett K. S. (2000) *Science, 290,* 1927–1937. [3] Byrne S. and Murray B. C. (2002) *JGR, 107(E6),* 5044, doi:10.1029/2001JE001615. [4] Edgett K. S. et al. (in press) *Geomorphology*. [5] Burr D. M. et al. (2002) *Icarus, 159,* 53–73. [6] Edgett K. S. and Malin M. C. (2002) *GRL, 29(24),* 2179, doi:10.1029/2002GL016515. [7] Hynek B. M. et al. (2002) *LPS XXXIII*, Abs. #1408.

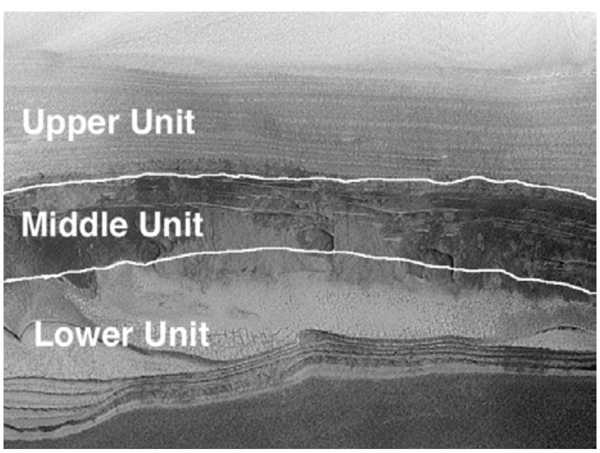

Figure 1. Three north polar stratigraphic units exposed in Chasma Boreale arcuate scarp. Sub-frame of MOC image E21-01534; 84.8°N, 356.6°W; 2.3 km wide.

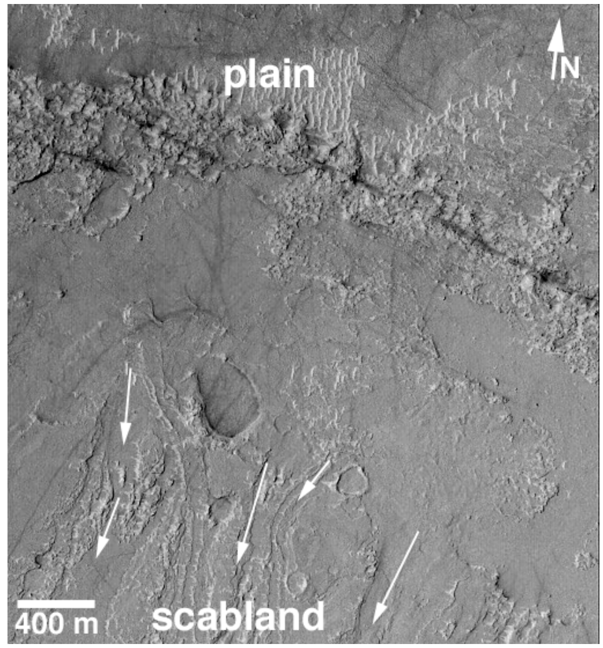

Figure 2. The Athabasca Vallis channeled scabland emerges, fully-born, from beneath plains near 10.3°N, 202.3°W. Arrows indicate direction of fluid flow inferred from channel landforms. Sub-frame of MOC image E21-01518.

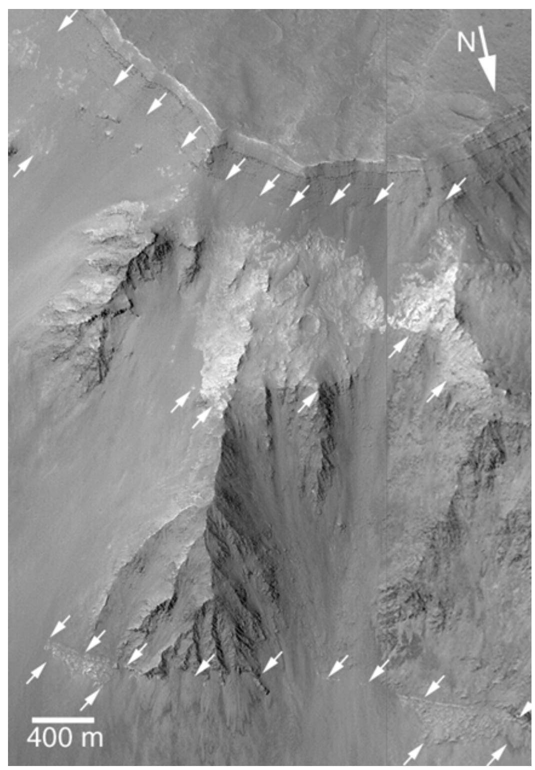

Figure 3. Light-toned layered outcrops in the southwest wall of Ganges Chasma. Arrows indicate locations of outcrops; there are two light-toned units exposed at this location. This is a mosaic of sub-frames of MOC images M04-01352 and E17-01695, located near 8.8°S, 52.4°W.