**VALLEYS AND CHANNELS IN THE MARTIAN ROCK RECORD.** K. S Edgett and R. M. E. Williams, Malin Space Science Systems, Inc., P. O. Box 910148, San Diego, CA 92191-0148, USA.

**Synopsis:** The upper crust of Mars is a layered, cratered volume [1, 2]. The geologic history of Mars is preserved in layered rock to depths probably > 10 km. The record is, of course, incomplete, with erosional unconformities marking the places in which the record has been destroyed. Erosional unconformities can often be recognized by the presence of filled and buried impact craters and valleys or channels. The present surface of Mars is the product of the last vigorous erosional and depositional episodes that occurred on the planet. Ancient craters and valley systems presently at the surface may not have always been at the surface. Some were filled, buried, and then exhumed. Some valley systems today remain only partly exposed at the surface; others have been erased or partly erased as the strata through which they cut have been eroded away. Still others have been inverted, and, finally, many ancient valley systems probably remain buried, locked tightly within the martian rock record.

**Gale Crater Example:** Gale Crater illustrates, at a small scale, the nature of the upper martian crust at a global scale. North-central Gale Crater contains a mound of layered, sedimentary rock that is more than twice the thickness of the Phanerozic rock sequence exposed in Arizona's Grand Canyon (Fig. 1). The 5 km high mound contains several different rock units distinguished by bedding properties, relative albedo, and erosional form [3, 4]. Between some of these units lie clearly distinguished erosional unconformities. Craters and valley/channel systems that formed on these erosional surfaces were later filled and buried by subsequent sedimentary materials. Eventually, some of these filled and buried craters and channels were exposed to the modern surface environment by erosion. The top of the layered sequence lies above the rim of Gale Crater, indicating that Gale itself was not only filled, it was once completely buried and later exhumed.

**Northwest Meridiani Example:** A regional-scale example of the layered, cratered volume nature of the upper martian crust can be found in northwestern Sinus Meridiani and southwestern Arabia Terra [1]. There, craters with diameters up to 65 km are interbedded with the layered bedrock of the region (Fig. 2). The layers are laterally heterogeneous as illustrated by the different physical properties of sedimentary rocks within and outside a 65-km-diameter crater at 8°N, 7°W. Hundreds of repeated beds that form yardangs and erode into a stair-stepped pattern are preserved within the 8°N, 7°W, crater; these are in contrast to the more massively-bedded strata surrounding the crater. Within this study region lies an inverted channel with two sinuous branches and an apparent terminal deposit (or "pond") (Fig. 2b). Stratigraphically, this small inverted valley system lies several hundred meters to a kilometer below the layered, sedimentary rocks examined by the Opportunity (MER-B) rover in 2004. Its relation to the MER-B site and its setting among a thick layered sequence that includes filled, buried, and exhumed craters of 10s of kilometers diameter attests to the complexity of the geologic history of the region.

**Eberswalde Crater Fan:** In late 2003, Malin and Edgett [5] described the best evidence for the past action of liquid water ever found (up to that time) on Mars. A delta-like fan is located in a crater immediately northeast of Holden Crater near 24.3°S, 33.5°W (formerly "Holden NE Crater," but provisionally named Eberswalde Crater by the International Astronomical Union). The fan is a part of the martian rock record. It is an exhumed feature that was once buried beneath an unknown amount of rock. Upon exhumation, finer and/or more poorly indurated material between the channels in the fan were removed, leaving the channels as high-standing, inverted features [5, 6]. Some of the valleys that may have contributed sediment to this fan still exist today, but others have been removed, perhaps when the strata through which they cut were stripped away.

**Aeolis Fan:** Landforms somewhat similar to the Ebserwalde Crater fan are found in the Aeolis region, immediately north of the cratered highland/lowlands dichotomy boundary. Dozens of locations in this area exhibit inverted channels at different levels within a stratigraphy of materials that have been eroded by wind to form yardangs. Figure 3 shows a fan in which a radiating pattern of inverted ridges is partially exhumed from beneath stratigraphically higher material. The problem with the spectacular fan in Figure 3 (and its similar, neighboring inverted channel landforms) lies in the fact that, unlike Eberswalde Crater, there are no obvious contributing valleys connected to the proximal end of the fan. The conduits through which sediment was delivered to this location are either still buried, or have been eroded away.

**Eastern Arabia Valleys and Inverted Valleys:** Eastern Arabia Terra abounds with valley network systems. The region also exhibits considerable erosion and exposure of formerly filled and buried impact craters in a layered upper crust. Some of the valley network systems in the region have been inverted as erosion removed the rock surrounding a former valley, then left its floor standing high as a sinuous caprock protecting less-resistant rock beneath it. Portions of other valley network systems have vanished completely as the rock through which the valleys cut was removed. One unnamed valley in eastern Arabia (33°N, 314°W) transitions from negative to positive relief along its course (Fig. 4). Similarly, some of the southern reaches of Auqakuh and Huo Hsing Valles exhibit inverted relief in some areas, and complete removal (stripping away of the rock units cut by the valley) in others.

**Discussion:** The observations presented here are related merely to give a glimpse into a growing picture of the nature of the upper martian crust. Most importantly, the recognition that valley systems (and even some outflow channels, such as Mawrth Vallis), as we see them expressed at the surface today, are the products of the combined forces of burial, exhumation, and erosion. In planview, some of the major martian valley systems, such as Scamander and Nanedi Valles, appear to originate with no clear source region and/or terminate abruptly with no associated deposit. They seem to be coming from nowhere and/or going nowhere. The discontinuous preservation of martian valley systems may partially explain several puzzles commonly observed and discussed over the past three decades:

Q1. Where are the lower order tributaries to the valley networks?

A1. Some cut through strata that were long ago removed by erosion; others are filled, buried, and locked beneath the surface within the martian rock record.

Q2. Why do some valleys appear to abruptly originate full born?

A2. Because their proximal ends may still be buried within the martian crust; alternatively, they may have occurred in strata that were removed by erosion.

Q3. Why do some valleys seemingly disappear with no obvious deposit at the distal end?

A3. Because the distal end of the valley and its deposits may either still be locked within the rock record, or these materials were removed by erosion.

And so forth. The point here is that every valley system evident at the surface of Mars today, whether of negative or positive relief, needs to be considered in a full, three-dimensional context, with recognition that many such systems occur within a complex rock record that is today only vaguely known from what we can see at the planet's surface.

**References:** [1] Edgett, K. S., and M. C. Malin (2002) *GRL*, *29*(24), 2179, doi:10.1029/2002GL016515. [2] Edgett, K. S., and M. C. Malin (2004) *LPSC XXXV*, Abstract 1188. [3] Malin, M. C., and K. S. Edgett (2000) *Science*, *290*, 1845–2020. [4] Edgett, K. S., and M. C. Malin (2001) *LPSC XXXII*, Abstract 1005. [5] Malin, M. C., and K. S. Edgett (2003) *Science*, *302*, 1931–1934. [6] Moore, J. M., et al., (2003) *GRL*, *30*, 2292, doi:10.1029/2003GL019002.

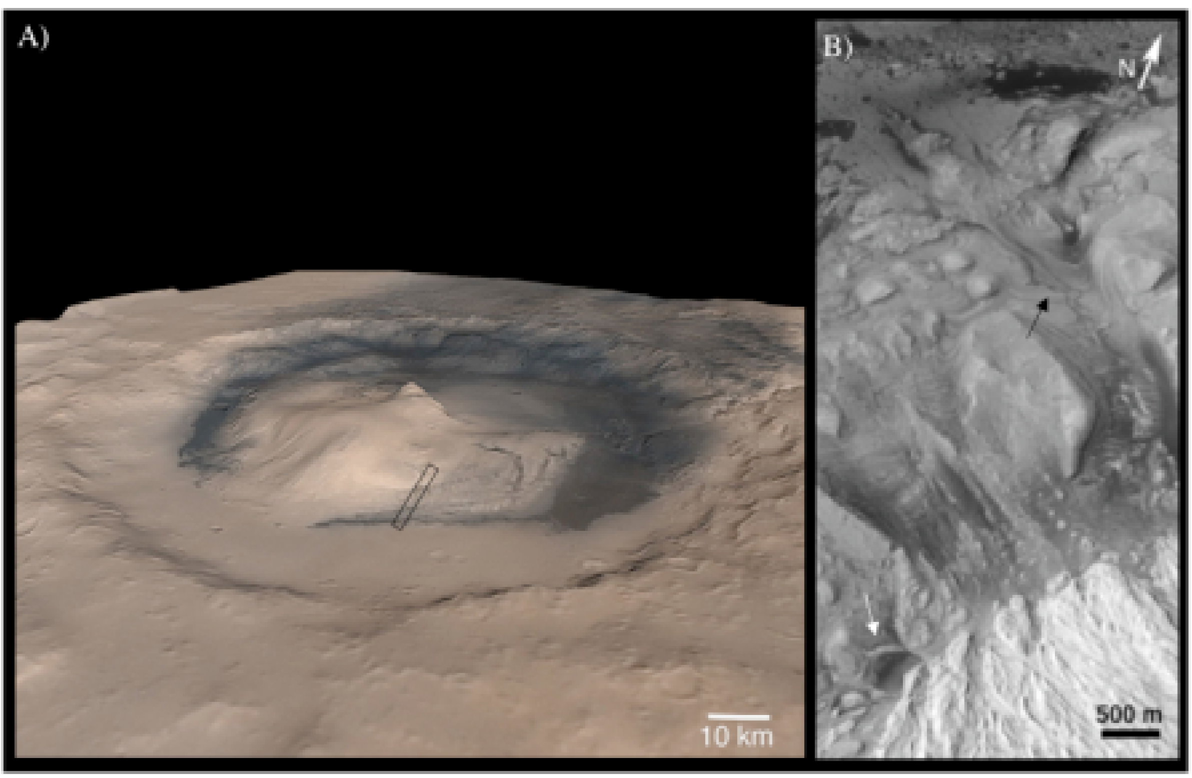


**Figure 1: A)** Oblique view looking southeast at Gale Crater and 5 km-high interior mound of layered material. Black box corresponds to MOC image M03-01521. **B)**. Detailed view of M03-01521with partly exhumed impact crater (white arrow) marking location of an unconformity in the layered sequence. Black arrow marks location of exhumed, partially-filled channel cut into layered outcrops. See [3,4] for further details.

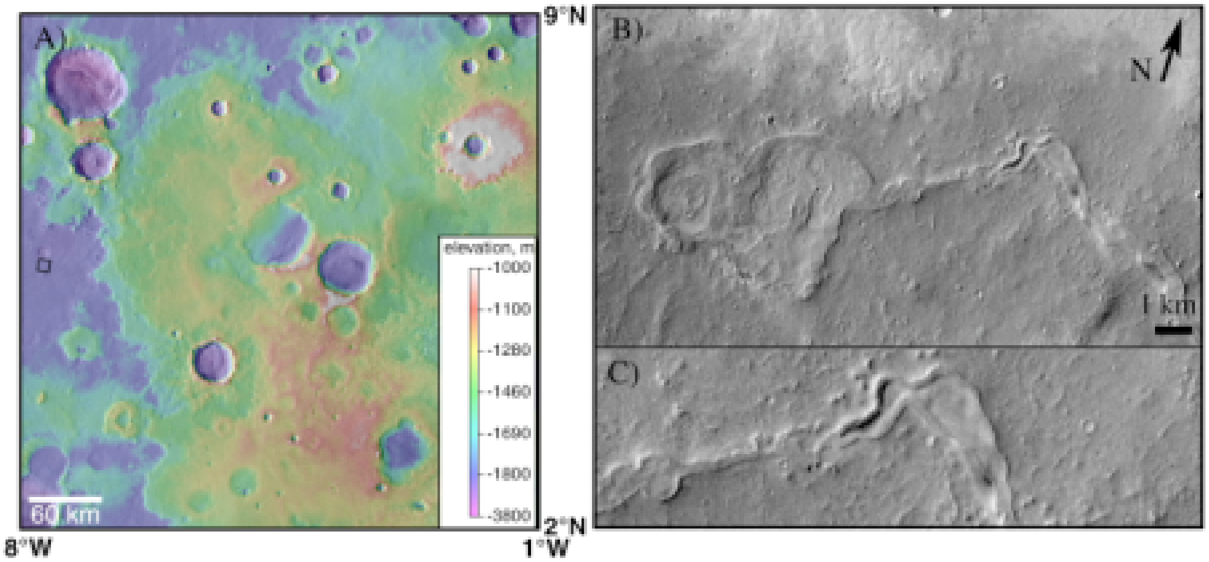


**Figure 2:** **A)** Topographic map of northwest Sinus Meridiani and southwest Arabia Terra. Note the elevation scale is not linear. Black box indicates location of B). A stratigraphic column and further details about the layered, cratered volume story for this region are presented in [1]. **B)** THEMIS VIS V04132003 shows an inverted channel system with an inverted deposit at its distal end that may be former region of ponding. **C)** A 2x enlargement of B) to highlight the two sinuous inverted ridges which meet to form a single inverted ridge near image center.

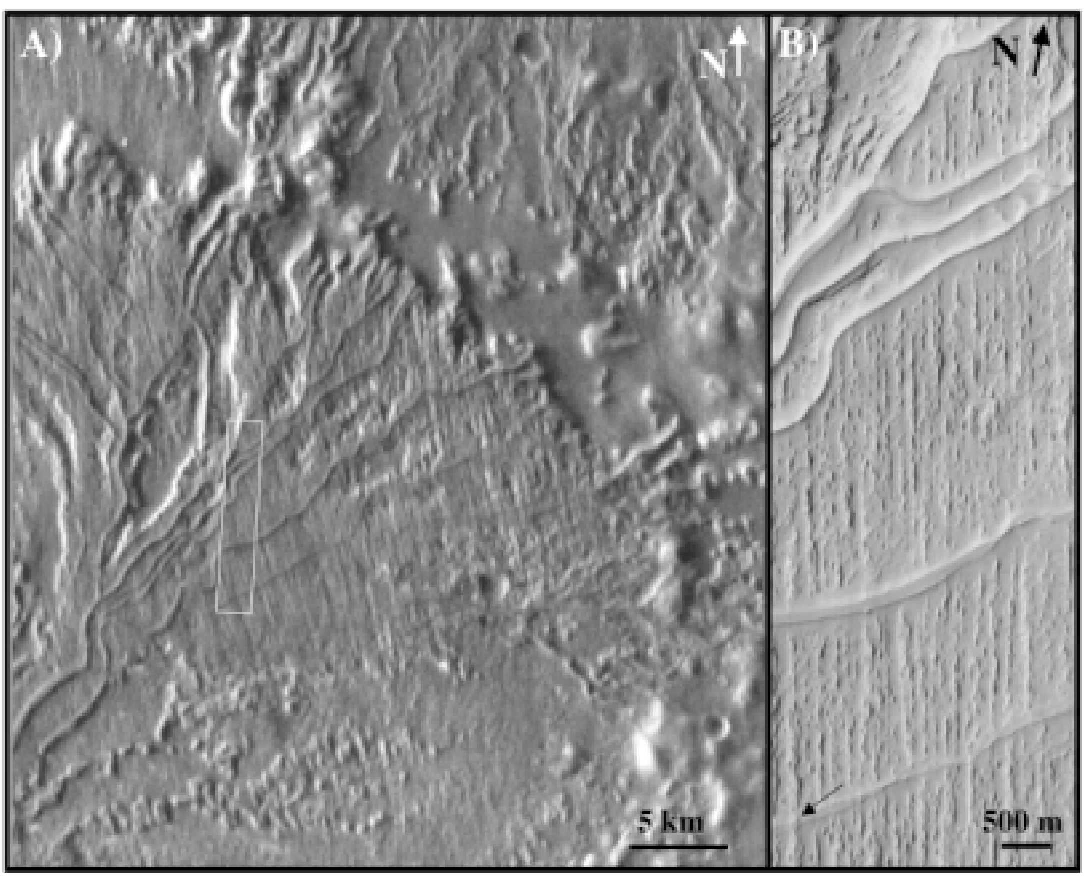


**Figure 3:** **A)** THEMIS IR image I05588001 of a fan-shape landform centered at 6.3° S 208° W in Aeolis Mensae region. A radiating pattern of bifurcating ridges is being exhumed from beneath a stratigraphically higher layer. White box is location of B). **B)** MOC NA E18-00307 illustrates the branching ridges are below strata that is eroding to form yardanges (arrow).

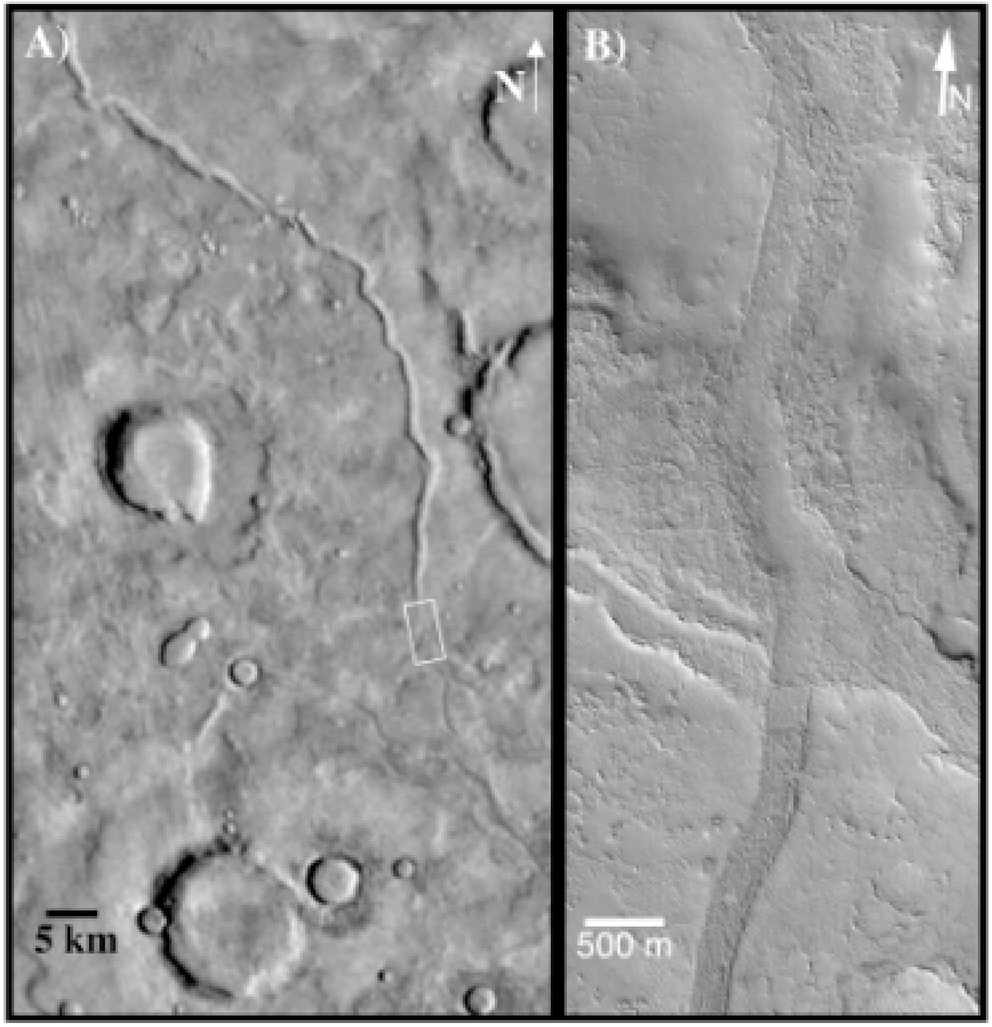


**Figure 4: A)** Viking MDIM view of unnamed valley in eastern Arabia Terra centered at 33°N, 314°W with negative relief along much of its course. No tributary channels are evident in the source region. Rather, the valley appears to originate full born. The white box is the location of cutout from MOC image R09-00568, shown in **B)**. At this location, the ancient valley landform transitions from positive to negative and back to positive relief.