VALLEYS IN THE MARTIAN ROCK RECORD. R. M. E. Williams[1], and K. S. Edgett[2], [1]CEPS/NASM MRC 315, Smithsonian Institution, Washington, D.C. 20013-7012, williamsrm@si.edu, [2]Malin Space Science Systems, Inc., P.O. Box 910148, San Diego, CA 92191-0148, USA.

Synopsis: Filled, buried, and exhumed craters at a variety of scales (diameters ranging from meters to >100 kilometers) are found at multiple stratigraphic levels within the upper 10 or more kilometers of the martian crust [1]. Similarly, valleys systems are also part of the layered upper crust [2] and exhibit a variety of preservation states including partial or discontinuous exposure and inverted relief evident in Mars Orbiter Camera (MOC; 1.5-12 m/pix) and Thermal Emission Imaging System (THEMIS; 10-100 m/pix) images. Inversion of relief occurs by denudation in cases where floor material of a channel or depression is more resistant (intrinsically, armored by clasts or via cementation) than its surroundings, or where material that filled a channel is more resistant to erosion. The less resistant rock into which the channel was originally cut is eroded away, and the former topographic low is preserved at higher elevation than the surrounding terrain. The valley systems, as observed today, are the products of the combined forces of burial, exhumation and erosion. The martian rock record indicates that fluvial processes were not confined to the earliest epoch but operated past the earliest time of heavy impact cratering. Select examples of valleys within the martian rock record are presented here. They illustrate a variety of fluvial environments.

Gale Crater: Gale Crater illustrates, at a small scale, the nature of the upper martian crust at a global scale. North-central Gale Crater contains a ~5 kilometer thick mound comprised of several different layered rock units distinguished by bedding properties, relative albedo, and erosional form [3]. Between some of these units lie clearly distinguished erosional unconformities. Craters and valley systems that formed on these erosional surfaces were later filled and buried by subsequent sedimentary materials. Eventually, some of these buried craters and valleys were exposed at the modern surface by erosion. A filled valley is evident within a channel on the northern flank of this layered mound and is part of the multiple cycles of erosion and deposition recorded within this sedimentary rock sequence. The top of the sequence lies above the rim of Gale Crate indicating that Gale itself was not only filled, it was buried and has been exhumed.

Arabia Terra: Arabia Terra and adjacent areas in Sinus Meridiani exhibit considerable erosion and exposure of formerly filled and buried impact craters in a layered upper crust. Inverted valleys and valleys nearly removed by erosion of the rock into which they were cut are also present all across Arabia Terra, particularly the eastern region, and in northern Meridiani (Fig. 1). For example, one unnamed valley in eastern Arabia (33^{o}N, 314^{o}W) transitions from negative to positive relief along its course with the channel floor preserved locally as a low-relief plateau (Fig. 2). 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.

Distributary Fans: Inversion of relief also preserves details of depositional settings. Malin and Edgett [4] discovered a distributary fan and associated layered sedimentary rock complex located in the provisionally-named Eberswalde Crater, located near 24.3°S, 33.5°W. The fan is comprised of at least three lobes which are defined by cross-cutting ridges interpreted to be inverted relief channels. The morphometric character of the landform led two independent research groups to interpret this landforms as an eroded or exhumed deltaic deposit [4, 5]. Noteworthy is the identification of a cutoff meander loop (in inverted relief), direct evidence of persistent fluvial activity within the system. Some of the valleys that may have contributed sediment to this fan still exist today, but others were removed, perhaps when the strata through which they cut were stripped away.

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 likely still buried, or alternatively, have been eroded away.

Discussion: One of the problems with valley network research as it has been conducted for the past 30+ years is the lack of recognition that the valley networks occur in a stratigraphic context. The modern surface expression of valleys, whether in negative or positive relief forms, provides an incomplete picture of the valley system when it formed. In some cases, the source areas for valley are still buried or occurred in rock that has long since been eroded away. In other cases, only segments of the original valley are visible at the surface today. Many valley systems occur within a complex rock record that is today only vaguely known from what is observed at the planet's surface.

References: [1] Edgett K. S. and Malin M. C. (2002) *GRL, 29,* 2179, doi:10.1029/2002GL016515. [2] Edgett K. S. and Malin M. C. (2004) *LPS XXXV*, Abstract#1188. [3] Malin M. C. and Edgett K. S. (2000) *Science*, *290*, 1927-1937. [4] Malin M. C. and Edgett K. S. (2003) *Science*, *302*, 1931-934. [5] Moore J. M. et al. (2003) *GRL*, *30*, 2292, doi: 10.1029/2003GL019002.

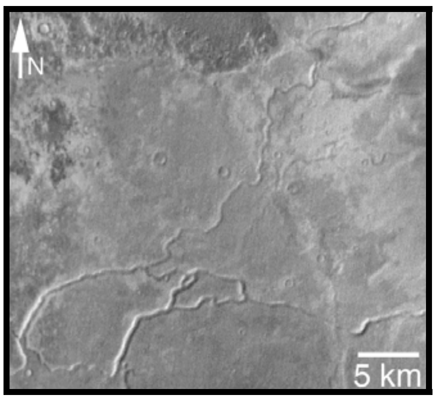

Figure 1: Example of inverted valleys in northeast Sinus Meridiani, THEMIS I01173002, I03707002.

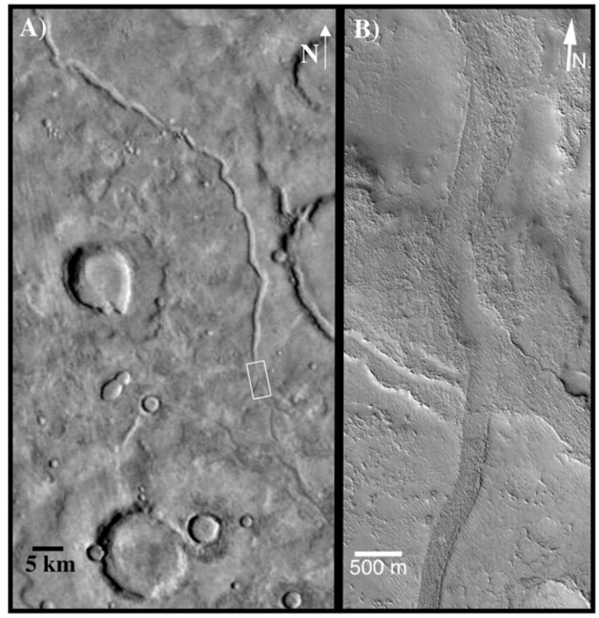

Figure 2: A) Viking MDIM view of valley in eastern Arabia Terra centered at 33°N, 314°W, with negative relief along much of its course. The white box is the location of cutout from MOC image R09-00568, shown in **B)**. At this location, the ancient valley landform transitions from positive to negative and back to positive relief.

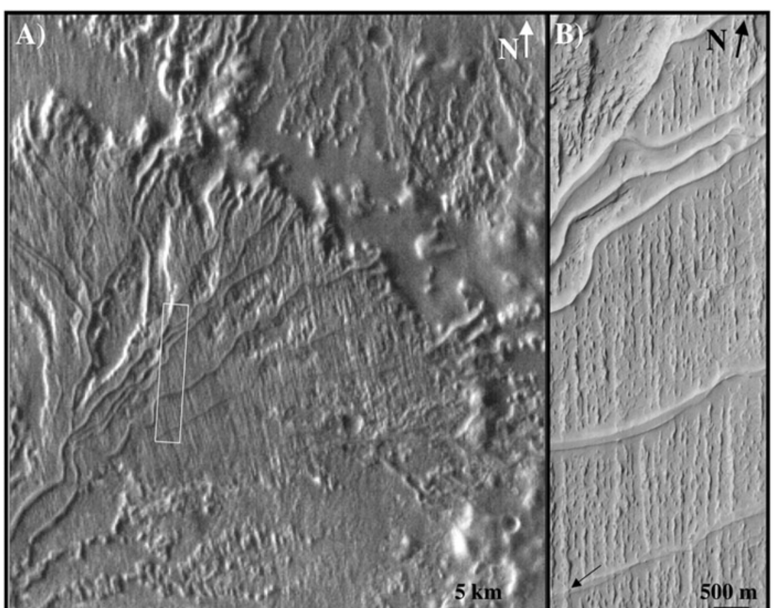

Figure 3: A) Fan-shaped landform centered at 6.3°S 208°W in Aeolis Mensae region (THEMIS I05588001). A radiating pattern of bifurcating ridges is being exhumed from beneath a stratigraphically higher layer. White box is location of B). **B)** MOC E11-00307 shows that the branching ridges are below strata that are eroding to form yardangs (arrow).