REMNANTS OF THE COURSES OF FINE-SCALE, PRECIPITATION-FED RUNOFF STREAMS PRESERVED IN THE MARTIAN ROCK RECORD. R. M. E. Williams[1], M. C. Malin[2], and K. S. Edgett[2], [1]CEPS/NASM MRC 315, Smithsonian Institute, Washington, DC 20013-7012, USA, [2]Malin Space Science Systems, PO Box 910148, San Diego, CA 92191-0148 USA.

Introduction: The martian rock record includes interbedded valleys and streams at dozens of locations around the globe [1]. A spectacular suite of small, branched landforms, comparable in scale and topology to terrestrial creeks formed by precipitation and surface runoff, has been exhumed (and, in some cases, inverted) by erosion in and near the Valles Marineris (Fig. 1a). These occurrences attest to the rich and complex geologic history of the layered rocks cut by the walls of the Valles Marineris chasms. The assumption since Mariner 9 has been that the plains cut by the Valles Marineris are surfaced and underlain by flood basalts [*e.g.*, 2]. However, the layered sequences, and the preservation of erosional surfaces, particularly the streams themselves, indicate a very different history.

West Juventae Inverted Streams: Fine-scale branching networks of sinuous ridges located just beyond the west rim of Juventae Chasma, first noted by Malin and Edgett [3], have been exposed by erosion of light-toned, layered, rock. The ridges are the inverted courses of former streams (Fig. 1b). The stream features were preserved within rocks at the very top of the stratigraphic sequence cut by the chasm's west wall. They occur at several different levels within the layered stratigraphy. The rock beneath the inverted stream beds is finely layered. Four discreet third- and fourth-order stream networks have drainage densities among the highest observed on Mars (0.9–2.3 km^{-1}) and have been compared with terrestrial systems of the same scale. Rough order-of-magnitude discharges computed from Chezy/Manning equation and meander relations (~10–20 m^3/s) appear more consistent with bank-full peak discharge conditions than persistent or continuous flow. These values are generally comparable to similarly sized networks on Earth. Inverted streambeds consequent upon topographic highs (Fig. 1c), including a mare-type ("wrinkle") ridge that existed before the layered sequence into which the streams were cut and preserved, are first-order tributaries to the system, a rare occurrence on Mars.

Ganges, Coprates, and Melas: A few fine-scale, inverted as well as negative-relief stream features also occur on plains immediately south of Coprates Chasma and Melas Chasma as well as west of Ganges Chasma (Fig. 1d). At Ganges, the majority of landforms are just beginning to be inverted and exhumed. At Coprates, the features have negative relief, while at Melas they are inverted (ridges).

Echus Chasma: A group of landforms related to these observations also occurs west of and was cut by the west wall of Echus Chasma. These were initially described by Mangold et al. [4], who noted their presence in ~100 m/pixel Mars Odyssey THEMIS images. However, when examined at Mars Global Surveyor (MGS) Mars Orbiter Camera (MOC) scale, distinct valleys are not evident. The valleys have been widened and degraded by erosion to the point where they are barely distinguished at high resolution; the thermal signature results from the eolian bedforms that occupy the low points of these broadened valleys. At meter-scale resolution, these valley features are discontinuous and not connected to each other in the manner inferred by Mangold et al. [4]. THEMIS and MOC images together show that the valley features are confined to a suite of layered rock, above which and below which (to the depth made visible by erosion, at least) there are no preserved streams. Moving from west to east, toward the west rim of Echus Chasma, the streams transition from positive (*i.e.*, inverted) to negative relief as erosion has exposed different horizons (and preservation styles) within the strata. As at Juventae Chasma, stream features occur at several different levels within the stratigraphy.

Southwest Melas Chasma: A portion of southwest Melas Chasma exhibits evidence for fine-scale stream networks and depositional fans preserved within layered, sedimentary rock (Fig. 1e). These features are older than the related landforms described above. Here, a large bench of the chasm wall (> 100 x 25 km in extent) has dropped or slumped down into the chasm. Fine-scale stream features, including fragments of networks and both negative and positive forms, are observed at different stratigraphic positions within this block. Network continuity is difficult to trace because, in some cases, parts of the fossil streams have been eroded away or, in other cases, they are still buried within the bedrock. One deep depression reveals two fan-shaped forms, apparently distributary depositional fans, at different levels within the strata (Fig. 1f). Prior investigations [4, 5] have noted the occurrence of broader valleys on this block; these broader valleys are cut through the rock in which the fine-scale streams are preserved. MOC images illustrate that the

previously described networks are not drainages—they are not continuous, and in detail we have been unable to replicate the network patterns mapped in this area by Mangold et al. [4].

Conclusions: The observations presented here provide three key contributions to Mars science: (1) The fine-scale inverted streams—particularly the well-preserved suite and its association to pre-existing topographic forms west of Juventae Chasma—require precipitation-fed runoff to have formed. Rainfall seems most likely, in order to provide the volumes of liquid necessary. (2) As noted by Mangold et al. [4], these landforms and the layers in which they are preserved indicate a very different history than previously envisioned to form the uppermost plains cut by the Valles Marineris chasms. Because these plains are not heavily cratered, these observations require that precipitation-fed runoff occurred beyond the end of the period of heavy cratering (*i.e.*, into the Hesperian). (3) Over most of Mars, erosion and burial has destroyed most of the surface expression of first order tributaries and fine-scale networks. Such networks are preserved, however, in the martian rock record and exposed by erosion under unique circumstances in localized areas. Similar-scale networks of inverted streams occur elsewhere on Mars [1], but the most spectacular examples, and potentially the youngest, are those described here, associated with the Valles Marineris.

References: [1] Williams R. M. E. and Edgett K. S. (2005) *LPSC XXXVI*. [2] Whitbeck, N. E. et al. (1991) USGS Map I–2010. [3] Malin M. C. and Edgett K. S. (2003) *Science, 302,* 1931–1934 (note 13). [4] Mangold N. et al. (2004) *Science, 305*, 78–81. [5] Weitz C. et al., (2003) *JGR, 108,* doi: 10.1029/2002JE002022

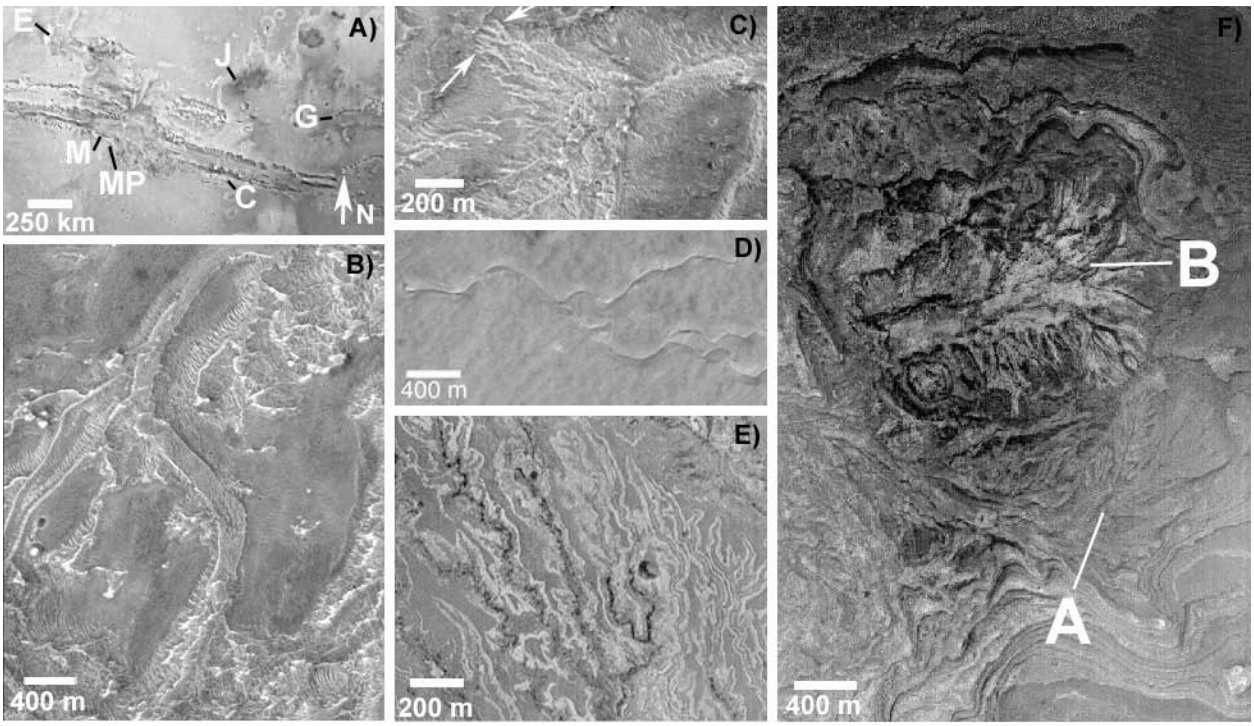

Figure 1: A) Location map for sites of fine-scale stream landforms referred to in text: E=Echus Chasma, J=Juventae Chasma, C=Coprates Chasma, G=Ganges Chasma, M=southwest Melas Chasma, MP=Melas Chasma. B) Sinuous inverted ridge network located on plains above west rim of Juventae Chasma (MOC image R08-02192). C) Branching tributary network with first-order segments (between two arrows) preserved in inverted relief on plains west of Juventae Chasma (R12-00450). D) Inverted stream landforms west of Ganges Chasma (E22-00303). E) Negative-relief stream features in southwestern Melas, eroded into thinly-bedded (at decameter scale) rock of alternating light and dark tones (R10-03663). F) Two fan-shaped landforms at different stratigraphic levels in a deep depression in southwest Melas. The stratigraphically higher fan is the southernmost. The channels that fed these fans are still encased within the rock (R11-03655). North is to the upper right in B–F.