MGS MOC THE FIRST YEAR: GEOMORPHIC PROCESSES AND LANDFORMS. M. C. Malin and K. S. Edgett, Malin Space Science Systems, P.O. Box 910148, San Diego, CA 92191-0148, U.S.A. (malin@msss.com, edgett@msss.com).

Introduction: During its first year of operation (Sept. 1997 to Sept. 1998), the Mars Global Surveyor (MGS) Mars Orbiter Camera (MOC) obtained high resolution images (2–20 m/pixel) that provide new information about landforms and geomorphic processes on Mars. This paper summarizes some of the year's results—observations pertaining to sedimentology are described in a companion paper [1].

Volcanic Landforms: *(1) Young, Fluid Plains Lavas.* The plains surfaces of the Elysium Basin, Amazonis Planitia, and Marte Vallis are dominated by relatively young features (including kilometer-sized, rotated plates and flat plates separated by sinuous pressure ridges) whose dimensions indicate vast lava floods and ponds. *(2) Olympus Mons.* Most of the upper and middle flanks are dominated by ridged or troughed textures with very few defined lava flows. This texture is interpreted to indicate very fluid lavas. The lower flanks show many flows with leveed central channels, perhaps indicating that the lavas became less fluid as they made their way down the slopes. The east side of Olympus Mons has eolian bedforms which might be the result of wind-worked tephra [1]. *(3) Arsia Mons.* The ridges of the west terminus of the giant 'lobe' on the west side of Arsia Mons appear to have been exhumed via eolian erosion. Their genesis remains unknown but models involving glacial origin are doubtful given a lack of glacial landforms. *(4) Elysium Mons.* The summit, upper and middle flanks show no lava flows but appear instead to be thickly mantled by fines (tephra?). *(5) Alba Patera.* The surface is covered by an uncratered and eroded material consisting of closely-spaced, subkilometer-scale knobs. This material overlies craters and lava flows, and obscures evidence as to the nature and origin of valley networks on the north flank of the volcano. *(6) Apollinaris Patera.* The fan-shaped deposit that emanates from the caldera on the southeast side of the volcano embays, and is therefore younger than, the immediately adjacent yardangs of the Medusae Fossae Formation.

Valles Marineris: The walls of most Valles Marineris troughs show layering, even several kilometers below the rim. The layers might be volcanic and/or sedimentary material. Some of the "interior layered deposits" are massive rather than layered, calling into question hypotheses of past lakes in the Valles Marineris. The Valles Marineris hold some mysteries: for example, an exposure of layered material in western Candor Chasma has no superposed craters, bedforms, mantles, nor does it have gullies, yardangs or other erosional features—these observations suggest that unknown processes have been active recently on the floor Candor Chasma to expose these layered outcrops.

Ocean Hypothesis: MOC has seen no definitive "smoking gun" landforms that can be attributed to oceans that might have once covered some or all of the northern plains and adjacent lowlands. More than 20 images were targeted to test *specific* shore features proposed in peer–reviewed publications. Some of these images show no shore features—*e.g.*, the west side of the Olympus Mons aureole, and around massifs in the Cydonia Mensae. Other images show a contact between two geomorphic units, but the unit on the proposed "seaward" side is topographically higher than on the "landward" side, while others show a contact with the correct geomorphic relationship but no coastal landforms, and still others show no contact or shore-like landforms at all. Lineations identified as 'benches' or 'terraces' on the walls of fretted terrain canyons appear to have been caused by mass movements rather than wave erosion.

Northern Plains Landforms: The story of the northern plains is one of layered material and partly exhumed, buried impact craters. Nearly all images show craters that have been partly exhumed from beneath layered material. Some craters have remnant layered buttes on their floors. Many of the craters have flat rims. Another feature common to the northern plains are rounded knobs that appear to have material shed from them as if by 'exfoliation'; some of these resemble eroded diapirs ringed by "flat iron" tilted beds, and many of them have bouldery surfaces. None of the knobs or craters exhibit 'shorelines'. Very few eolian bedforms are seen on the northern plains except in the north circumpolar sand sea, and polygonal surface patterns are found in some locations but are not abundant.

Valleys and Channels: *(1) Valley Networks in Cratered Terrain.* These are very old and much of their morphology has been obscured by eolian mantles and dunes. Dunes are common on the valley floors and they hide any primary fluvial features that might occur. One image shows a valley network system that is structurally controlled and has a series of adjacent pits aligned along the same structural trend—this case suggests a valley network formed by collapse and subsurface flow. No valley networks imaged by MOC show evidence for overland flow or fine networks of smaller, contributory valleys—this suggests that precipitation was not a factor their formation. *(2) Long, Meandering Valleys.* These include troughs of the Nanedi Valles system, of which one shows a channel incised into the valley floor. The channel in Nanedi Valles might be an indicator of sustained water flow. Other wide, sinuous valleys such as Nirgal Vallis, Evros Vallis, and Scamander Vallis do not show similar channels. *(3) Kasei Valles.* The lower (north-south) portion of the

Kasei Valles system includes lobate flows that embay longitudinal ridges and grooves on the valley floor. One of the lobate flows shows a knobby, bouldery surface interpreted to be a mud or debris flow. These flows seem to indicate events that took place some time after the original floods. *(4) Ares–Tiu Valles.* Images near and including the Mars Pathfinder site show a rippled surface. The ripple texture is related to outflow floods, not eolian processes. A similar texture is seen further to the north (25.1°N, 34.8°W), and is attributed to floods from Tiu Vallis. No other images of outflow channel surfaces show these rippled textures. *(5) Outflow in Cerberus.* MOC has confirmed the existence of outflow channel-like landforms (longitudinal ridges, grooves and streamlined islands) in south Cerberus (10.3°N, 202.6°W). The streamlined islands are cut by a younger, deep trough of the Cerberus Rupes. *(6) Valleys On Plain Southeast of Olympus Mons.* Sinuous and meandering valleys on the plain southeast of Olympus Mons were noted in Viking images. More and finer-scale valleys have now been found. These contain streamlined islands and have flows (lava or mud) emanating from their mouths.

Lakes and Ponds: No definitive (or “smoking gun”) evidence for past lakes have been found, despite acquisition of images showing new details about some previously proposed lakebeds such as Gusev Crater and several images of small degraded craters with rims breached by valley network troughs. Two craters in southern Noachis Terra (65°S, 14°W and 67°S, 15°W) show smooth, flat, dark surfaces that might be related to the ponding of liquid water or lava. Both are associated with low-albedo dune fields, and therefore might instead be eolian surfaces. An analogous (although bright instead of dark) eolian surface is found adjacent to a dune field in western Arabia. While no definite lakebeds have been found, some images show flat, bright, smooth surfaces that resemble desert playas. These are probably crusted soils exposed by eolian deflation.

Fretted Terrain: The story of the fretted terrain appears to be complicated, and the landforms polygenetic. We think the relevant processes at least include the widening of valleys and disintegration of mesas and buttes by scarp retreat. The lack of small craters on these surfaces suggest that the formative processes might be continuing today. Old terms such as ‘debris apron,’ ‘lineated valley fill,’ and ‘concentric crater fill’ appear to be too genetic to properly describe the landforms of the fretted terrain. *(1) Fretted terrain aprons* (formerly, debris aprons) are common at the base of escarpments and surrounding massifs at the interface between north Arabia and the northern plains. These show no evidence for surficial transport of material—no gullies, leveed channels, or other features that would make them analogous to alluvial deposits on Earth. Instead, they appear to result from a combination of processes that include scarp retreat, incorporation or ingestion of material shed from scarps into the apron, pitting and perhaps attendant eolian deflation, and very minor longitudinal movement. The evidence for longitudinal movement or flow is weak at best, and includes small terminal ridges at the contact between plains and the apron surface. Evidence for transverse shear is likewise weak. *(2) Lineated valley floors.* Many of the valleys in north Arabia have longitudinal-lineated (ridged and grooved) materials on their floors. In these valleys, the walls are smooth and there is evidence for downslope movement of materials. Despite the smoothness of these walls, an impact crater that intersects one of the valleys reveals that the bedrock is layered. The lineations on valley floors often mimic the planimetry of the valley walls and rims, and thus might indicate the former locations of the canyon walls as they have retreated. No evidence for glacier-like flow has been found, and the planforms of degraded craters on these surfaces have hardly been deformed. Some valleys in north Arabia share the smooth walls and detached slope material characteristics, but do not exhibit lineated floors. Some of those without lineated floors have eroded layered deposits, suggesting considerable removal of material. *(3) Concentric patterns on crater floors.* There are two types of what was previously termed ‘concentric crater fill’. The first is analogous to the lineated floors in fretted terrain valleys. The second type appears to be eroded intracrater layered deposits. We believe that this difference led to some controversy in the literature regarding Viking observations of concentric patterns on crater floors in the fretted terrain and northern plains.

Polar Regions: Sedimentary features observed at high resolution in the north polar layered deposits are discussed in [1]. North polar cap surfaces were seen at resolutions of 2–4 m/pixel. The permanent cap and ice-free polar layered deposit surfaces appear very textured at meter scales and high solar incidence. The pattern observed, along with the absence of long shadows, suggests that the texture consists of features 10’s to 100’s of centimeters high abundant on the scale of a few meters. One trough in the south polar cap has a lineated floor similar to those in north Arabia fretted terrain valleys; no such features are evident in the troughs of the north polar cap.

Layers Everywhere: Layers are evident in outcrops and deflated terrain nearly everywhere on Mars—layers occur in the polar caps, northern plains, heavily cratered terrains, volcanic plains, ridged plains, and on crater floors. These observations suggest that Mars is much more like the Earth than like the Moon, yet Mars is quite uniquely “martian”.

References: [1] Edgett K. S. and Malin M. C. (1999) *LPS XXX*, this volume.