MGS MOC THE FIRST YEAR: SEDIMENTARY MATERIALS AND RELATIONSHIPS.

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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 sedimentary material on Mars. This paper describes sedimentology results, other results are presented in a companion paper [1].

Dark Mantles: Contrary to pre-MGS assumptions, the large, persistent, low albedo (<0.1) regions Sinus Meridiani, Sinus Sabaeus, and Syrtis Major, are largely covered by smooth-surfaced mantles, rather than bedforms of sand. These regions contrast with other low albedo surfaces—such as the dark collar around the north polar cap—which are dune fields. Imaging of low-albedo Acidalia Planitia was insufficient to determine the nature of its surface. Dark mantles imply the existence of low-albedo, fine-grained sediment (silt, clay) transported via suspension.

Bedforms and Mantles on Tharsis Volcanoes: MOC images show that eolian sediment on each of the four large Tharsis volcanoes is not uniform in thickness nor extent. For example, the lower north flank of Pavonis Mons exhibits a very thick mantle of many meters, while the middle north flank is less-thickly mantled, and the upper east flank has only a thin mantle of both lower albedo and variable extent. The middle west flank of Pavonis Mons has a thicker mantle than the middle east flank. The middle east flank of Olympus Mons has eolian bedforms, while the middle west flank has little or no surface cover. Bedforms also occur at high elevations on Arsia Mons. Bedforms on these volcanoes indicate the presence of sand-sized material (*i.e.*, possibly tephra), and either the occurrence of winds of sufficient strength to transport sediment under extremely low atmospheric pressure conditions, or a relatively recent, thicker atmosphere.

Grooved Mantle Surfaces: Some mantled surfaces have undergone eolian erosion that leaves ridges and grooves that are aligned with the dominant wind direction. Good examples are found within the ‘radar Stealth’ region of southwestern Tharsis, other examples are seen in deposits covering plains to the north of Ascraeus Mons and Elysium Mons.

Mantles in Arabia Terra: Most of Arabia is covered by material with relatively high albedo (>0.27) and low thermal inertia (<200 J m^{-2} $s^{-0.5}$ K^{-1}). MOC images show that the region is—as proposed prior to MGS—mantled. However, the surface material exhibits very different textures in northern relative to southern Arabia. South Arabia mantles have a uniform, smooth texture. North Arabia surfaces have a rough texture that indicates that the material has been modified by an unknown, possibly latitude-dependent process.

Bright and Dark Bedforms: In terms of relative albedo, there are three classes of martian bedforms: those with albedos that are darker, brighter, or indistinguishable from their surroundings. Bright bedforms tend to be superposed on dark surfaces and are most common in Sinus Sabaeus. Other bright bedforms occur on intermediate-albedo surfaces such as Isidis Planitia and around the Granicus Valles. Two examples have been found where low-albedo dunes have blown over and partly obscure older, bright bedforms—these occur on crater floors in west Arabia Terra, and might imply that these particular bright bedforms are indurated or composed of coarse grains (*e.g.*, pebbles). Eolian bedforms brighter than their surroundings imply a compositional difference (particle size and/or mineralogy) relative to dark bedforms.

Bright Sand on Daedalia Planum: Thermal inertia and albedo derived from Viking IRTM observations suggested that west Daedalia Planum is mantled by at least a few centimeters of bright dust. However, MOC images show a surface of dark lava flows with a spatially-variable cover of bright material and bedforms—in other words, the surface cover is bright, saltated sand, not dust. One picture shows an impact crater with a dark, non-depositional wind streak in its lee—the image bears incredible resemblance to aerial photographs of bright sand and wind streaks on a basalt volcanic field near Amboy, California.

Active Bedforms: Two lines of evidence suggest that some dunes are active today. Dunes in a low-albedo dune field near 20.3°N, 280.7°W have sharp brinks at the top of each slip face and exhibit faint lineations on the slip faces that suggest recent slumps. The second line of evidence comes from the north polar dunes, which became visible in late July 1998, following the start of northern spring. At this time, the polar dunes were covered by a thin coating of frost. This frost could only be as old as the winter which ended in mid-July 1998. Many of the dunes exhibit dark spots from which radiate dark streaks. Streaks are oriented in similar directions from one dark spot to the next. These are interpreted to be patches of dark sand that were exposed from beneath the seasonal frost. The streaks indicate the passage of wind gusts which mobilized some of the dark sand as recently as July–September 1998.

Inactive Bedforms: Some eolian dunes and bedforms are inactive. Bedforms with albedos that are indistinguishable from the surrounding terrain are most likely to be inactive and perhaps covered by a thin mantle. The best examples of inactive dunes are found in a portion of the Olympus Aureole (Lycus Sulci), in which several dunes—of albedo indistinct from surrounding terrain—have been over-ridden by dark streaks of mass-wasting origin.

Bedform Morphology: Martian bedforms come in a range of shapes and sizes, but most reflect a unidirectional wind regime with some local topographic influences. MOC reveals a plethora of small (meter-scale) drifts that, in the absence of particle size and wind transport information, defy typical classifications as “dunes” or large “ripples”. Ripple-like bedforms are common on the floors of tectonic troughs and valley networks, and their crests are always perpendicular to the longitudinal trend of the valley. Other small ripple-like features occur on intermediate-albedo plains (*e.g.*, Isidis Planitia) and are often oriented in a manner that indicates local topographic control (*e.g.*, sometimes their crests are radial to hills and raised crater rims). Some bedforms show the influence of local topography on wind regime as elongate horns extending from barchans (*e.g.*, in Herschel Basin) or from ripple-like forms (*e.g.*, near Granicus Valles). In general, intermediate-sized, low-albedo bedforms on crater floors and in the north polar sand sea appear lower and broader than their terrestrial counterparts, and some do not have slip-faces. In some locations (*e.g.*, Ganges Chasma), dark dunes grade downwind into large, thick masses that exhibit no bedforms. No definitive longitudinal (linear) or star dunes have been seen thus far.

Dark Depositional Wind Streaks: Wind streaks associated with low albedo intracrater material in west Arabia Terra are thought to result from deflation of dark sediment from the adjacent crater floors. Prior to MGS, most of the literature on these streaks considered them to be deposits of saltated sand or to be zones of eolian erosion. MOC images of these streaks show them to be mantles (*i.e.*, silt- and clay-sized material).

Bright Depositional Wind Streaks: Prior to MGS, no examples of bright depositional wind streaks resulting from the deflation of bright material on a crater floor were identified, nor were they expected because bright, saltated material had not been discovered. Several examples of such wind streaks have now been identified near Nirgal Vallis and in Ares Vallis. These are small, thin deposits relative to the dark depositional streaks that dominate the landscape of western Arabia Terra.

Sedimentary Structures in the Polar Layered Deposits: In addition to modern eolian sedimentary features, several examples of ancient sedimentary deposits have been inferred to occur on Mars. An example that dates back to the Mariner Mars missions is the polar layered deposits. MOC images of the north polar cap have provided the following sedimentologic observations: there are (a) bedding unconformities, (b) deformed beds, and (c) many more and thinner layers than were previously known. We have also seen that some of the “layers” in the north pole cap are actually *ridges*; examination of Viking 2 orbiter images shows additional ridges that were previously undocumented.

Mass Movement: The most dramatic mass movement features at the MOC imaging scale are dark slope streaks. These were also seen in some Viking orbiter images, and they typically occur on steep slopes within high albedo, dust-mantled terrain (Tharsis, Arabia, Amazonis, Elysium Planitia). These are considered to be the result of sudden downslope flow of dry silt and/or clay-sized sediment. Darker streaks superpose lighter streaks, indicating that dark streaks are younger. We have also seen examples of bright slope streaks—these are related to similar movement of material eroded from bright outcrops. The second dramatic mass movement features are boulder tracks—only one example has been found—it occurs on the south rim of Schiaparelli Basin where several house-sized boulders have eroded out of a dark cliff and rolled downslope, over a mantled surface .

Boulders at the Base of Cliffs as Evidence for Sedimentary Layers in the Valles Marineris: Layered materials have been seen by MOC to be common throughout all major martian terrains—the northern plains, the ridged plains, cratered terrains, and volcanic plains [1]. Layers have been observed in the walls of the Valles Marineris all the way to the bottom of the troughs. Except in the far western portion of the Valles Marineris system—adjacent to definite volcanic plains—we have seen few boulders among the debris on the slopes nor on the floors of the Valles Marineris troughs. This stands in sharp contrast to canyons found on the east and west flanks of the Elysium Rise and within the Tharsis region. Like the Valles Marineris, the canyons in Tharsis and Elysium exhibit layered walls. They also commonly show lava flows at the surface that have been truncated by the canyon-forming process. Unlike the Valles Marineris, boulders (some as large as houses) are abundant at the bases of cliffs and on the floors of these deep volcanic-region canyons. Given the similar heights of these canyon walls and the presence of layering, these observations suggest that the layered material in the Valles Marineris may be fundamentally different in terms of strength, competence and lithology. We speculate that the layers in the Valles Marineris might be composed of sedimentary material that is not as densely lithified as rocks formed of solid lava. Alternatively, the layers could be composed of deeply weathered volcanic rock—so deeply weathered that it is friable and not capable of forming boulders, or any boulders present in the Valles Marineris are simply too small to be seen in 3–4 m/pixel images. Images to be obtained during the MGS Primary Mission will have 1.5 m/pixel resolution and may help resolve this issue.

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