

**EXAMPLES OF MARTIAN SANDSTONE: INDURATED, LITHIFIED, AND CRATERED EOLIAN DUNES IN MGS MOC IMAGES.** K. S. Edgett and M. C. Malin, Malin Space Science Systems, P.O. Box 910148, San Diego, CA 92191-0148, USA.

**Introduction:** Eolian dunes are created from grains transported in wind by saltation and traction. Under martian conditions, as on Earth, the particles involved are typically sand-sized (62.5–2000  $\mu\text{m}$ ) [1]. Lithified dunes are sandstones. Sandstones derived from eolian dunes preserve the bedding characteristics of the parent bedforms, and the upper surface when it erodes can sometimes resemble the undulating surface of a dune field (this happens, for example, to provide the modern surface expression of the Navajo Sandstone where it outcrops on the Colorado Plateau in North America).

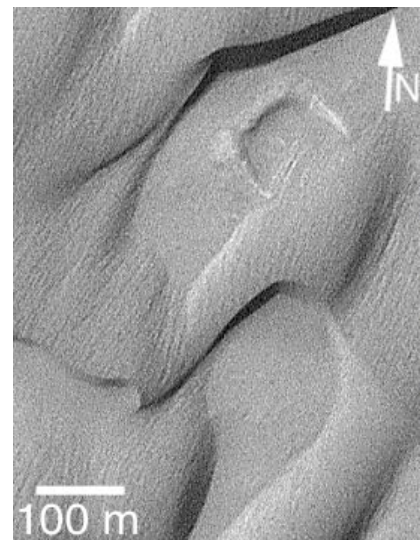
Mars Global Surveyor Mars Orbiter Camera (MOC) images obtained in 1999 have spatial resolutions in the range 1.4–15 m/pixel. The highest resolution images are comparable to aerial photographs commonly used in terrestrial geologic field studies. Several excellent examples of indurated and lithified eolian dunes have been found in MOC images. These dune materials provide unambiguous evidence for the presence of a specific type of sedimentary rock (sandstone) on the planet Mars.

**Herschel Basin:** The most striking early MOC examples of indurated or lithified dunes came from the floor of Herschel Basin. Herschel is a 300 km-diameter impact basin located in Terra Cimmeria at 14°S, 230°W. Its floor includes patches of dark material that from low-resolution Viking and Mariner 9 images could not be resolved into dunes. Fig. 1 shows a representative high resolution view of the dunes in Herschel Basin. The dunes have a low albedo relative to their surroundings, and they have typical barchan and crescentic forms. What is unusual about the Herschel dunes, relative to all other dunes seen thus far by MOC, is the ridged-and-grooved texture of the dune surfaces. The grooved texture on the dunes runs from the lower stoss, over the crest, and around the sides of each dune. In some cases, the grooves extend into low, dark mounds and patches on the surrounding terrain. The ridge-and-groove pattern on the Herschel dunes is interpreted to be caused by wind erosion. Essentially, these are yardangs formed by eolian scour and plucking of sand-sized grains from an indurated (semi-lithified) material. The processes that might have lithified these dunes *in situ* are unknown.

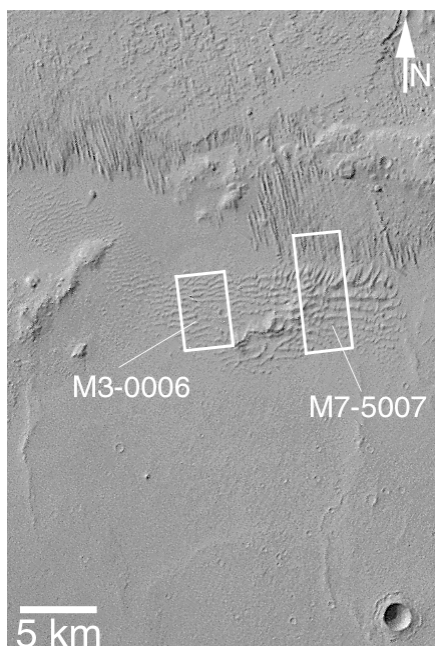
**Apollinaris Sulci:** A second example of lithified dunes is found near the southern margin of the Apollinaris Sulci ridged terrain near Gusev Crater and Apollinaris Patera. Fig. 2 shows a mosaic of Viking orbiter images of the dune field. One thing that was always puzzling (prior to the advent of MOC images) about

this particular dune field was that it did not have a distinct, low albedo like most other large dune fields on Mars. Peterfreund [2; p. 149–150] noted its presence and speculated that the sand needed to create this dune field was derived from the erosion that formed the long, sharp yardang ridges of the Apollinaris Sulci. Edgett and Blumberg [3; p. 458–459] believed this dune field to resemble the tall, star dune-like bedforms in the desert near Dumont, California. Two MOC images cover a large portion of the Apollinaris Sulci dune field, as illustrated in Fig. 2. The first image, M03-00006, acquired 1 July 1999, revealed that the landform seen in the earlier Viking images (Fig. 2) was indeed a dune field—barchan shaped hills are clearly visible in this image (Fig. 3). The MOC image also provided an unexpected result—the dune field is quite heavily cratered, and the craters are so old that most exhibit no ejecta deposits (these apparently have been removed). The second image (Figs. 4, 5), M07-05007, was obtained 26 September 1999, and showed a pedestal crater on the dunes (“P” in Fig. 5) and a contact relationship relative to the Apollinaris Sulci that suggests exhumation of the dune field. The dunes appear to have been (1) lithified, (2) cratered, (3) buried by the material of the Apollinaris Sulci, then (4) exhumed in relatively intact form from beneath this material.

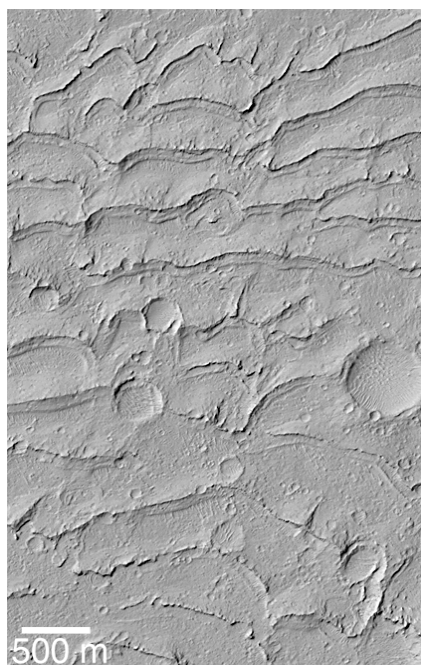
**Conclusions:** Indurated and lithified dunes present the most unambiguous evidence that Mars has sedimentary rock in the form of eolian sandstone.



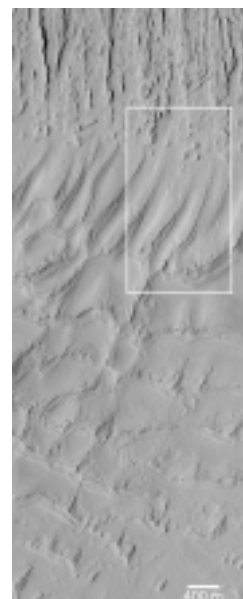
**Figure 1.** Representative view of grooved surfaces on low albedo dunes in Herschel Basin. Sub-frame of MOC image M00-03222, illuminated from the upper left and located near 15.3°S, 228.2°W.



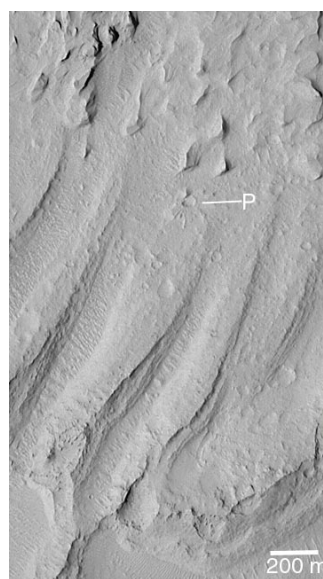
**Figure 2.** Mosaic of Viking images 436S03, 436S04, and 436S05, showing the dune field located at the southern edge of the Apollinaris Sulci ridges. The two boxes indicate the locations of MOC images shown in Figs. 3 (M03-00006) and 4 (M07-05007). The dunes are located at 12.8°S, 181.9°W.



**Figure 3.** Cratered surface of the dune field near Apollinaris Sulci. Excellent examples of 'fossilized' transverse dunes are present. Sub-frame of MOC image M03-00006, illumination from the left. See Fig. 2 for context.



**Figure 4.** Cratered eastern portion of the dune field near Apollinaris Sulci. White box shows location of Fig. 5. Ridges in the upper 1/5 of the image are the yardangs of the Apollinaris Sulci. The dunes might have emerged from beneath these ridges. Sub-frame of MOC image M07-05007, illumination from the left. See Fig. 2 for context.



**Figure 5.** Close-up of a portion of MOC image M07-05007, showing a pedestal crater (P) superposed upon the cratered dune ridges, and the emergent character of the dunes at the contact with the Apollinaris Sulci material (top 1/4 of image). For context, see Fig. 4.

**References:** [1] Iversen J. D. and White B. R. (1982) *Sedimentology*, 29, 111–119. [2] Peterfreund A. R. (1985) Ph.D. Diss., Ariz. State Univ., Tempe. [3] Edgett K. S. and Blumberg D. G. (1994) *Icarus*, 112, 448–464.