Cracks and fins in sulfate sand: Evidence for recent mineral-atmospheric water cycling in Meridiani Planum outcrops? G. V. Chavdarian and D. Y. Sumner, Geology Department, University of California-Davis, Davis, CA 95616, gvchavdarian@ucdavis.edu, sumner@geology.ucdavis.edu

Introduction: The Mars Exploration Rover Opportunity, on Meridiani Planum, is documenting sulfate-rich sedimentary rocks (the Burns Formation) that formed in eolian environments with some evidence for overland water flow [1], [2]. Cross stratification styles in much of the outcrop are characteristic of eolian "pin-stripe" lamination from wind ripple migration and slip faces of dunes [1]. Contractional cracks on outcrop surfaces define centimeter to decimeter scale polygons that crosscut bedding in Endurance Crater and on the plains of Meridiani (Figure 1A). The perpendicular-to-outcrop surface orientation of the cracks is inconsistent with synsedimentary contraction. Some cracks in Endurance Crater are associated with fins, which are mm-thick, platy features that protrude a few centimeters above outcrops (Figure 1B). Fin geometry is consistent with differential cementation along cracks, followed by differential weathering. Frost observed on Opportunity demonstrates modern atmospheric water cycling. We use observations from an analog site at White Sands National Monument, New Mexico, to provide insights into processes forming cracks and fins.

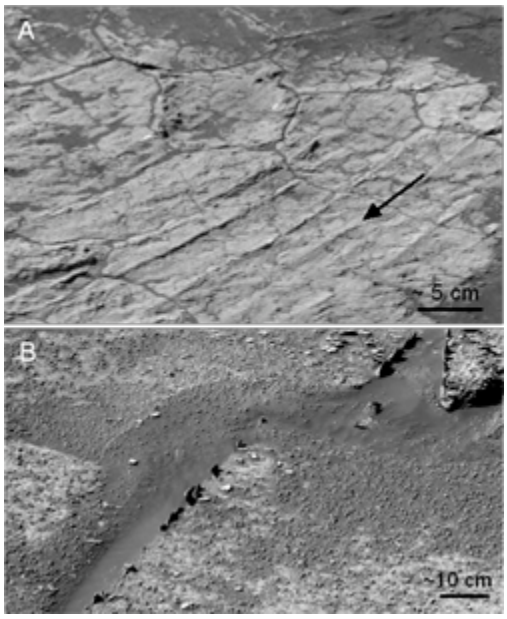

Figure 1: Images from Opportunity, courtesy of NASA/JPL Caltech. A: Cracks in "Escher" showing raised rims along cracks and along sedimentary layers (arrow) demonstrating differential cementation (after 07-SS2-02-Escher-B251R1.jpg). B: Fins on "Razorback" extend above the outcrop surface along fractures (after 1p142569702eff3221p2378712c1.27663.GIF).

Cracks and Fins in Gypsum Sand: Dunes and playas at White Sands National Monument provide excellent analogs for sedimentary structures in the Burns Formation because of the ubiquitous sulfate (gypsum) sand and the similarity of depositional environments. Fieldwork at White Sands in January, March, June, and September 2005 demonstrated that cracks and fins form seasonally in the gypsum sand [3]. In January, sand was moist and cohesive from abundant frost, and unfilled polygonal cracks formed in sand along interdune-dune boundaries, on dune slopes, and in pedestals of cemented dune sand (Figure 2). Cracks on dune slopes crosscut bedding as do Meridiani cracks. In March, June, and September, cracks on dune slopes were covered and dry, and not actively forming. However, ~10% of stoss dune surfaces contained sharply defined, unfilled cracks in the uppermost sand layer in June following a substantial rainstorm prior to the start of observations.

Figure 2: Cracks on dune slope in gypsum sand in January 2005 at White Sands National Monument.

Two types of fins are present at White Sands: tan fins and white fins [3]. Slightly cemented tan fins were only present in January when abundant frost was present (Figure 3A). Tan fins are thin, platy, preferentially cemented features that protrude a few centimeters out of the dune sand along crack edges and along differentially eroded ripple cross lamination. Tan fin surfaces always face into the wind and are composed of finer grains than the surrounding sediment. White fins were present but rare in January, March, and June, and absent in September (Figure 3B). White fins are present on dune slopes and on cemented pedestals. White fins always face upwind when differentially eroded along laminae and cracks, but face any direction on pedestals. Wind adhesion structures at White Sands form throughout damp interdune areas and on dune slopes. They are recognized as adhesion structures based on their upwind growth and the incorporation of finer grains than the surrounding sand.

Results: The presence of damp, unfilled, fresh cracks following frost events or sharply defined, unfilled cracks following rainstorms suggest that atmospheric water cycling promotes crack formation in sulfate sand; evaporation of water, cementation of sand, and shrinking of sand volume promotes crack formation. Field observations of variable

cementation along crack edges and adhesion structures suggest that tan fins form from 1) preferential cementation along cracks and 2) adhesion of fine-grained particles to structures above the sediment surface. Near-surface water cycling may also play a role in tan fin formation since these features were only observed in January when nighttime temperatures were sufficiently low to form a heavy frost. We propose that the frost percolates into the cracked dune sand; moisture evaporates along cracks due to increased airflow, precipitating cements along crack edges (Figure 4). A moisture-wicking effect pulls additional water to the cracks, which precipitates more cement as it evaporates. As the cemented crack edges are exposed at the surface, adhesion of fine-grained particles further strengthens them. White fin formation is similar to tan fin formation but occurs in the subsurface. These or similar processes may be important for crack and fin formation in Meridiani Planum outcrops, providing evidence for recent water cycling between sulfate outcrops and the Martian atmosphere.

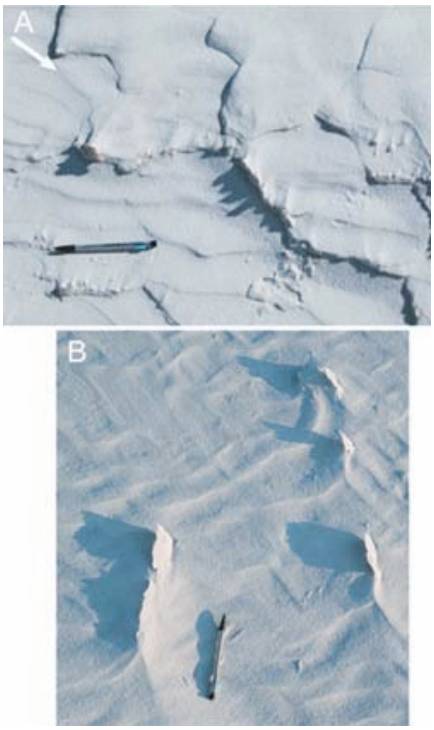

Figure 3: A: Tan fins that stand up to a centimeter above the sand along crack edges. Arrow indicates a depositional laminae. B: White fins that stand up to 3.5 cm above the sand.

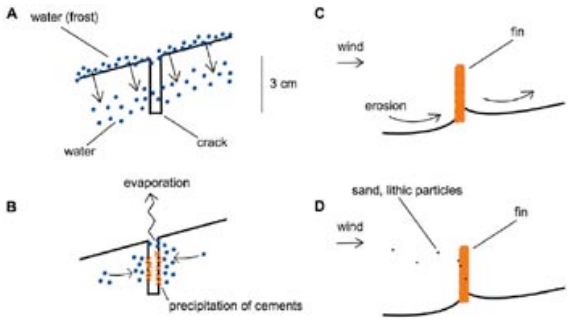

Figure 4: A: Water from frost seeps into sand and cracks. B: Increased airflow in cracks causes evaporation and precipitation of cements. Moisture-wicking pulls additional moisture to cracks, where more cements precipitate. C: Erosion of dune sand leaves more cemented crack edges exposed. D: Adhesion of fine-grained particles strengthens fins.

References:

[1] Grotzinger J. P. et al (2005) *EPSL, 240,* 11-72. [2] Squyres S. W. and Knoll A. H. (2005) *EPSL, 240,* 1-10. [3] Chavdarian G. V. and Sumner D. Y. (In Press) *Geology*.