

WIND-DRIVEN PARTICLE MOBILITY ON MARS: INSIGHTS FROM MER OBSERVATIONS AT “EL DORADO” AND SURROUNDINGS AT GUSEV CRATER. ¹R. Sullivan, ²R. Arvidson, ¹J. F. Bell III, ⁴M. Golombek, ²E. Guinness, ⁵R. Greeley, ³K. Herkenhoff, ³J. Johnson, ¹S. Squyres, ⁶S. Thompson, ⁷P. Whelley, and ¹J. Wray. ¹CRSR/Astronomy, Cornell University, Ithaca NY 14853 rjs33@cornell.edu, ²Washington University, St. Louis, MO, ³USGS, Flagstaff, AZ, ⁴JPL, Pasadena, CA, ⁵ASU, Tempe, AZ, ⁶U. Nevada-Reno, Reno, NV, ⁷SUNY-Buffalo, Buffalo, NY.

Introduction: The >7 km traverse and longevity of the Mars Exploration Rover *Spirit* at Gusev crater have allowed unique observations for addressing problems of wind-driven particle mobility on Mars. In particular, the field of dark, mafic ripples known as “El Dorado” was a unique stop on *Spirit*’s traverse, where dust-raising, active mafic sand ripples, and inactive light-toned coarse-grained ripples interact, allowing observations to address several long-standing global martian issues of dust mobility, sand mobility, and the origin of transverse aeolian ridges.

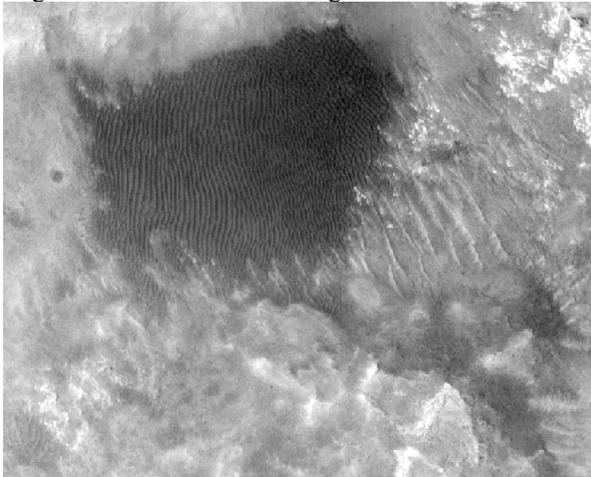


Figure 1. The ripple field “El Dorado” spans ~170 m on the SSE flank of Husband Hill. *Spirit* visited the NE corner of the deposit. Light-toned bedforms (coarse-grained ripples) interfinger around the margin of the deposit. (From HiRISE PSP_003900_1650_RED)

Observations: El Dorado (Fig. 1) is potentially analogous to many similar dark features observed from orbit that have been interpreted as aeolian deposits of various kinds. *Spirit* visited El Dorado during sols 706-711 of its mission, and found ripples ~0.3 m high, 2-3 m apart composed of very slightly crusted (nearly cohesionless) $\leq 300 \mu\text{m}$ diameter mafic sand. Right on the undisturbed surface, near the ripple crest where *Spirit* conducted in situ observations, the sand is well-rounded and well-sorted 200-300 μm grains, but below about a mm depth (revealed by the wheel scuff and other disturbances) the 200-300 μm grains are mixed with and dominated by finer grains $\leq 100 \mu\text{m}$. The same sand mixture is found less conspicuously in

smaller, widely-scattered deposits elsewhere in the Columbia Hills, as well as in deposits out on the plains. Particle size-frequency characteristics suggest El Dorado-like sand has been segregated by wind from the fine-grained mafic regolith present everywhere across the landing site, as sampled in three wheel trenches out on the plains. Strong wind events on sols 417-422 and during the summer 2007 dust storms saltate this sand, causing perceptible ~2 cm migration of ripple crests in deposits SSE of El Dorado during sols 1260-1265, erasure of tracks in sandy areas, and changes to dust mantling the site. More frequently, transient dust devil tracks affect the surface of El Dorado as seen from orbit and in distant *Spirit* Pancam views. These curvilinear dark streaks eventually fade (brighten) as they are superposed by newer streaks (Fig. 2). Dust raising is accomplished without obvious damage to the nearly cohesionless sandy ripple crests.

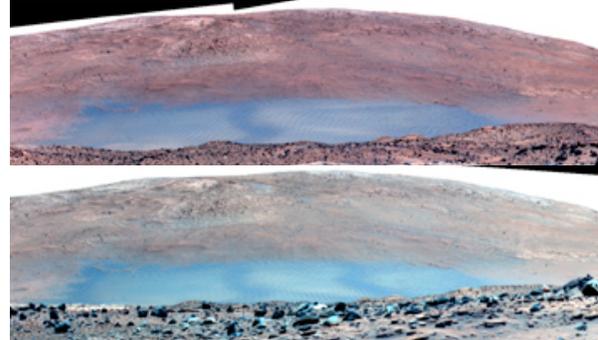


Figure 2. *Spirit* Pancam L257 (753, 535, 432 μm stretched to RGB) views showing typical dust devil-related changes to El Dorado (sol 1081 above, sol 1101 below).

Dust vs. Sand Mobilization: From orbit, only minor surface changes to a small number of dark-toned dunes have been reported across Mars, but raising of clay-sized dust occurs frequently [1-5]. This conflicts with wind tunnel studies that have shown sand is easier to entrain than clay-sized dust [6]. This is a long-standing paradox of martian aeolian studies in which winds responsible for frequently raising dust do not seem to significantly affect dunes composed of (presumably more easily-entrained) sand-sized particles.

Applying observations from El Dorado and elsewhere along *Spirit*’s traverse, the disparity between dust mobilization and sand mobilization on Mars is

due largely to two factors: (1) dust occurs on the surface as fragile, sand-sized aggregates [7] that are easily-entrained and disrupted, compared with individual clay-sized air fall particles; and (2) induration of the regolith is pervasive, observed all along traverses of both *Spirit* and *Opportunity*, for a combined traverse exposure >17 km across two very different landing sites on opposite sides of the planet. Induration exists even within El Dorado, but apparently does not develop very far before being reset by disruptive strong wind events that saltate the sand. In between these strong wind events, the passage of thermal vortices (i.e., dust devils, if dust loading is sufficient to make these visible) helps sweep dusty air fall from the surface, maintaining contrast with surroundings while hardly affecting the nearly cohesionless sandy surface. This implies that threshold wind friction speeds for the dust aggregates are far less than for the $\leq 300 \mu\text{m}$ El Dorado sand. The ubiquity of the dust aggregates, found also at Meridiani Planum, indicates an electrostatic process and particle habit that likely is prevalent in dusty areas all across Mars.

Coarse-grained Ripples and TARs: Light-toned bedforms investigated by *Spirit* at Gusev are coarse-grained ripples (i.e., bedforms with coarse grains mantling finer-grained, sandy interiors [8]). Currently they are crusted and dust-covered (Fig. 3). Larger light-toned bedforms observed more distantly by *Spirit* are morphologically more complex, but we interpret these as coarse-grained ripples also, large enough and resistant enough to erosion that they commonly have finer particle drifts banked against them and secondary ripples on the flanks of the primaries (Fig. 4). We propose that many of the numerous smaller, linear, light-toned bedforms of uncertain origin seen in high resolution orbital images across Mars (sometimes referred to as Transverse Aeolian Ridges or TARs [9,10]) are coarse-grained ripples also. Although coarse-grained ripples are far less common on Earth than ripples and dunes having unimodal particle size-frequencies, on Mars the lack of free quartz available to establish an abundant, durable, very well-sorted sediment supply for saltation should make coarse-grained ripples relatively more common. Wind organizes poorly-sorted debris into coarse-grained ripples, so in the absence of long-lived quartz, we speculate that coarse-grained ripples should be relatively more common on Mars than on Earth. Coarse-grained ripples move relatively slowly and require a flux of saltating finer grains to drive their coarser grains in creep; these characteristics make these features more vulnerable to immobilization by induration that develops during extended periods of quiescence. Indurated coarse-grained ripples around

the fringes of the active sands of El Dorado show no obvious signs of erosion. The vulnerability to immobilization and resistance to erosion of these features at Gusev suggests durability and the potential for longevity; this might be another reason why small, linear, light-toned bedforms are so numerous across the surface of Mars.

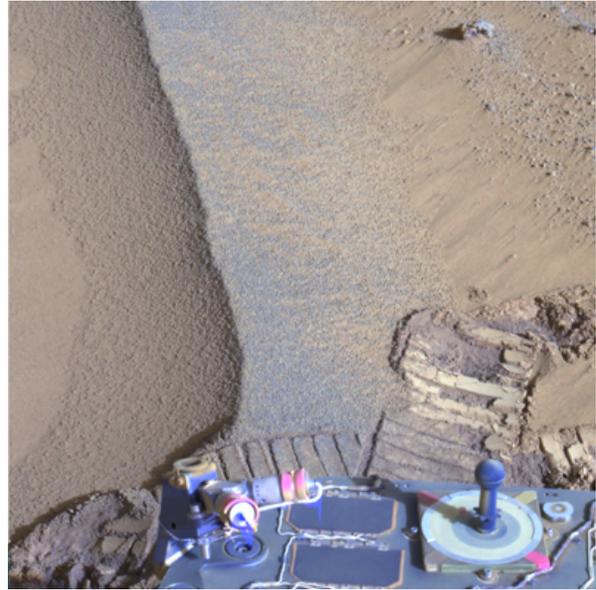


Figure 3. Coarse-grained ripple very near the summit of Husband Hill. Wheel track in right center is 16 cm wide. Pancam L247 (753, 601, 432 μm images stretched to RGB) image obtained on sol 607.



Figure 4. Large light-toned bedforms, ~ 0.5 m high, tentatively identified as large coarse-grained ripples. Sol 730 Navcam view.

References: [1]Zimbelman (2000) *GRL*, 27, 7, 1069-1072. [2]Malin and Edgett (2001) *JGR*, 106, 23429-23570. [3]Fenton (2006) *GRL*, 33, doi:10.1029/2006GL027133. [4]Bourke et al. in press, *Geomorphol.* [5]Cantor et al. (2001) *JGR*, 106, 23653-23688. [6]Greeley and Iversen (1985) *Wind as a Geological Process*. [7]Herkenhoff et al. (2004) *Science*, 305, 824-826. [8]Sharp (1963) *J. Geol.*, 71, 617-636. [9]Bourke et al. (2003) *LPSC XXXIV*, Abstract #2090. [10]Wilson and Zimbelman (2004) *JGR*, 109, doi:10.1029/2003JE002057.