MARS EXPLORATION ROVER *SPIRIT* INVESTIGATION OF THE “EL DORADO” SAND DEPOSIT.

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Introduction: Reddish, relatively bright air fall dust is widespread across the *Spirit* landing site within Gusev Crater. The transience of dust devil tracks observed in the multi-year record of MOC images indicates dusty air fall continually obscures somewhat darker materials across the site. A few enduring dark-toned areas within the Columbia Hills are exceptional. MOC images show these darker patches consistently remain significantly darker than surrounding terrain, indicating air fall dust is less stable on substrate at these locations. *Spirit* visited the largest, 170 m-wide dark patch, termed “El Dorado,” for in situ investigation. Dark patches similar in some respects to El Dorado have been observed from orbit at many locations on Mars in a wide range of settings; many of these features have been interpreted as aeolian deposits of one kind or another (e.g., [1-5]). Objectives of *Spirit’s* visit to El Dorado were to characterize this unusual unit not previously encountered, investigate potentially active aeolian material, and obtain data to help calibrate and inform interpretations of orbital observations of other, similar features elsewhere on the martian surface.

***Spirit’s* activities at El Dorado:** *Spirit* visited El Dorado during sols 706-711 of its mission, driving 8 m into the unit and executing a turn-in-place wheel scuff. Undisturbed material was sampled by the Mössbauer spectrometer and APXS. APXS data were collected also from subsurface material exposed in the 2 cm-deep cavity created by the wheel scuff. MI images were obtained at both locations, plus a third location where wheel motion created and preserved a very shallow “road-cut” exposure.

Bedforms and Presence of Dust: Bedform relief and trough widths near the rover’s position were variable, but representative values are ~0.25 m and ~3 m, respectively. Much smaller secondary ripples with wavelengths 0.1 m or less occur on the flanks of the larger bedforms and within the troughs between them. A narrow, bright, reddish band exposed on SW-facing ripple flanks indicates brighter material can be incorporated into the bedforms, then become exposed subsequently by erosion, e.g., by bedform migration. No angle-of-repose slopes have been recognized in the rover’s vicinity.

The record of MOC images shows that subtle brightness changes occur over time from place to place within the generally dark El Dorado unit. These changes would have been unnoticeable without at least some renewable, transient dust accumulation to provide contrast, so the surface of El Dorado was not expected to be entirely dust-free. *Spirit’s* visit confirms this. Pancam and Navcam images show alternating reddish stripes ~10 cm-wide in many places around the rover. These markings probably represent slightly higher concentrations of air fall dust lingering within low-relief troughs of small, secondary ripples of sand.

Grain characteristics: MI views of the undisturbed surface are dominated by well-rounded 200-300 μm sand. Most grains are opaque but rare grains that are translucent or glinting (saturating the dynamic range of the camera) are also present. At the very shallow “roadcut” exposure, surface regolith is only very slightly cohesive, with cohesion seeming to decrease further—perhaps vanish—within a few mm of the surface. Below this depth the dominant grain size is smaller, perhaps around 100 μm (not well-resolved) and sorting is difficult to evaluate directly.

Composition: Pancam multispectral data on the undisturbed, relatively dust-free sand show steadily negative 754-1009 μm spectral slopes, consistent with the presence of olivine. Disturbed materials show surprising spectral diversity, including materials with slightly positive 934-1009 μm slopes (suggesting the presence of pyroxene). These findings are consistent with preliminary analyses of Mössbauer[6] and APXS[7] data which indicate El Dorado material is basaltic olivine- and pyroxene-rich sand grains intermixed with some dust and other minor components.

Grain cohesion vs. mobility: There is evidence that bulk regolith cohesion at El Dorado is only very slight, essentially zero by engineering standards. Rolling wheel movements formed narrow ridges resembling levees containing each wheel track. Flanks of these ridges show short, lobate textures characteristic of flows of dry, cohesionless, well-sorted grains. The Mössbauer imprint into initially undisturbed material is a relatively poor-fidelity casting, partly due to collapse of what could have been small vertical walls. This characteristic, along with the relative lack of molded clods distributed by the wheel cleats, indicates relatively poor abundances of grains fine enough to serve as a supporting, moldable matrix to fill pores between the larger sand grains. We infer then that the El Dorado materials in bulk are relatively “cleaner” of silt- and clay-sized particles (unresolvable by MI) compared with cloddier materials excavated at most other areas by *Spirit* and *Opportunity*.

Discussion: The size of the major El Dorado bedforms, their lack of angle-of-repose slipfaces, and their (perhaps crudely-perceived) bimodal particle size-frequency are consistent with an interpretation as megaripples (not dunes).

Other, less extensive, dark-toned fields of unidentifiable bedforms in the Columbia Hills (glimpsed only at long range earlier in *Spirit*’s traverse) are located on SSE slopes, like El Dorado. The dark-toned ripples glimpsed at long range appear well-organized into parallel alignments, suggesting formative wind directions grossly up- or downslope. Such patterns are harder to discern for the El Dorado ripples seen from *Spirit*’s position. Material in the smaller, unvisited dark ripple fields likely was driven from the SSE, up against hillslopes where grain and bedform progress becomes difficult and residence times likely increase, hence developing a concentration of these particles and bedforms in these areas. The origin of El Dorado likely is similar. Some support for this idea is provided by features in MOC image S12-00095. This image shows that many dust-devil tracks in previous MOC imagery have been erased, replaced with NNW-trending wind streaks indicating winds from SSE strong enough apparently to mobilize dust from aerodynamically rough surfaces and partly clean them off. If wind events like these periodically visit the site, they would blow in the same direction that would mobilize and trap loose sand up against shallow basins on the SSE flanks of the Columbia Hills, where El Dorado and the other dark ripple fields are located.

Lighter-toned transverse ripples have been familiar along *Spirit*’s traverse[8]. Although rarely investigated, these features are dustier and otherwise seem much less likely to be active than the dark-toned ripples of El Dorado. Different wind regimes or exposures to wind cannot be responsible for differences in activity, because some light-toned ripples occur along the margins of El Dorado.

Observations of bedforms at Meridiani Planum by *Opportunity*[9] have shown active and inactive windblown particles/bedforms present together, within the same area. These observations, reinforced by observations of wind-related changes to older rover tracks at Meridiani, highlight the importance of competition between the frequency of strong, mobilizing winds vs. the rate of surface induration processes[10]. At Gusev, the same competition occurs. As at Meridiani, the main factors are (1) particle size, (2) the rate of the indurating process, and (3) the strength-frequency of wind events. Light-toned transverse ripples at Gusev, if similar to feature “Serpent” investigated on sol 73, have larger, therefore harder-to-move, surface grains. Mobility of such features might also date from an era when stronger winds occurred more frequently, helping to defeat surface induration processes by periodically resetting them through mobilization.

In contrast, the very slight crusting and cohesion seen currently at the surface of El Dorado is unlikely to function very effectively as armor against mobilization by wind. While the presence of cohesion makes initiation of particle movement more difficult, wind advecting past local roughness/relief creates local turbulence inflicting much higher-than-average surface shear stresses on localized surface patches—places where initiation of particle motion is more likely to occur despite slight cohesion between grains. As long as initiation occurs somewhere in the deposit—even if only a small population of particles moves initially—saltation impacts should rapidly destroy the very fragile surface crust, liberating a reservoir of particles underneath to participate in a growing cascade to fully developed saltation involving much of the deposit. In this scenario the saltation cloud may initially consist of smaller, more easily moved particles, but these in turn can break loose any still-crusted larger particles to start moving in impact-driven creep or directly in saltation. Faint dust-devil tracks across El Dorado are visible in MOC image R02-00357. Dust devils (or equally strong dust-free vortices) provide an alternative method for regularly applying high shear stress to mobilize grains within the deposit, resetting the induration process.

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