**WIND-DRIVEN EVOLUTION OF MARTIAN NEAR-SUBSURFACE REGOLITH.**
R. Sullivan[1], W. Goetz[2], B. Hallet[3], M. Madsen[4], M. Malin[5], S. Roland[6], D. Rubin[7], and the MSL Science Team. [1]CRSR, Cornell University, Ithaca, NY USA 14853, rjs33@cornell.edu; [2]Max-Planck-Institut für Sonnensystemforschung, Katlenburg-Lindau, Germany; [3]U. Washington, Seattle, WA, USA; [4]Niels Bohr Institute, U. Copenhagen, Copenhagen, Denmark; [5]Malin Space Science Systems, San Diego, CA, USA; [6]SOEST, U. Hawaii at Manoa; [7]USGS Pacific Coastal & Marine Science Center, Santa Cruz, CA, USA.

**Introduction:** The early phases of the Mars Science Laboratory (MSL) mission allow testing of hypotheses relating to the state and origin of martian regolith. Prior to MSL, close-up views of martian regolith were returned from three diverse sites: Gusev (MER Spirit) and Meridiani Planum (MER Opportunity) are equatorial locations on opposite sides of the planet, whereas the Phoenix site is at a high latitude. Despite the geologic diversity among these three sites, it is remarkable that regoliths at all three locations share the following characteristics: (1) trenched regolith away from aeolian bedforms is volumetrically dominated by grains <125 μm; (2) aeolian impact ripples, if present, are volumetrically dominated by grains <125 μm; and (3) aeolian coarse-grained ripples (also called mega-ripples, granule ripples, aeolian ridges), if present, have a surface layer of 1-2 mm grains and interiors that are volumetrically dominated by grains <125 μm [1-3]. At all three sites there seems to be a relative scarcity of grains 350-750 μm. On this basis it was hypothesized that regoliths at all three sites represent similar evolutionary "end states" derived largely from physical weathering caused by aeolian processes, with the implication that similar regolith characteristics could be common in the near-subsurface in many other places across Mars [4]. MSL affords the opportunity to test this hypothesis at yet another site on Mars with close-up views provided by the MArs Hand Lens Imager (MAHLI) [5] at MSL Curiosity's landing site on the floor of Gale crater.

**Background:** Initial theoretical work (e.g., [6]) indicated that martian winds must be many times stronger than on Earth to activate loose ground particles. Once entrained by wind, however, kinetic energies of martian grains would be much higher, with greater potential for damage to the grains during return collisions with the particle bed. On this basis, Sagan et al. [7] proposed that aeolian grain evolution on Mars followed a "kamikaze" pattern in which an initially coarse grain, entrained only rarely by the strongest of strong wind events, would be abraded by high kinetic energy impacts and migrate through successively smaller size-frequencies at an ever-increasing rate (as entrainment became easier and thus more likely) until the grain was essentially turned to dust. Consequently, it was proposed that sand-sized grains might be relatively short-lived and perhaps rare on Mars.

Instead, MER Microscopic Imager (MI) views of trenched and scuffed regoliths showed regoliths that were volumetrically dominated by very fine sand, mixed with unresolved finer grains whose presence was revealed by weakly cohesive remolding during interactions with the rover wheel cleats or the Mössbauer contact plate. The Phoenix results, although representing a smaller, much more localized sample, were similar [1,3]. The size-frequency of this material (even if known less precisely for the MER sites due to MI resolution limitations) is consistent with grains that have evolved by attrition to sizes smaller than the most easily moved 100-150 μm interval. More importantly, at smaller grain sizes kinetic energies have been reduced proportionally by the cube of the particle radius, so grain-to-grain collisions become less effective for evolution to even smaller grain sizes. For example, sorted 50 μm grains are less susceptible to mobilization than 125 μm grains [3], and once entrained, the kinetic energy of a 50 μm grain is only 6% of a 125 μm grain at similar impact speeds.

**MSL Observations:** A sand shadow [8-11] of aeolian material adjacent to rocks at location "Rocknest" was wheel-scuffed, as well as scooped into five times. MAHLI images revealed the materials comprising the bedform. Air-fall dust mantles 1-2 mm very coarse sand at the surface, and the bedform interior is dominated by grains <125 μm, analogous to coarse-grained ripples encountered at both MER sites (Fig. 1).

These observations at four diverse landing sites, now including initial MSL experience at Rocknest, suggest the following stages of aeolian grain evolution (Fig. 2): (1) The coarsest grains initially would be driven in creep, only (by other, smaller, saltating grains), and attrition rate would be limited. At this stage the grains are more target than projectile, pushed and tumbled in creep, with rounding increasing as grain mass slowly is lost (thereby contributing to silt and clay-size populations, including raw material for air fall dust). (2) When grain size evolves to below ~800 μm, the probability of saltation increases and the grain can participate directly in high-energy saltation trajectories; this process accelerates as attrition reduces grain size, which in turn increases susceptibility to saltation. (3) Further grain evolution below ~125 μm is slowed by decreasing susceptibility to entrainment and (more importantly) decreased KE-related collisional damage. (4) The process is slowed even further, to a practical end-state, when a grains gets small enough for suspension behavior to become more likely (because suspension greatly limits repetitive impacts during any strong wind event). Our current numerical work suggests this cut-off is at about 30-50 μm. The final resulting regolith would be an end state of grains 30-125 μm evolved through attrition from larger sizes, mixed with the poorly sorted debris from this process comprised of similar and smaller sizes (including finer silt and clay sizes). The finest grains, no longer participants in repeated saltation impacts during strong wind events, are instead subject to periodic lofting into suspension followed by falling out as dust that, on the ground, combines into loose aggregates that are disrupted easily during lofting in the next strong wind event in a repeating, short-term "dust cycle."

On a planet where aeolian processing of surface materials has been common under dominantly dry climates for hundreds of millions, perhaps billions, of years, this grain evolution scenario could be applicable for near-subsurface regoliths across much of Mars. If so, this would help explain why small samples of trenched regoliths from diverse and widely distributed landing sites share particular regolith size-frequency characteristics (e.g., ~1-2 mm saltation-driven creep fractions, relative scarcity of grains 300-750 μm, abundance of grains <125 μm). Regolith grain size-frequency characteristics at both MER sites, the Phoenix site, and (so far) the MSL site, might be representative of many regolith units across the martian surface that have been processed by wind at some point in the past. An important next test of this hypothesis would be a MSL MAHLI investigation of near-subsurface regolith exposed by wheel scuffing or trenching, but away from aeolian bedforms.

**References:** [1] Goetz, W. et al. (2010) *J. Geophys. Res.-Planets*, *115*, E00E22. [2] Sullivan, R. et al. (2011) *J. Geophys. Res.-Planets*, *116*, E02006. [3] Pike, W. et al. (2011) *Geophys. Res. Lett.*, *38*, L24201. [4] Sullivan R. et al. (2010) AGU Fall meeting P53A-1489. [5] Edgett, K. S. et al. (2012) *Space Sci. Rev.*, *170*, 259-317. [6] Iversen J. D. and White B. R. (1982) *Sediment.*, *29*, 111-119. [7] Sagan, C. et al. (1977) *J. Geophys. Res.*, *82*, 28, 4430-4438. [8] Bagnold, Physics of Blown Sand and Desert Dunes, 188-193. [9] Kocurek et al. this meeting. [10] Goetz et al. this meeting. [11] Edgett et al., this meeting.

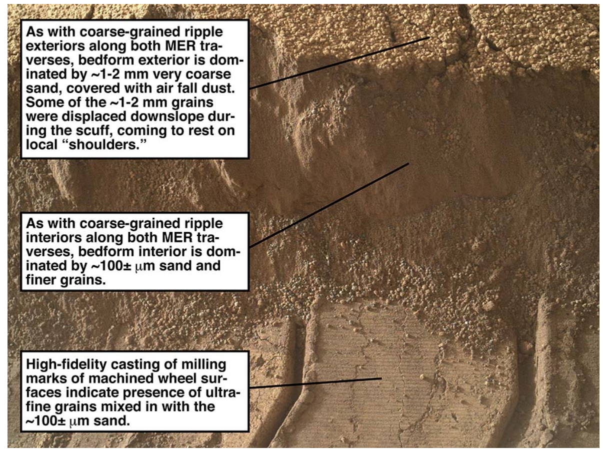


*Figure 1. MAHLI view of wheel-scuffed "road cut" into aeolian material at Rocknest, showing similarities to coarse-grained ripples encountered along both MER traverses. Wheel cleat indentations are ~6.5 cm apart. (MAHLI image 0058MH0029001000E1.)*

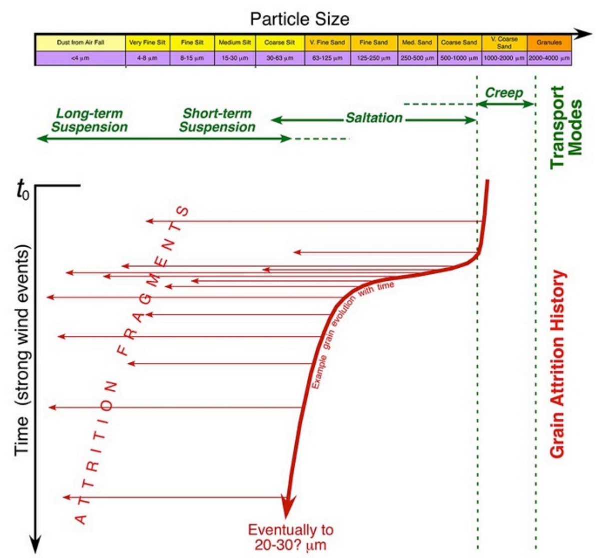


*Figure 2. Hypothesized regolith grain evolution from attrition during aeolian activity, leading to an end-state grain size-frequency comprised of poorly sorted particles <125 um, as seen close-up in trench/scuff walls and floors on four in situ missions, now including one example (Rocknest) at MSL's site at Gale crater. Green section shows typical aeolian transport modes as a function of grain size. Red path shows an example grain evolutionary history, with y-axis pointing downward with time. Attrition becomes more rapid when size allows saltation, but slows again as grain size becomes even smaller. Horizontal arrows represent stylized attrition events contributing debris to silt and clay sizes from size reduction of the main grain.*