COARSE-GRAINED RIPPLES ON EARTH AND MARS: FIELD STUDIES AND WIND TUNNEL EXPERIMENTS.

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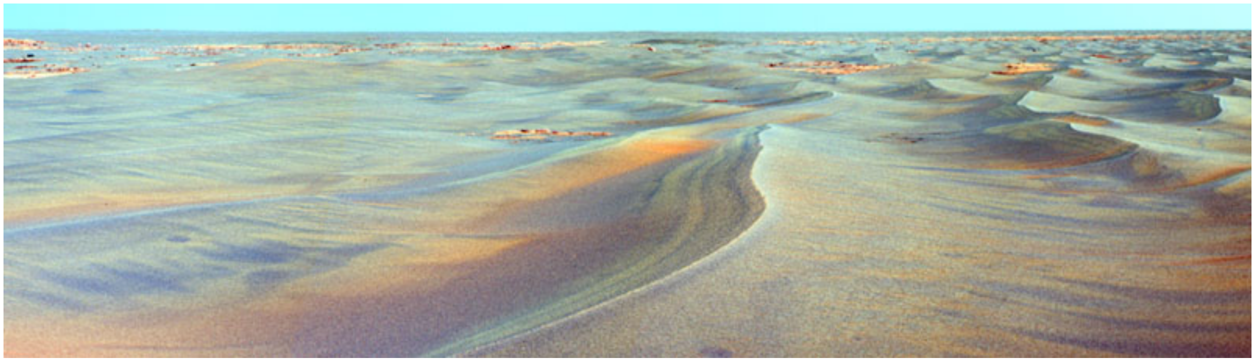

Fig. 1. MER Opportunity Pancam false-color mosaic showing Meridiani plains covered with coarse-grained ripples. Note banding on east-facing flanks. Coarse-grained ripple surfaces are 1-2 mm grains, but interiors are dominated by ~100 μm sand.

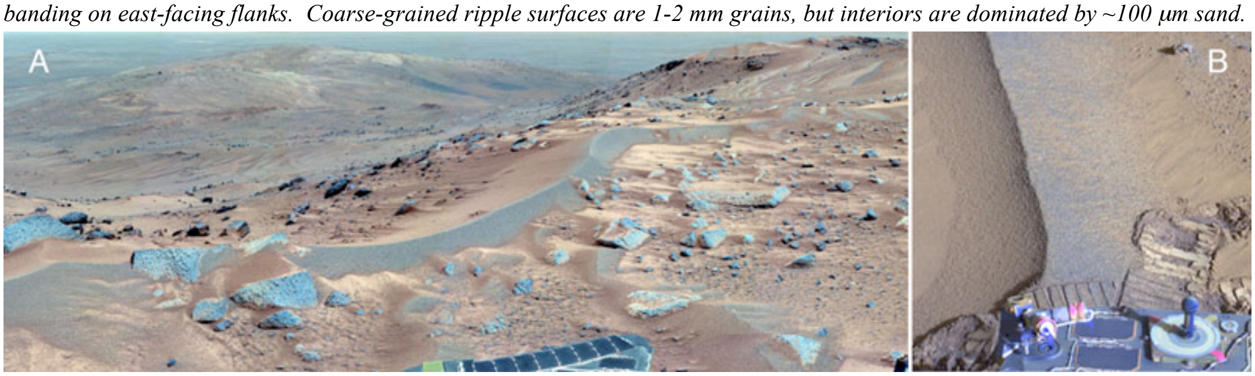

Figure 2. MER Spirit Pancam false-color views of coarse-grained ripples near the summit of Husband Hill. (A) Coarse-grained ripple stretches across this view; others in background. (B) Close-up view of another example nearby. Wheel track is 16 cm wide.

Introduction: Coarse-grained ripples are distinctive because of their dual-mode grain size-frequencies, the enormous sizes they can reach, and their style of downwind migration that is different from ordinary ripples. Coarse-grained ripples were recognized at the Viking Lander 2 site [1] and have been encountered at both Mars Exploration Rover sites (as the dominant aeolian bedform, e.g., Figs. 1-2) [2-4]. Coarse-grained ripples also are candidates for many of the smaller examples of numerous transverse aeolian ridges (TARs) distributed widely across Mars [4-5]. Coarse-grained ripples are self-armoring, durable, and develop from mixed-sized grain deposits. Such deposits should be relatively common on Mars compared with better-sorted deposits dominating extensive aeolian sand seas on Earth that commonly have been influenced by one or more cycles of hydraulic processing and chemical weathering. With durable, coarse-grained ripples abundant on Mars, preservation of sedimentary structures from coarse-grained ripple migration should be expected in martian sedimentary rocks.

However, very few terrestrial studies exist dedicated to sedimentary structures created by migrating coarse-grained ripples, and those studies lack the desired level of detail for guiding interpretation of martian outcrop sedimentary structures at the scale of hand lens imagery (e.g., MER MI, MSL MAHLI). To fill this gap, we are undertaking (1) fieldwork at sites known from previous work to exhibit modern and ancient sedimentary deposits formed by coarse-grained ripple migration, and (2) wind tunnel experiments to illuminate the mechanics of coarse-grained ripple development and to help explain observed differences between terrestrial and martian examples. Our poster serves as a progress report for our initial fieldwork and wind tunnel experiments.

What's special about coarse-grained ripples? Ordinary, familiar aeolian ripples form where sand supply is unimodal and abundant, and all grains participate in saltation; these ripples react quickly to changes in wind direction. [e.g., 6-7]. Ripples of an entirely different nature form where sediment supply is bimodal and the coarsest fraction is too large to saltate, and can be driven only in creep by the saltating finer grains. These bedforms have been referred to variously as aeolian ridges, granule ripples (even when the coarse grains are not granule size), megaripples, and other terms [3, 6-12]. We refer to these features generally as "coarse-grained ripples" (e.g., [3]). Coarse-grained ripples move and react to changing wind conditions much more slowly than ordinary ripples, because crests advance only at the pace of creep of the largest grains concentrated there. Protection of ripple crowns by the coarse fraction leads to large ripple heights, durability against erosion, and considerable profile asymmetry if winds remain unidirectional [6-7]. Very large ripples can result from this process on Earth [13-15]. Sectioning reveals that coarse-grained ripple interiors are dominated by the fine (saltating) fraction, and the coarser (creep) grains generally are concentrated only beneath the crest and as a thin, draping carapace elsewhere, therefore their coarse-grained surface appearance is somewhat deceptive.

Fieldwork: *Coachella Valley, CA:* A strong wind storm in April of 2011 offered an unusual opportunity to observe coarse grained ripples migrate along the boundaries of the dry Whitewater River channel. During the wind storm, 250 μm sand saltated to heights that made viewing upwind difficult, while on the ground 2 mm grains were observed to creep, driven by impacts from the vigorously saltating 250 μm sand. The day following the windstorm, two coarse-grained ripples separated by 7 km were sectioned, and their internal structures documented at resolutions similar to MER MI and MSL MAHLI. In the first ripple cross-section, 93 cm long by 19 cm deep (greater than the ripple height of 13 cm), internal structure was dominated by concave-up bands up to 2 cm thick, distinguished by contrasting grain sizes of either ~250 μm or ~2 mm. Subtle, concave-up, downwind-dipping lineaments were apparent within some of the thicker bands of ~2 mm grains, distinguished only by alignment of multiple grain top surfaces. Perhaps these subtle grain top alignments developed during periods when winds were strong enough for the finer saltating grains to dislodge only the most exposed coarser grains in creep. Alternating thin beds of coarser and finer grains probably reflect changing relative abundances of coarser and finer sand from the dry river bottom during formative wind events. Relatively high coarse:fine abundances (compared with most reports by other workers at other sites) within the cross-section suggest that while coarse-grained ripples commonly are described as volumetrically dominated by fine grains, in fact the actual coarse:fine size-frequency is not a characteristic of this bedform class but depends only on the available mobile grain supply—and only when strong, formative winds are blowing. Sectioning of the second, smaller (8 cm high) coarse-grained ripple 7 km further downwind revealed downwind-dipping structures with little to no concavity.

Moab, UT: An attempt was made to recover one of the few sites of ancient coarse-grained ripple sedimentary structures reported in the literature [10] in Navajo Sandstone but this was unsuccessful. Instead, several new candidates were found, with a 500-800 μm coarser fraction distributed in what appear to be preserved coarse-grained ripple cross-sections exposed in Entrada Sandstone within Arches N.P. We will display these in our poster for discussion and evaluation.

Wind Tunnel Experiments: Wind tunnel experiments allow us to examine, under controlled conditions, the relative importance of individual factors that eventually contribute to preserved sedimentary structures in the rock record. A commonly accepted maximum limiting grain diameter ratio between the coarse (creep) and fine (saltating) grains that will still permit ripple growth and migration is 7:1 (e.g., p. 155 of [6]), but the observed ratio on Mars from MER trenches is at least 15:1 [16]. In the presence of a saltation flux, both the cross-sectional area and mass of a coarse grain influence it's momentum exchange potential for creep mobility. We have recently completed wind tunnel experiments measuring creep rates of sphere groups having constant mass and variable diameters 1.6-3.0 mm, and sphere groups with constant diameter (1.6 mm) and variable density of 1.2-6.1 g/cm^3. We will present preliminary analysis of these experiments in our poster for discussion and evaluation.

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