AEOLIAN SEDIMENTARY PROCESSES AT THE BAGNOLD DUNES, MARS: IMPLICATIONS FOR MODERN DUNE DYNAMICS AND SEDIMENTARY STRUCTURES IN THE AEOLIAN STRATIGRAPHIC RECORD OF MARS.

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Introduction: Wind-blown sand dunes are ubiquitous on the surface of Mars and are a recognized component of Mars' stratigraphic record. Our current knowledge of the aeolian sedimentary processes that determine dune morphology, drive dune dynamics and create aeolian cross-stratification are based upon orbital studies of ripple and dune morphodynamics, rover observations of stratification on Mars, Earth analogs, and experimental and theoretical studies of sand movement under Martian conditions[1-3]. In-situ observations of sand dunes (informally called the Bagnold Dunes) by the Curiosity Rover in Gale Crater, Mars provide the first opportunity to make observations of dunes from the grain-to-dune scale thereby filling the gap in knowledge between theory and orbital observations and refining our understanding of Mars' aeolian stratigraphic record.

Orbital observations of the Bagnold Dunes. The Bagnold Dune Field trends northeast to southwest along the base of Aeolis Mons. Mapped migration of the dunes and ripples indicate that the dunes are migrating nearly 0.5m per Earth year to the south-southwest[4]. Dune morphology and ripple crest line orientations indicate that at least two winds are active in the field. Barchan dunes flank the north side of the field and have primary slipfaces oriented to the S-SE that appear smooth in High Resolution Imaging Science Experiment (HiRISE) imagery, and a secondary, westward-facing lee slope, on which ripples migrate obliquely downslope. Linear dunes occur in the core of the field and have opposing NW-SE facing slipfaces and SW ripple migration along the axis of the dune.

In-situ observations of the Bagnold Dunes. Curiosity's traverse through the Bagnold Dune Field was part of a campaign to investigate dune and ripple morphology and sand chemistry and mineralogy[5]. Curiosity traversed between two barchan dunes at the northern margin of the dune field and stopped at the stoss slope of a dune informally named High Dune and at the primary and secondary lee slopes of a dune informally named Namib Dune. This abstract describes sedimentary structures observed during the traverse of the barchan dunes and discusses the implications of these structures for dune dynamics and the Martian aeolian sedimentary record.

Methods: We use the suite of cameras on Curiosity, including Navigation Camera (Navcam), Mast Camera (Mastcam) and Mars Hand Lens Imager (MAHLI), to make observations of the Bagnold Dunes. Measurements of sedimentary structures are made where stereo images are available.

Results: *Primary Slipface.* Despite the smooth appearance of the primary slipface of Namib Dune in HiRISE imagery, the lee slope has abundant structures indicative of the modern sedimentary processes. Most of the slipface appears to have had active grainflows, which are now largely covered by wind ripples and larger, 1-5 meter wavelength ripples[6]. Grainflows initiate at the dune brink or at mid-slope and extend to the base or terminate mid-slope. The source areas for the grainflows are visible as oversteepened scarps. Mid-slope grainflows appear to initiate at horizontal fractures that form across areas covered in wind ripples. The base of the grainflows are lobate and taper to a wedge either at the base of the dune onto the interdune area or onto a package of basal wind ripples. Large ripples are most clearly developed near the brink and the base of the parimary slope. The large ripples at the brink are forming along alcoves generated by grainflows. The crest lines of the large ripples are oriented vertically along the slope and have distinct stoss and lee sides that imply along-slope transport from E to W along the western arm of Namib Dune.

Secondary Slipface. The secondary slipface of Namib Dune is covered by large ripples. These ripples are continuous over the brink from the stoss slope and migrate down and along the steep secondary lee slope from the N to S. The large ripples migrate to the base of the secondary lee slope and into the interdune area.

The crest lines of the large ripples on the secondary lee slope are straight to sinuous and overall less sinuous than those on the stoss slope of Namib Dune. The large ripples have angle-of-repose lee slopes indicated by grainflows. Grainfall and deflected wind ripples are also visible at the base of the ripples and along the curvature of the ripple lee slope. The stoss slopes of the large ripples are covered with wind ripples.

Stoss Slope. The stoss slopes of Namib Dune and High Dune show a range of ripple types. Typical wind ripples and large ripples mantle the crest of Namib Dune. The large ripples have sinuous crest lines and an asymmetric profile and migrate to the brink line of Namib Dune. Wind ripples cover the stoss slopes of the large ripples. Coarse-grained ripples are present at the base of the stoss slope of High Dune. These ripples have straight to sinuous crest lines and are more symmetrical in profile than the large ripples. Grains coarser than those found along the ripple slopes and in the troughs are concentrated at the ripple crests. Typical wind ripples cover the troughs of the coarse grained ripples. These ripples give way up the stoss slope of High Dune to the large ripples with asymmetric profiles.

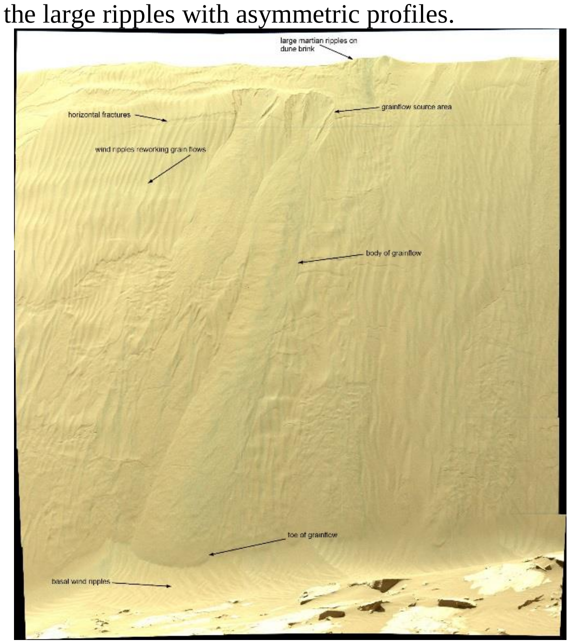

Figure 1: Mastcam mosaic of part of the slipface of Namib Dune. Image is stretched to enchance the sedimentary structures. Structures are labeled on the image.

Discussion: *Implications for Dune Dynamics.* The gravity-driven sedimentary processes occurring on Namib Dune are typical of those found on Earth. At first observation, grainflows are similar in size and shape, which, as anticipated from orbital studies, implies that dunes move similarly to those on Earth. The grainflows and source-area scarps do not indicate significant induration of the sand, but some surface cohesion is implied by the horizontal fractures. Grainfall was not observed on the dune or within the interdune area, but was observed in the lee of large ripples. The ripple covered basal plinth onto which grainflows flow may be a remnant wedge of grainfall from an earlier transverse wind event. The reworking of the slipface by wind and large ripples implies that the most recent wind acting on the slipface was oblique to primary and secondary crestline. Secondary flows from the primary and secondary slipfaces converge at the westward dune horn.

Traction driven processes deviate significantly from Earth analogs. Large ripples are not present on Earth dunes. On Mars these may affect the gravity driven processes on the dune lee slope and wind flow across the dune. Large ripples migrating over the slipface may impart a different brinkline dynamic than on Earth. For example, these ripples may control the distribution of grainflows on the lee slope as they migrate over the brink. The presence of large ripples on the stoss-slope also imparts a roughness element that is different from dunes on Earth, which may, in turn, influence the speed up of wind over the stoss slope and transport over the brink of the dune. The discovery of these ripples requires a reanalysis of the overall dynamics of dunes on Mars.

Implications for the Mars' aeolian rock record. The presence of the typical suite of gravity-driven sedimentary processes on the lee slope of Namib Dune implies that grainflow and grainfall sedimentary structures should also exist in Mars' rock record and appear similar to those on Earth. The reworking of grainflows by wind ripples indicates that shifts in winds and crest line sinuosity should also be present in the rock record and recognized by the juxtaposition of the ripple and grainflow stratification. The presence of wind ripples on the lee slopes indicates that typical, pinstripe lamination, which has been previously observed[2,7] should also be present.

The discovery of the large ripples has significant implications for Mars' stratigraphic record (see Lapotre et al. [6] for a full discussion). The presence of large ripples migrating along both the primary and secondary lee slopes implies that planar or trough cross-stratification may be present that represents the migration of large ripples. Planar stratification may form where the ripples are more 2-dimensional, such as occurs on steeper areas of the lee slopes, whereas trough cross stratification may form where the ripples are more 3-dimensional, sinuous. Under strongly oblique winds, large ripple stratification may dominate lee slope stratigraphy, such as on the secondary lee slope of Namib Dune, and appear much like compound dune cross-stratification. Under moderately oblique to transverse flows, large ripple stratification may form at the base of lee slopes and be juxtaposed to upslope grainflows.

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