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MARS HAND LENS IMAGER (MAHLI) EFFORTS AND OBSERVATIONS AT THE "ROCKNEST" EOLIAN SAND SHADOW IN CURIOSITY'S GALE CRATER FIELD SITE.

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Introduction: The Mars Science Laboratory (MSL) mission is focused on assessing the past or present habitability of Mars, through interrogation of environment and environmental records at the Curiosity rover field site in Gale crater. The MSL team has two methods available to collect, process and deliver samples to onboard analytical laboratories, the Chemistry and Mineralogy instrument (CheMin) and the Sample Analysis at Mars (SAM) instrument suite. One approach obtains samples by drilling into a rock, the other uses a scoop to collect loose regolith fines.

Scooping was planned to be first method performed on Mars because materials could be readily scooped multiple times and used to remove any remaining, minute terrestrial contaminants from the sample processing system, the Collection and Handling for In-Situ Martian Rock Analysis (CHIMRA). Because of this cleaning effort, the ideal first material to be scooped would consist of fine to very fine sand, like the interior of the "Serpent Dune" studied by the Mars Exploration Rover (MER) Spirit team in 2004 [1].

The MSL team selected a linear eolian deposit in the lee of a group of cobbles they named "Rocknest" (Fig. 1) as likely to be similar to "Serpent Dune". Following the definitions in Chapter 13 of Bagnold [2], the deposit is termed a "sand shadow". The scooping campaign occurred over ~6 weeks in October and November 2012. To support these activities, the Mars Hand Lens Imager (MAHLI) acquired images for engineering support/assessment and scientific inquiry.

Rocknest Sand Shadow: The sand shadow falls within the class of Mars eolian landforms for which the albedo is indistinguishable from surrounding terrain (Fig. 1). This is an indictor that the sand shadow probably has not been subject to many recent impacts of windblown, saltating grains and, like the surrounding terrain, it is mantled with dust. In the vicinity of the five scoop locations (Fig. 1), the deposit—estimated from rover engineering camera stereogrammetry—was ~12 cm thick between sand shadow crest and substrate.

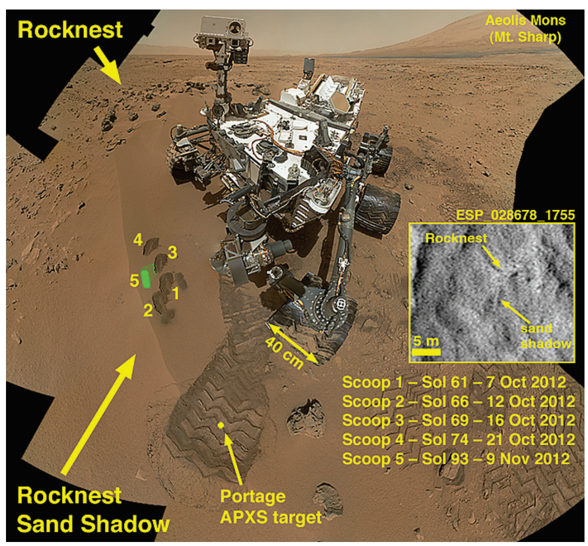

Fig.1. Rocknest sand shadow, wheel scuff and 5 scoop locations. This is a mosaic of 55 MAHLI images acquired on Sol 84 (31 October 2012). The inset is from MRO HiRISE image ESP_028678_1755 acquired on 8 September 2012; north is up.

Observing Strategy: To support the Rocknest campaign, Curiosity's MAHLI was used for:

Interrogation of sand shadow for suitability for scooping, cleaning, sieving, and sample delivery. MAHLI acquired images of 30–100 µm/pixel in the wheel scuff/imprint (Fig. 1) and determined that the sand shadow indeed consisted largely of the desired particle sizes for CHIMRA cleaning and sample passage through a 150 µm sieve for delivery to CheMin.

Range-finding for scoop placement. Candidate scoop locations were imaged using MAHLI's autofocus capability to determine scoop placement, for all five scooping events, to within about ±2 mm.

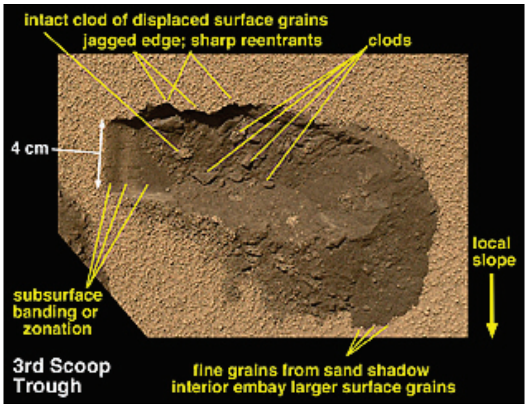

Fig. 2. Observations regarding the nature of the Rocknest sand shadow as revealed by scooping. This is a sub-frame of a Sol 84 (31 October 2012) MAHLI image.

Foreign Object Debris (FOD) Detection. A piece of MSL hardware debris was observed on the surface of the Rocknest sand shadow and MAHLI was used on Sol 65 (11 October 2012) to investigate it. Thereafter, MAHLI images were acquired at ~100 µm/pixel, in association with ~31 µm/pixel range-finding, to check that no FOD was present at each scoop site. This ensured that no materials from Earth would be ingested into CheMin and SAM.

Science Documentation. Most MAHLI images acquired at the Rocknest site were obtained for engineering purposes. Specific science imaging included documentation of APXS placement at Portage (in wheel scuff; Fig. 1), imaging of the sedimentological attributes of the scoop troughs (Fig. 2), and high resolution views (Fig. 3) of the sand—both *in situ* and of sieved (≤ 150 µm) samples delivered to the the rover's Observation Tray (O-Tray).

Observations:

Sand Shadow Structure. The bulk sediment is fine and very fine sand (Wentworth classification [3]) with an unmeasured proportion of infiltrated silt and clay-sized grains. Images of trough walls show subsurface zones of differing color arranged parallel to the sand shadow surface (Fig. 2). The upper ~0.5 cm is dominated by a 1–3 grains-thick layer of coarse and very coarse sand. The coarse grains are coated by dust that is clumped, forming patterns reminiscent of an architectural ceiling treatment known as popcorn; similar textures were observed by the Spirit and Opportunity Microscopic Imagers [4]. The upper ~0.5 cm of the drift is sufficiently indurated such that clods consisting of the coarse/very coarse sand (with interstitial fines) and, in some cases, with the dust coating still intact, were displaced by the scooping process (Fig. 2).

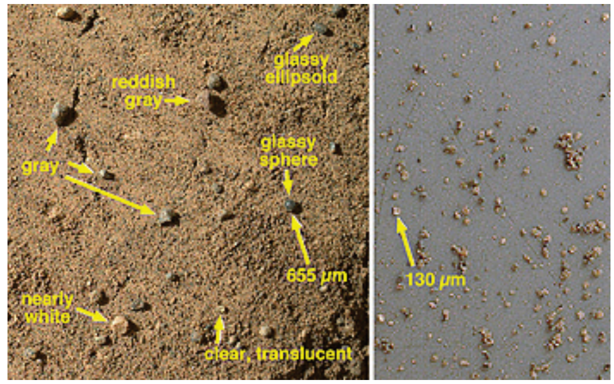

Fig. 3. *Left:* Observations of the coarse/very coarse sand in the Rocknest sand shadow. These are grains that tumbled down, losing their coating of fine dust, onto a surface flattened by a rover wheel, as seen by MAHLI on Sol 58 (4 October 2012). *Right:* MAHLI view of fine and very fine sand deposited by the sample processing/handling system on the rover's Ti O-Tray on Sol 73 (20 October 2012). Clear/yellow-ish, translucent crystal fragments are seen, as well as white opaque grains and reddish-brown grains; these represent a portion of the sands delivered to SAM and CheMin during the Rocknest campaign.

Coarse and Very Coarse Sand. MAHLI images of the coarse sand grains (Fig. 3) show they have a variety of colors, lusters, shapes, and roundness. The grains include gray and red lithic fragments, clear/translucent crystal fragments, and glassy ellipsoids and spheres. Some mineral crystal faces or cleavage planes were observed as bright glints on flat-topped, angular grains in sunlight in the scoop troughs and wheel scuff areas.

Fine and Very Fine Sand. The fine and very fine sands were only poorly resolved in the majority of the images acquired during the campaign. The highest resolution views were of the < 150 µm grains deposited on the O-Tray (Fig. 3). These included angular, clear/translucent crystal fragments, dark/black opaque grains, as well as red, nearly white, and gray particles.

Some Interpretations: Before Curiosity's wheels and scoop disrupted the Rocknest sand shadow, the deposit was inactive in terms of recent eolian saltation and traction; the crusted upper ~0.5 cm and the dust coating its surface both attest to this inactivity. The sand includes both lithic and crystal fragments as well as spheres and ellipsoids of a glassy luster; the latter might be frozen impact or volcanic melt droplets [5].

References: [1] Sullivan *et al.* (2008) *JGR 113*, doi:10.1029/2008JE003101. [2] Bagnold (1941) *The Physics of Blown Sand and Desert Dunes*, Methuen, London. [3] Wentworth (1922) *J. Geol. 30*, doi:10.1086/622910. [4] Herkenhoff *et al*. (2008) In *The Martian Surface: Composition, Mineralogy, and Physical Properties* (J. F. Bell III, ed.), Cambridge Univ. Press. [5] Yingst *et al.* (2013) *LPSC 44*.