ON THE EOLIAN TRANSPORT DURABILITY OF SAND-SIZE MUDSTONE CLASTS – THE POTENTIAL FOR MARTIAN SAND DUNES THAT ARE COMPOSED OF FINE GRAINED AGGREGATES AND IMPLICATIONS FOR INTERPRETING MUDSTONE STRATA AT GALE CRATER, MARS. Zalmai Yawar[1], Juergen Schieber[1], Robert Sullivan[2], Michelle Minitti[3], and Ken Edgett[4], Dept. Geol. Sci, Indiana Univ., 1001 E 10th Str., Bloomington, IN 47405; [2]CCAPS., Cornell Univ., Ithaca, N.Y.; [3]Framework, Silver Spring, MD; [4]Malin Sp. Sci. Sys., San Diego, CA; zyawar@gmail.com.

Introduction: Prompted by enigmatic cross-bedding in mudstones of the Murray formation at Gale crater, we investigated whether mudstone aggregates can potentially withstand transport abrasion long enough to allow formation of dune forms.

Whereas we commonly think of mineral grains such as quartz, feldspar, etc. when talking about eolian dunes, there are reports of modern terrestrial examples of eolian dunes that form when mud/mudstone aggregates are transported by wind. Known under names like "parna", "clay dunes" and "soil sands", they form when winds rework desiccated mud crusts, and likely have analogs in the rock record that are unrecognized in ancient floodplain and lacustrine deposits.

To this end we prepared a "sand" by crushing a soft mudstone, and observed its transport and degradation behavior. After 7 months of continuous motion in a laboratory wind chamber, 90% of the initial material still remains and minimal average travel distance is 530 m per grain. It appears that by the time 50% of the initial grains have been destroyed, 10 or more km of average transport distance is achieveable, and assembly of dune-like bedforms is plausible.

Figure 1: Circular wind chamber (left), and its lid (right) that carries the motor driven propeller.

Methods: Sand size particles (2 mm and smaller) of a soft mudstone were placed in a circular wind chamber, where sustained air flow (ca. 25 km/hr) was generated by a motor-driven propeller (Fig. 1). The mudstone-sand was sieved and photographed at the onset of the experiment, and over the course of 7 months the sand was repeatedly weighed and photographed to document loss of sediment (to airborne dust), enhanced grain rounding, and changes in grain size distribution. The part of the sediment load that turned into dust was removed on a daily basis by running the air in the chamber through a vacuum cleaner.

Results: After 7 months, 13% of the sediment load was lost. However, only half of that amount was actually lost to abrasion. The other half was lost during intermittent sieve analysis (Fig. 2).

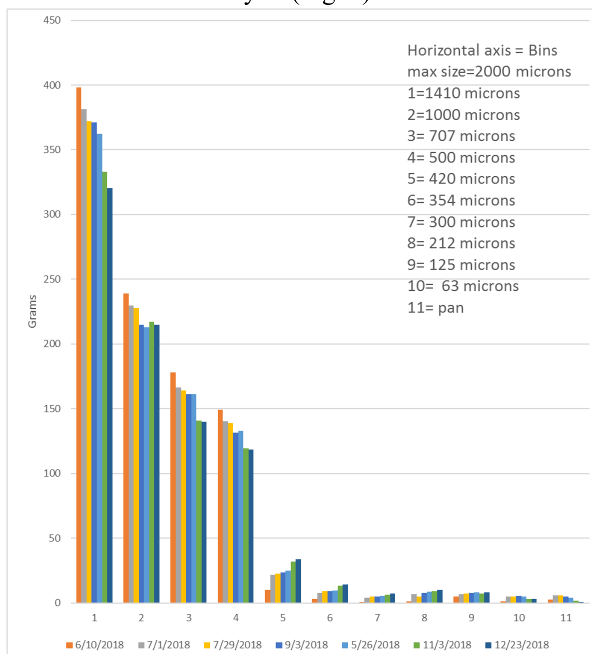

Figure 2: Grain size distribution over the course of 7 months. Coarse sand classes decline as grains are fragmented and rounded, medium sand size classes increase correspondingly.

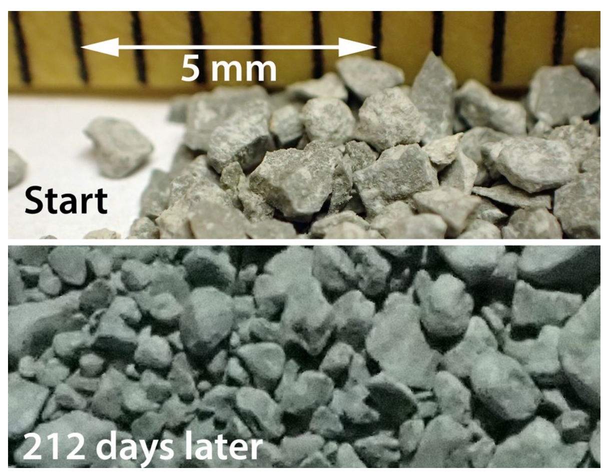

Figure 3: Smoothing and rounding of initially angular mudstone grains over 7 months.

In the course of the experiment the originally angular grains showed increasing smoothing of edges and general grain rounding (Fig. 3). In addition, the proportion of the coarse grain populations (0.5 to 2 mm) decreased, whereas that of the medium to fine grain populations (0.2 to 0.5 mm) increased (Fig. 2).

Using film clips of the moving grain carpet, and examining changes between frames, one can estimate the average rate of grain movement per film frame, and also the distance of grain movement as long as the grains stay within the field of view. Grains that move past the field of view can not be counted, thus our measure of grain travel per unit area and time is a minimum estimate. Averaging over the entire field of view (47 mm x 83 mm) we estimate that these grains would have averaged 530 meters of downwind motion in the 7 months that this experiment has been running (the experiment is planned to run for 12 months).

If we assume linear grain loss due to abrasion, we can estimate that it will take 3 years until 50% of the original grains have been destroyed, at a mimumum average travel distance of ca. 2.7 km. For reduction of the original grains to 10%, approximately 5 years will need to pass, at a minimum average travel distance of 5 km. To arrive at these figures, corrections for sieve loss were applied. Given that we are currently not able to evaluate the travel distance contribution by faster moving grains (travelling past the field of view), the real travel distance must be significantly larger, most likely in excess of 10 km.

Implications for Gale Crater Mudstones: The Curiosity rover carries an arm-attached camera, the MArs Handlens Imager (MAHLI), for closeup characterization of Mars surface rocks. The highest possible resolution of MAHLI under ideal conditions 14 microns per pixel [1], which allows resolution of particles as small as 45-60 microns. This is coarse silt, but still falls within the mudstone category of commonly used classification schemes [2]. Utilizing earth analogs and "single pixel variability" one can "push" MAHLI resolution to the mid-silt range [3].

MAHLI has been an extremely useful tool for grain size detection of Gale crater strata, but in places we have encountered rocks where apparent grain sizes are inconsistent with grain sizes inferred from sedimentary structures, such as cross-bedding.

One example is the the Hartmann's Valley member (HVM) of the Murray formation. MAHLI suggests that the dominant rock type should be mudstone [3, 4], even though the interval contains what appears to be large scale cross-stratification [5]. The apparent fine grain size seen by MAHLI is puzzling, because it is inconsistent with the particle sizes that would be expected for either fluvial or eolian cross-bedded strata. In order to be transported under Martian surface conditions fine sand is required in both scenarios [4].

In order to better appreciate what we might see with MAHLI if our eolian shale sand (Fig. 3) had been compacted into a rock, we did just that with our experimental materials, and then sectioned them and examined the resulting surface by SEM (0.4 microns per pixel; sand size grains clearly visible). Then we reduced resolution to 15 microns per pixel (+-best achievable MAHLI resolution) and sand grains were no longer visible. What was left at that point was a random scattering of pixels with different gray levels, very much like the "single pixel variability" seen in HVM mudstones with MAHLI [3]. It is therefore perfectly possible that cross-bedded mudstones at Hartmann's Valley originated as eolian dunes composed of mud-dominated composite particles [6].

Discussion and Conclusion: Eolian dunes composed of detrital, pelletal cohesive materials of sand size have long been known from aeolian environments on Earth, where they are sometimes described as "parnas", "clay dunes" or "soil sands". The clay pellets derive from the margins of drying salt flats and exposed and desiccated lake beds. Mechanical disintegration of mud curls provides sand size fragments that then are transported and piled up into dunes.

Applied to the Murray formation lacustrine mudstones, one could for example envision extensive exposure and desiccation of lake muds during lake lowstands or when the lake dried out completely. If such conditions persisted for long time intervals, they could have allowed formation of eolian dunes on the former lake bed. Because the requisite mud aggregates were locally derived, transport distances on the order of a few km would have sufficed to build up a sheet of dunes that were composed of mud aggregates.

The envisoned scenario may also apply to other localities along the rover traverse. For example, Mastcam images of ridge-like features in the clay trough south of the Vera Rubin Ridge (target "Lairig Ghru", Sol 2264) show large scale cross-stratification similar to that observed in the HVM. If the rocks in question are (as currently expected) indeed mudstones, formation by eolian accumulation of mud aggregates would be a plausible genetic model.

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