AEOLIAN TRANSPORT IN OLYMPIA UNDAE, MARS, BASED ON A FIELD STUDY AT WHITE SANDS NATIONAL MONUMENT, NEW MEXICO, USA.

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Introduction: Olympia Undae is Mars' largest dune field, spanning more than 200,000 km^2. The sand is dominated by mafic materials [e.g., 1,2] with the most recent study suggesting a mixture of iron-bearing glass and high-calcium pyroxene [3]. OMEGA data showed that gypsum ($CaSO_4 \cdot 2H_2O$) was present in the eastern portion of the dune field [4], mainly concentrated at dune crests [5-8]. The occurrence of gypsum is a mystery, given the Amazonian age of the dunes and the prevalence of most other sulfates in much more ancient deposits [9]. Hypotheses for its origin include alteration from filtered brines [10], erosion from older polar strata [7], and erosion from underlying hydrothermal deposits [11].

To better understand how aeolian processes redistribute gypsum and mafic minerals (e.g., soft and hard minerals), we performed a field investigation at White Sands National Monument (WSNM) in New Mexico, USA. The WSNM dune field is nearly entirely composed of gypsum sand, and it is the largest known gypsum-bearing dune field on Earth. This work focuses on samples taken on and near the stoss slope of a dune located at the upwind (western) margin of the dune field, along the northern border of WSNM. This area lies along a transport pathway of dolomite ($CaMg(CO_3)_2$) grains that mix with the gypsum, potentially interacting in ways analogous to that of the harder and denser grains common to Olympia Undae.

Results: As described previously [12,13], XRD, VNIR, and Raman spectra of samples from the stoss side of the dune, as well as from coarse-grained ripples nearby, indicate a marked spatial pattern in mineral distribution. The XRD results are summarized in Table 1.

Table 1. Weight percent of >1 mm grains.

	Gypsum	Quartz	Dolomite	Calcite
Dune:				
Lower stoss	30	2	60	7
Upper stoss	60	2	39	-
Coarse-grained ripples:				
Upwind[1]	13	5	69	12
Near dune crest	30	-	63	7

[1]A few hematite, prehnite, and microcline grains were also found.

For >1 mm grains, samples from both the dune and the coarse-grained ripples indicate a windward enhancement of gypsum grains towards the dune crests, with a corresponding depletion of dolomite and other minerals. In contrast, finer grains were made of 95-100 wt.% gypsum, with <5% quartz (note that [14] reported a median grain size of 400 μm at WSNM). The quartz content was typically higher in smaller size fractions (<150 μm), but it did not vary spatially.

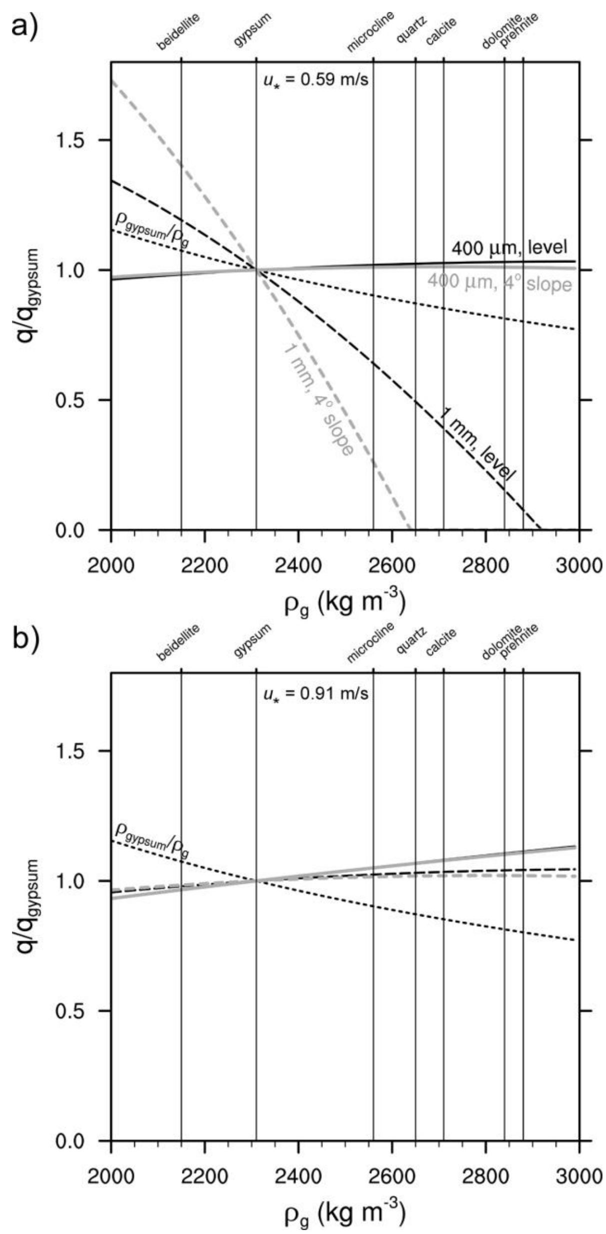

Figure 1. The saltation mass flux *q* of 400 μm and 1 mm grains relative to gypsum grains of the same size calculated at a) u_* = 0.59 and b) 0.91 m/s. The dotted line shows the creep mass flux relative to gypsum grains. At u_* = 0.59 m/s, saltation of 1 mm grains segregates them by density far more efficiently than creep; however, this relation does not hold in much stronger winds.

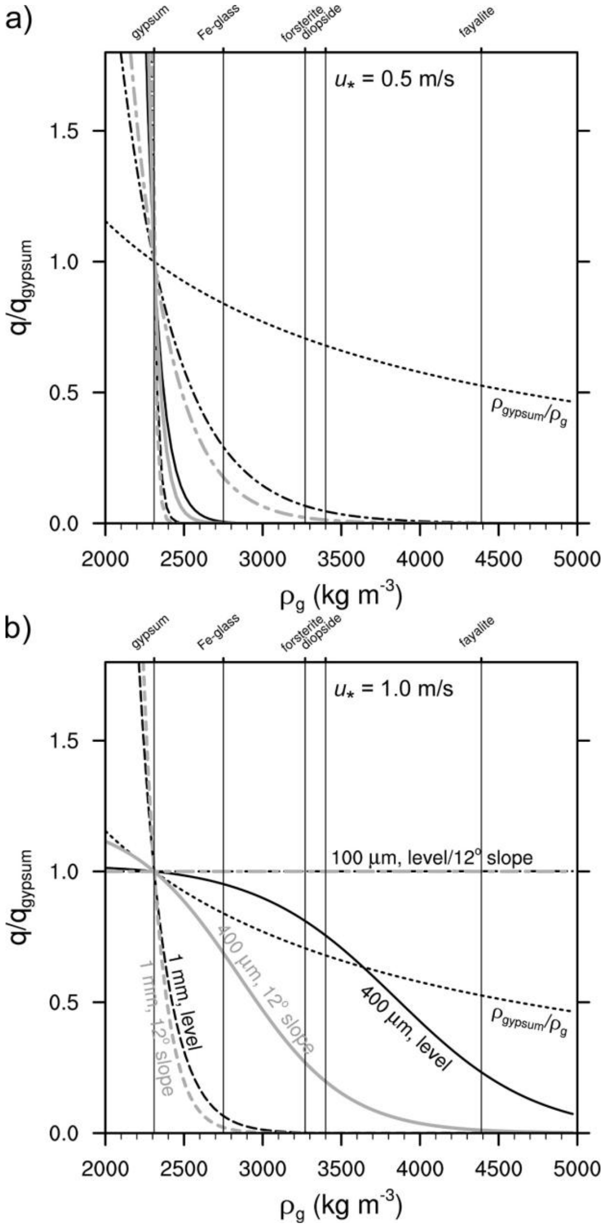

Figure 2. Same as Fig. 1 but for Olympia Undae, Mars. The saltation mass flux *q* of 100 µm, 400 µm, and 1 mm grains relative to gypsum grains of the same size calculated at a) u_* = 0.5 and b) 1.0 m/s. The dotted line shows the creep mass flux relative to gypsum grains.

Discussion:

White Sands. Creep alone does not explain the sudden depletion in grains denser than gypsum at the western margin of the WSNM dune field [13]. The formative friction velocity (u_{*f}) for this dune field was estimated to be 0.39 m/s [14], which could be enhanced by ~1.4x to 0.59 m/s by compression of air flow up the stoss slope [15]. Using [16], and accounting for the 4° stoss slope [17], the resulting sand flux (q) relative to that of gypsum (q_{gypsum}) for 400 µm and 1 mm grains is shown in Fig. 1a as a function of grain density. On a level surface, 1 mm dolomite grains have a mass flux ~0.15x that of 1 mm gypsum grains, but they cannot saltate on the 4° dune slope. Strong wind events are capable of saltating 1 mm dolomite grains on the dune slope (Fig. 1b), but they do not segregate the grains by density. Thus, coarse-grain transport up the dune stoss slope has consisted of a combination of:

1) creep when winds are too low to saltate the large grains (u_* < ~0.59 m/s) but strong enough to saltate the plentiful 400 µm gypsum sand (u_* > ~0.36 m/s), and

2) saltation when winds are strong enough to lift the coarse gypsum grains (u_* > ~0.54 m/s), but weak enough that they saltate gypsum grains more effectively than higher-density grains (u_* < ~0.91 m/s).

Mars. The Mars Climate Database (MCD, http://www-mars.lmd.jussieu.fr) predicts friction velocities ranging from 0-0.36 m/s in Olympia Undae. The ~12° stoss slopes [18] impact sand flux estimates [19], so that the strongest winds (with a speedup of 1.4x to 0.5 m/s from [15]) produce a marked impact on transport as a function of grain density (Fig. 2a). At 100 µm, iron-bearing glass has an estimated sand flux ~0.18x that of 100 µm gypsum grains, which would produce the observed concentration of gypsum at dune crests. Doubling the wind strength (Fig. 2b) reduces the segregation by grain density on 100 µm grains (although not on larger grains). If the sand in Olympia Undae is comprised of 100 µm grains, like that elsewhere on Mars [e.g., 20], then we predict the formative friction velocity $u_{*f} \leq$ ~0.36 m/s, as modeled by the MCD. If the sand grains are larger then u_{*f} would increase accordingly.

Tentative conclusion: Measurements of the spatial distributions of grain mineralogy on a dune can be used to constrain formative friction velocities.

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