FORMATION OF COARSE-GRAINED MEGARIPPLES ON EARTH AND MARS: INSIGHT FROM WIND TUNNEL EXPERIMENTS AND THE ARGENTINEAN PUNA

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Introduction

The understanding of the formation mechanisms, rates, and particle fluxes of Martian aeolian bedforms is informed by terrestrial analog fieldwork, commonly augmented with wind tunnel and modeling studies. Martian dunes and sand ripples have fairly close terrestrial morphometric analogs, emphasizing the role of saltation and impact splash in both environments. However, Transverse Aeolian Ridges (TARs) are a class of Martian bedform with a morphology intermediate between megaripples and reversing dunes for which a viable terrestrial analog is much harder to find [1-5].

The gravel megaripple fields in Catamarca province, Argentina [6-8] are located in one of the windiest parts of the Argentinean Puna and may be the best terrestrial analog for TARs [9]. In the region of the Cerro-Blanco caldera complex, late Pleistocene ignimbrites ranging in age from 13,000 to 70,000 years dominate the landscape [10,11]. They contain about 5% by volume of lithic clasts with densities ranging from 2600 to 3000 kg m^{-3}, and up to 10% crystal-poor pumice clasts with densities of ~800 to 1300 kg m^{-3}.

Until now, there has been a poor understanding of the threshold speeds needed to set the various coarse-grained materials into motion, namely the pumice, lithics, and quartz granules, and what effects the role of impacting sand and pumice has on these thresholds. There is a mature literature on the threshold studies of spherical particles sand as a function of size and density [11], but no studies (that we are aware of) on wind speeds needed to move clasts of the specific size, density, and shape that we find in the Puna. These results are reported here.

Methods

The boundary layer wind tunnel at Arizona State University (ASUWIT) was used for these studies. Megaripple components collected in the field were placed in the tunnel test section. To simulate the impact of saltating particles in lowering threshold, quartz sand (Silver Sand #30, PW Gilibrand) was placed in the overhead hopper and dropped into the wind stream. Sunset Crater scoria at 800 µm average diameter was placed upwind of the test section in an unconsolidated pile that was blown downwind at a progressively greater flux as wind speed was increased. An overhead still camera took pictures with a 1-minute cadence over the experiment duration. Side-mounted video and still pictures downwind and above the wind tunnel floor viewed the runs in perspective. Wind speed was gradually ramped up from zero and stages of particle motion (vibrating, sliding, rolling, and saltating) as a function of composition and approximate size noted in recorded voice cues. An abstract describing the detailed analysis methods is presented at this conference [12].

The experimental matrix consisted of 6 samples from the Campo Purulla (CP), Campo Piedra Pomez (CPP), Laguna Purulla (LP), and White Barchan (WB) ripple fields. Of these samples, three classes of particles at a range of sizes were used: Coarse pumice from CP, LP, and WB; coarse lithics from all four areas, quartz granules from CPP, and quartz sand from WB. Materials were variously distributed in the tunnel.

Four of the ten experiments were run under pure fluid conditions, that is, with the only pre-threshold forces on the particles being lift and drag from the wind. The other six had quartz sand and scoria impacting the particles, as described above. These two cases are qualitatively labeled here as fluid and impact threshold, although the latter condition differ from the classic definitions [11].

Results

Clasts of cm-scale and larger were of sufficient size to note progressive stages of motion with increasing wind speed, beginning with vibrating, followed by creeping (sliding along the surface), rolling, and then saltation (Fig. 1). It is clearly seen that larger particles require greater wind speeds within a given stage and that the impact of quartz and especially scoria lowers threshold. This is also seen in a plot of wind speed at saltation threshold vs. particle size (Fig. 2). Depending on size, wind tunnel wind speeds of 3 – 16 m s^{-1} are needed to move pumice. Adjusting for the approximate atmospheric density differences between Tempe, Arizona (~400 m elevation), and the Puna at ~4500 m elevation gives equivalent velocities in the field of 4 - 21 m s^{-1}, respectively. Such conditions are common [9,13]. Data for the denser lithics are still being reduced, but qualitatively they also reached threshold under conditions of impacting quartz and scoria, but at higher wind speeds than the lighter pumice. As experiments progressed, we also observed that many particles clumped into patches that then served as nucleation sites for further particle accumulation (Fig. 3). This may be an analog to particles coalescing into nascent ripples, perhaps aided by pre-existing topographic ridges [9].

Discussion

These results show that on a relatively flat, low roughness surface equivalent to that for fresh ignimbrite bedrock, conditions should be sufficient to saltate sand and pumice granules and through impact creep, concentrate pumice, quartz, and lithic granules into ripples. Such high winds speeds are reached in the Puna, showing that current conditions can form the ripples. Martian equivalent winds speeds needed to move equivalent particles are rarely or never reached in the current environment, indicating that if TARs formed like megaripples in the Puna, emplacement was likely under past obliquity conditions of a denser atmosphere.

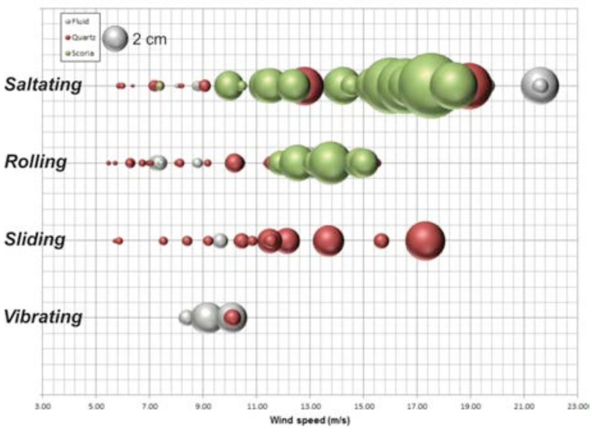

Figure 1: Stages of motion for pumice samples. The colors refer experiments in which only wind was blowing in the tunnel vs. runs that had saltating sand and scoria. The sizes of the spheres is the relative size of clasts. Velocities are those in Tempe, AZ - Because of the lower atmospheric density in the Puna, wind speeds there would be 1.3x greater than shown here.

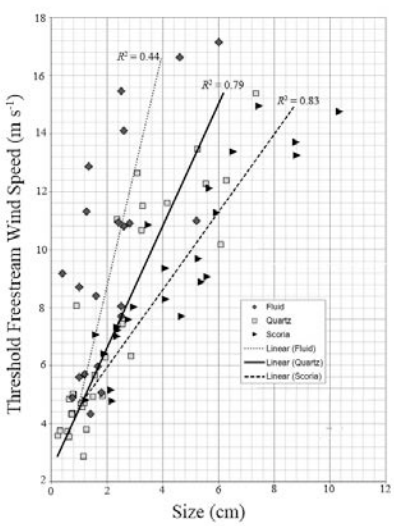

Figure 2: Freestream wind speed vs. clast size for pumice at saltation threshold. Lines are best linear fits to conditions of pure wind and those with saltating quartz and scoria. Because of the lower atmospheric density in the Puna, wind speeds there would 1.3x greater than shown here.

Fig. 3: Clumping of materials into nascent ripples. In this experiment (P-12-013) pumices and lithics were impacted by scoria particles. The time difference between the two slides is 26 minutes.

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