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Recent Developments in Understanding Wind Driven Erosion

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Abstract

The wind driven transport of granular material is an important environmental/climatic factor on Earth and even more so on Mars. Several related aspects of Aeolian activity are presently being studied in the laboratory. These include simulating wind driven erosion in the laboratory and the study of mineral change due to mechanical activation as well as quantifying erosion rates. The generation of electric fields and the effects of these electric fields on grain transport is also being investigated using environmental wind tunnel simulators.

1. Introduction

Terrestrial studies show that the generation of electric fields by granular transport is a widespread and important phenomenon (for example in sand/dust storms, volcanic activity and ice/snow transport) and that intense electric fields can then consequently affect the transport of granular material [1,2].

In laboratory studies of the effects of electric fields on sand and dust transport have focussed on levitation, reduced detachment threshold and enhanced transport. They have been based on the application of simple models in which the sand bed is assumed to be conductive. Recent work indicates that this assumption is in many cases not valid [3].

It is a well documented effect that under milling (mechanical fracturing) that silicates, due to their covalent lattice structure, forms activated surfaces. This so called mechanical activation can lead to an oxidizing behaviour, presumably due to dangling oxygen bonds. In previous laboratory simulations of (quartz, SiO_2) sand saltation, significant erosion was seen which lead to mechanical activation and allowed the quartz to become oxidizing. This was seen to be capable of oxidizing iron oxide and has been suggested as a mechanism by which the Martian dust became reddish (Hematite rich) [4].

In addition to the oxidized nature of the Martian dust, erosion induced chemistry may also explain several other surprising characteristics of this planet, specifically the presence of an unidentified oxidizing agent in the soil (observed by the NASA Viking landers) and the presence of chlorate (seen by the NASA Phoenix lander). Such processes may also be relevant to arid regions on Earth.

2. Wind Erosion and Mineralogy:

The simulation work studying wind driven erosion (saltation) is ongoing. The technique employed involves hermetic encapsulation and gentle mechanical agitation (tumbling) of granular samples, typically sand (>125µm), for periods of around 7 months (10million rotations). This leads to a drastic reduction in grain size and the formation of silt [4].

The process however is unlike milling in which larger grains are severely fractured (cleaved). In the case of saltation (and tumbling) it appears that the low velocity impacts lead to tiny localised chipping and the expulsion of micrometer (and even sub micrometer) fragments leaving behind tiny pits.

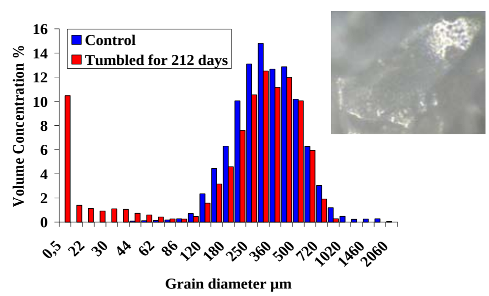

Figure 1 Grain size distribution measured before (blue) and after (red) simulated sand erosion and photograph showing a pitted quartz grain.

Interestingly the silt generated by the simulated sand erosion becomes cemented into well cohered agglomerates which appear as white spheres. This cementation may be a further result of the mechanical surface activation.

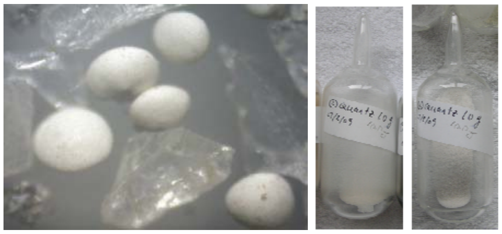

Figure 2 quartz grains and cemented quartz silt after simulated erosion (left). Roughened glass flask (centre) and after erosion showing also erosion of the glass (right).

Recent work has involved performing erosion simulations using a broad range of minerals (including various silicates). This work indicates that the dependence of erosion rate on mineralogy has an (intuitively) unexpected, though physically meaningful, behaviour.

2. Electrification and Electric Fields

In recent wind tunnel experiments the transport rate of wind driven sand was measured in the presence of an externally applied electric field. A simple physical model was applied and showed good agreement at low and high electric fields. Interestingly, however, at intermediate electric fields (see figure 3) poor agreement was seen.

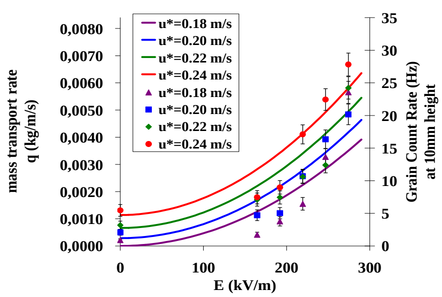

Figure: 3 Increased wind driven Sand transport rate seen in an electric field.

Observations of the sand bed under the influence of electric fields (in the absence of wind) showed the spontaneous formation of mounds which were interpreted as dielectric chain formation. This indicated that the assumption of a conducting sand bed is flawed and that at low electric fields the surface conductivity is low and extremely non-uniform (patchy). Recent detailed wind tunnel simulations have been performed which show that under arid (Mars like) conditions the effects of applied external electric fields are significantly more complicated than previously speculated and that the combined roles of granular electrification and electric field induced interaction require a far more detailed treatment to be properly accounted for.

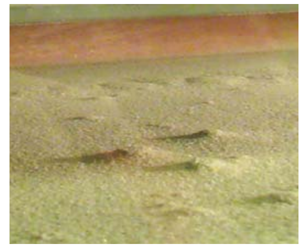

Figure 4 Sand bed exposed to an intense electric field.

4. Conclusions

The transport of granular materials by the wind has a major impact on our environment and yet is still relatively poorly understood, specifically the effects of electric fields, the generation of electric fields, the effects of wind induced erosion on surface chemistry/mineralogy and even the rates of erosion by wind driven processes. A detailed understanding of these phenomena requires the combination of extensive laboratory simulations, field testing/observation and modelling.

References:

[1] J.P. Merrison et al., Icarus **191**, 568 (2007)
[2] J.P. Merrison et al., *Planet. Space. Sci.* **56**, 426 (2008)
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[4] J.P. Merrison et al., Icarus, **205**, 716 (2010)