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Planetary Surface-Atmosphere Interactions

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Abstract

Planetary bodies having an accessible solid surface and significant atmosphere, such as Earth, Mars, Venus, Titan, share common phenomenology. Specifically wind induced transport of surface materials, subsequent erosion, the generation and transport of solid aerosols which leads both to chemical and electrostatic interaction with the atmosphere. How these processes affect the evolution of the atmosphere and surface will be discussed in the context of general planetology and the latest laboratory studies will be presented.

1. Motivation

Processes leading to the chemical evolution of planetary atmospheres is of general importance in planetology and specifically important in understanding the early Earth (and the origin of complex organics). The interaction between an atmosphere (wind) and a planetary surface leads to the generation and transport of granular material, this constitutes an important environmental/climatic factor on terrestrial like bodies.
These processes can lead to chemical alteration of the atmosphere in several ways. We are far from understanding these processes, which have only been poorly studied and even further from quantifying them. Two distinct phenomena will be discussed here; erosion induced chemistry and electrification effects.
They are being studied with laboratory techniques involving environmental wind tunnel facilities and techniques for long term erosion simulation.

2. Laboratory Simulations

Recreating wind driven particulate transport at a planetary surface within the laboratory requires control of wind flow, temperature, pressure and atmospheric composition (importantly including humidity). This can be achieved in a unique planetary environmental wind tunnel facility. Here studies have been performed of transport thresholds and rates, as well as quantifying the electrification of dust/sand and the effects of electrification and electric field generation.
A unique technique has been employed in order to simulate erosion in the laboratory. It involves gentle mechanical agitation (tumbling) of granular samples typically sand (>125μm), for periods of several months (1-10 million rotations). This leads to a drastic reduction in grain size and the formation of silt [4]. This process 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 enhanced production of micrometer (and even sub-micrometer) fragments.

Figure 1 microscope images of olivine (left) and Icelandic basalt (right) after simulated erosion showing fine (white) silt formation.

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.

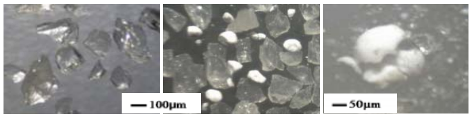

Figure 2 quartz grains before (left) and after (center) simulated erosion showing cemented quartz silt (right).

3. Wind Erosion and Chemistry

It is well documented that mechanical fracturing of silicates 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) and may also explain several other surprising characteristics of this planet, specifically the presence of an unidentified oxidizing agent in the soil [4]. The source of oxygen for this oxidation process was not determined in these earlier studies.

Recent work has involved performing erosion simulations in different atmospheres and performing detailed study of the atmospheric composition, specifically focussing on changes in the composition as a result of erosion induced surface activation.

It seems that this may lead to new mechanisms for atmospheric chemical alteration through interaction with (activated) surface material. Planetary reaction rates will be discussed.

4. Electrification and Electric Fields

The electrification occurs anywhere that surfaces contact, this is especially of importance in the transport (movement) of small particles. The process responsible is contact electrification, this process is still poorly understood and the focus of active research [3, 4].

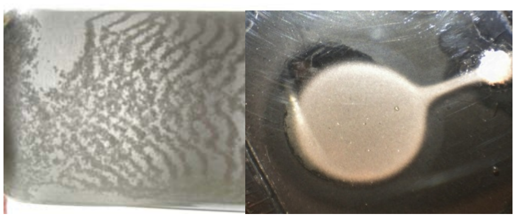

Figure 3 Grain electrification generating electric fields and dielectric chains under low humidity erosion simulation.

The role of liquid water films typically present on Earth (due to humidity) has a significant effect on electrostatic behaviour (e.g. allowing electrical discharging) as well as dominating inter-particle adhesion. Typically other planets do not have liquid water films (low humidity) due to low temperatures or pressures.

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.

The generation of intense electric fields and electrical discharge (lightning) induced atmospheric chemistry is known, but not studied in detail for a wide range of discharge types. For example electrical breakdown on small (μm-cm) scale corresponding to that of electrified grains or at extreme (low or high) pressures.

5. Conclusions

It is clear that wind driven particulate transport is not simply a method for planetary surface erosion, but leads to a wide variety of processes which can alter the atmospheric chemistry (and surface mineralogy).

Laboratory simulations are an effective tool in studying these phenomena, specifically processes of atmospheric alteration resulting from surface activation or electrification.

References:

[1] J.P. Merrison et al., Icarus **191**, 568 (2007)
[2] J.P. Merrison et al., *Planet. Space. Sci.* **56**, 426 (2008)
[3] K.R. Rasmussen et al., *Planet. Space. Sci.* **57**, 804 (2009)
[4] J.P. Merrison et al., Icarus, **205**, 716 (2010)
[3] J.P. Merrison, et al., Planet. Space. Sci., 60, 328-335 (2012)
[4] J.P. Merrison, Aeolian Research. 4, 1–16 (2012)
[5] C. Holstein-Rathlou et al., Icarus, 220, 1-5 (2012)