SAND TRANSPORT; A SOURCE OF MINERAL ALTERATION ON MARS

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Introduction: Here we present a possible new formation mechanism for the reddish Martian dust or specifically the oxidation process which has led to the presence of a reddish iron oxide in Martian dust which is presumed to be hematite.

This mechanism involves the wind induced erosion of sand (for example basaltic material). Such basaltic sand forms are observed widely across the Martian surface.

In the laboratory experiments presented here simulation of silicate sand erosion (specifically quartz sand) together with magnetite (observed in basaltic Martian material) leads to oxidization of the magnetite and the formation of hematite.

Motivation: The magnetic properties experiments upon the NASA Mars MER mission consisted of capturing windblown dust from suspension in such quantities to allow mineralogical analysis [1]. This study concluded that the Martian (airborne) dust essentially resembled (grey) basaltic regolith though with a highly oxidized (reddish) iron oxide phase, possibly nanophase. This leads to the assumption that the Martian dust is an erosion product of the basaltic sand, though the oxidization process remains speculative and has motivated further study for possible mechanisms.

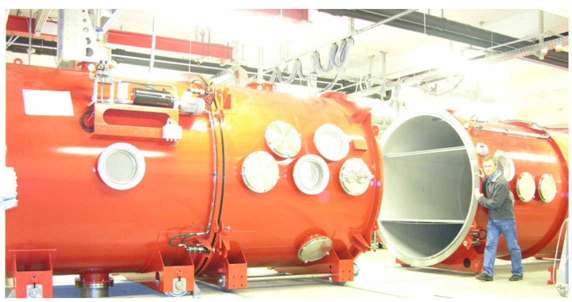

Figure 1 One of the Mars Simulation Facilities at AU

This study has originated as a continuation of the extensive simulation work taking place at Aarhus University in Denmark (AU) where several large scale simulation facilities are based [2]. The largest and most recent of which is shown in figure 1. This simulation work has concentrated on the formation, transport and physical properties of Martian dust (and sand) [3,4,5]. Processes of electrification and adhesion/cohesion of Mars dust analogue material has been observed. To investigate the long term (months-years) effect of wind induced granular transport and possible mineral alteration due to electrification (or other processes) this study was initiated.

Simulated Wind Erosion: In order to expose granular material to months-years of simulated wind induced erosion it is impractical to employ a large scale simulation (wind tunnel) facility. There are two important aspects of such simulation, specifically; 1. A controlled environment, 2. Gentle mechanical agitation. It was therefore proposed to construct small hermetically sealed flasks (with a well characterized atmosphere) containing granular material. Gentle mechanical agitation (tumbling) of this flask could then be used as an analogy to the process of saltation in which sand grains are temporarily entrained (suspended) by the wind before balistically impacting the sand bed.

To demonstrate erosion quartz grains with size >125µm were encapsulated and subsequently tumbling at a rate of 1Hz for 7 months (close to 10million rotations). Striking evidence for grain erosion was observed as shown in figure 2, i.e. a drastic reduction in grain size and the formation of silt sized grains (around 10% below 22 µm) [5].

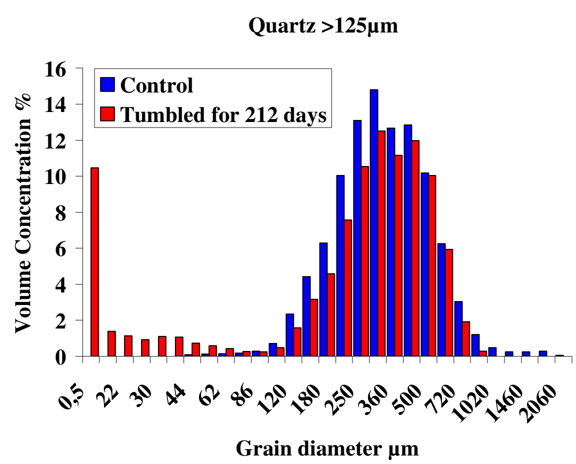

Figure 2 Grain size distribution measured before (blue) and after (red) simulated sand erosion

Erosion Induced Mineral Alteration: In order to demonstrate mineral alteration, specifically of the iron oxide magnetite (found to be present in Martian regolith) quartz sand (>125µm in size) as above was mixed with a small amount (1g) of fine magnetite powder (µm grains). This material mixture was then hermetically sealed within a glass flask and tumbled for around 7 months. Initial inspection of the flask revealed an optically thick (almost opaque) gray coating on the inside of the flask which when viewed in transmission was reddish/orange), though appeared pale gray/silvery in reflection. The coating resembled forms of desert varnish which may be formed in arid areas on earth.

Figure 3 Photograph of glass flasks containing quartz-magnetite mixture after a short time (left, 50 days) and extended (right, 212 days) exposure to simulated erosion.

X.ray diffraction spectroscopy (XRD) revealed that a large fraction of the magnetite had been converted into hematite (figure 4).

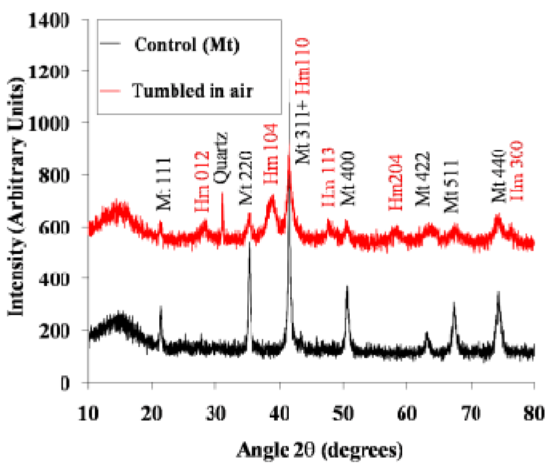

Figure 4 XRD of a granular magnetite sample (lower) and after simulated erosion (tumbling) together with quartz sand (for 212 days).

Interestingly although the hematite spectral lines were well characterized, they appeared broadened indicating that the hematite formed may be in the form of nanoscale particulates (of order 10nm). This may help explain why the dust removed from the flasks still appeared grey, though the material deposited on the flasks after sufficient exposure began to appear reddish. It is thought that aggregation/agglomeration of these nanoscale hematite particulates may occur after extended mechanical agitation and therefore lead to the formation of more crystalline (reddish) hematite.

The Mineral Alteration Process: The erosion induced conversion of magnetite into hematite was repeated with differing atmospheres including dry air (baked at 110C), ordinary humid air (wet air) and dry argon and low pressure (9mbar) CO_2. As seen in figure there is large increase in the amount of produced hematite after 50 days compared to 212 days, note that the concentration of hematite in the original (control wet/dry) samples was less than 1%. However there was only little variation in the production of hematite with atmospheric composition. This seems to indicate that the process does not involve electrical breakdown (ion production) and a more likely explanation is the mechanical activation of the mineral surfaces caused by the erosion. The mechanical activation of quartz (SiO_2) has been observed previously and has also been suggested as a possible source for the oxidizing nature of the Martian regolith.

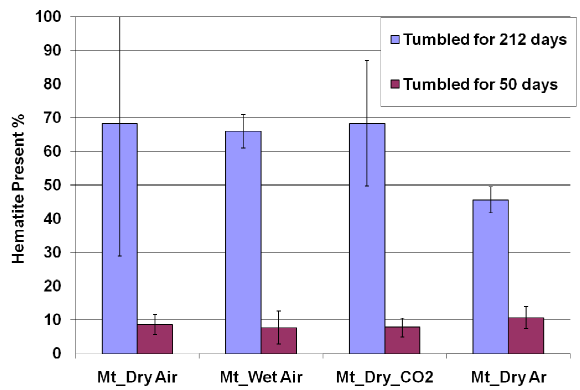

Figure 5 Erosion induced hematite formation from magnetite under varying conditions.

Conclusion Mars Observations: This constitutes the first demonstration of a formation mechanism for the reddish Martian dust involving a process known to occur on Mars (sand transport). Note that, as recently revealed by the NASA MER mission sand transport is also active on Mars presently, though at a low rate [7]. Erosion induced mineral alteration may also be associated with Aeolian sand transport on other planets (including earth).

References: [1] P. Bertelsen et al., *Science*, **52**, 693 (2004), [2] J.P. Merrison et al., *Planet. Space. Sci.* **56**, 426 (2008), [3] J.P. Merrison et al., *Planet. Space. Sci.* **54**, 1065 (2006), [4] J.P. Merrison et al., *Planet. Space. Sci.*, **52**, 279 (2004), [5] J.P. Merrison et al., Icarus **191**, 568 (2007), [6] J.P. Merrison et al., Icarus in press (2009) [7] Sullivan R.J. et al., J. Geophys. Res. 113, E06S07 (2008).