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Sediment transport by boiling seeping water: exploring effects of grainsize and atmospheric conditions

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Abstract

Many active and recently active surface processes on Mars have been controversially linked to the action of liquid water, yet the sediment transport capacity of water under martian environmental conditions is poorly understood. An understanding of the sediment transport capacity allows the amount of water required for any given landform to be back-calculated from its observed size/volume at the martian surface. Here we present a series of experiments where we explore the effects of grainsize, atmospheric pressure, humidity and temperature on the sediment transport capacity of seeping liquid water under martian conditions.

1. Introduction

A variety of active features including gullies [1], recurring slope lineae (RSL)[2], dune flows [3] and slope streaks [4] have been linked to liquid water flowing on the martian surface. However, liquid water is only transiently stable at the martian surface [e.g., 5] and this has led to these activities being linked to other (dry) processes [6–9]. Recent laboratory work has shown that, under martian atmospheric conditions, liquid water boils and in doing so transports more sediment than would otherwise be the case [10–12]. Here we expand the work of Massé et al. [10] and explore the factors that could influence the sediment transport by seeping flows, which under terrestrial atmospheric conditions transport no sediment, but under martian conditions transport sediment via boiling induced saltation.

2. Experimental set-up

As for previous experimental work [10–12] we use the Open University's large Mars Chamber to recreate the atmospheric conditions on Mars. For each experiment a roughened plane measuring 0.5x0.90 m is placed at an angle of 31° and covered with 3.5 mm of sediment. The water is introduced from an external reservoir via a series of solenoid values to produce a dripping flow at ~1.7g/min. We monitored: the temperature of the sediment, the air and the water, the atmospheric pressure and humidity. Time lapse video recordings and opportunistic stills and videos were used to monitor the progress of the experiment and record pertinent aspects of the sediment transport process(es). The water was run for ~40 min and the chamber was maintained at low pressure for 5 min after the water was stopped. In order to quantify the sediment transport we used close-range photogrammetry to produce elevation models before and after the experiments as per [11,12], which were then differenced to obtain a volume. We performed experiments at 6 and 9 mbar. We used three natural sediments with modal grainsizes of 200, 375 and the last with >1000 µm but comprising a mixture of various grain sizes.

3. Preliminary results

Our initial findings reveal that, as expected, the amount of sediment transported depends on grainsize: the smaller the grains the more saltation occurs and the more material is moved by saltation and granular avalanches (Fig. 1). This results in the more obvious ridges at the surface of the finer grained material (Fig.1). Interestingly in a mixed grainsize substrate, the smallest grains still saltate, so ridges are formed, but are less obvious as the larger grains do not move much. A lower atmospheric pressure seems to result in less sediment transport, as noted by Massé et al. [10]. Our results indicate that the saltation process is sensitive to atmospheric humidity as expected for a process driven by phase-change. As the surface conditions of Mars are at or below to the triple point, liquid water either dominantly boils or freezes. We found that when freezing dominates, the saltation process still occurs because the atmospheric humidity is maintained near zero (Fig. 1). Despite the bed being armoured by the ice [13], the sediment transport is on the same order as non-freezing conditions is still non-negligible.

4. Summary and Conclusions

We have expanded the range of atmospheric conditions and grainsizes under which transport of sediment via boiling induced saltation can occur. We find the process is robust to freezing conditions and can occur over a range of realistic humidity, temperature and pressure conditions. Future work includes scaling these present results to martian gravity and geoemorphic-scales and exploring a wider range of Mars-relevant grainsizes.

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References

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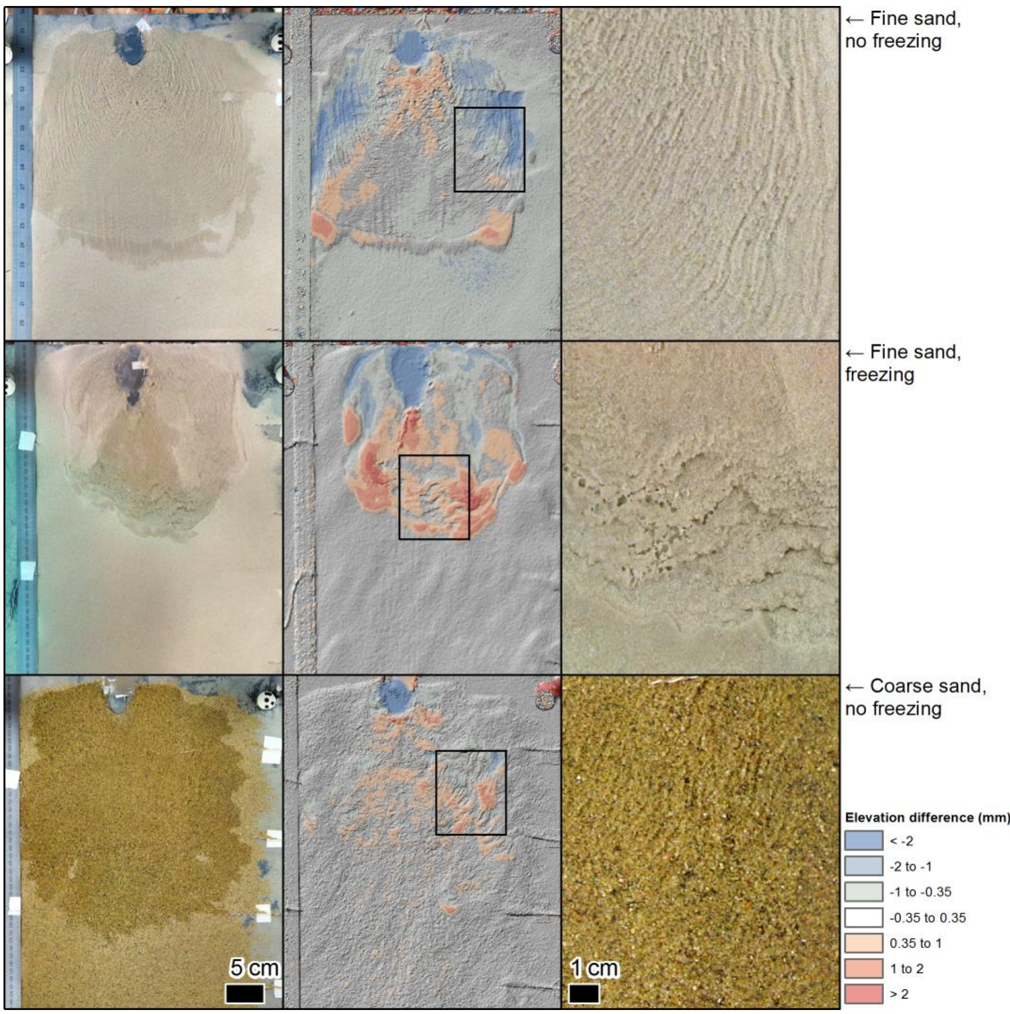

Figure 1: Top-down view of sediment surface after the experiment. Left: colour image, middle: height change superposed on a relief shaded elevation model, and right: detailed view of the ridges created by boiling – position on sediment indicated by box on middle panel.