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Experimental investigation of sand transport mechanisms by boiling liquid water under Mars-like conditions and potential implications for martian gullies and RSL

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Abstract

Active flow processes are currently ongoing at the surface of Mars, for example within gullies or RSL (Recuring Slope Lineae). One possible candidate involved in their formation and current activity is liquid water [1,2], but under current martian conditions liquid water is transient and can only be present in limited amounts [3]. However the surface temperature can locally exceed the melting point [4,5] on present-day Mars, leading to rapid boiling of liquid water. So far, little attention has been paid to the role of boiling in sediment transport processes. Recent study has highlighted that boiling water can drive unusual transport mechanisms leading to an enhanced transportation volume [6]. In our work [7,8] we conduct a series of experiments under low pressure to investigate the influence of both sand temperature (T_s) and water temperature (T_w) on the transport capacity of boiling liquid water under martian-like surface conditions. The experimental observations are then compared to physical laws. Results attest that among the two parameters, sand temperature is a driving parameter of sand transport by boiling water. This is enhanced at martian gravity.

1. Experimental set up and protocol

The experiments were performed under martian-like pressure (~9 mbar) in the Open University's Mars Simulation Chamber. The test bed was a rectangular tray, filled with a 5 cm thick layer of fine silica sand, set to an angle of 25° which is in the range of observed slope angles for martian gullies and RSL [2,5,7]. The water outlet was positioned at the top of the slope and controlled with a valve from outside. We performed experiments with 9 combinations of 3 different temperatures, 278 K, 288 K and 297 K for sand and water, respectively, which are consistent with temperatures measured at the surface of Mars [4,5]. Water was released for a duration of ~60 s with a mean flow rate of 11 m s^{-1}. We constantly monitored the sand temperature, water temperature, pressure, and humidity. The evolution of the test bed was recorded by cameras. We performed stereo-photogrammetry to produce digital elevation models and calculate the volumes of transported sand.

2. Experimental results

From observational data it is clear that the intensity of boiling was mainly driven by sand temperature while water temperature had only a minor influence. As sand temperature increases, the total volume of sand transported is increased by a factor of ~9 [7] while for different water temperatures it is rather constant (Fig. 1) [8]. The volume attributable to different transport mechanisms changed as the sand temperature increased. At T_s = 278 K, the majority of the sand is transported by overland flow while at $T_s \geq$ 288 K the majority is transported by mechanisms associated with boiling water, *i.e.* ejected pellets (sand-water mixture) and dry processes (including sand ejection and avalanches). We observe that the gas ejected by the boiling water is strong enough to create an air cushion at the bottom of pellets leading to their downslope levitation rather than rolling as observed at T_s = 278 K. Additionally, the produced gas is also able to eject single sand particles and drive dry avalanches. Water temperature plays a role in the duration of these dry processes which are longer at lower water temperature [8].

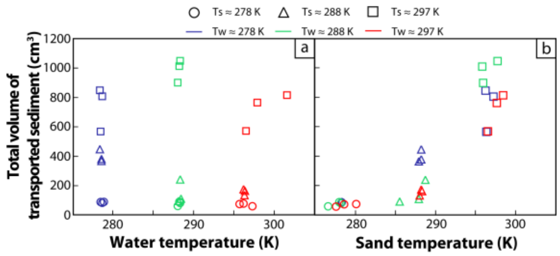

Figure 1: Transported sediment volume versus (**a**) water temperature and (**b**) sand temperature [8].

3. Transport mechanisms due to boiling and martian gravity scaling

Sand temperature is the main parameter controlling the boiling intensity because surface temperature drives the heat flux [9]. As liquid water is unstable it turns into gas and we observe single sand particle ejection and pellet levitation. In both cases the two forces in competition are the weight of the object and the force exerted by gas production. For sand ejection, we computed that for our experimental conditions and at T_s = 278 K grain ejection is very unlikely while at $T_s \geq 288$ K grains are ejected as observed in our experiments. If ejection does occur on Mars, the ballistic trajectory would be enhanced by a factor of 2.6 compared to Earth [8]. In addition, the increase of sand temperature leads to an increase in the duration of levitation of about several seconds and also a larger size range can potentially be lifted. We found that the levitation process under weaker Martian gravity is enhanced by a factor of ~7 and is able to transport larger objects for a longer time [7,8].

4. Conclusions

We find that sediment transport by boiling is characterised by grain ejection, granular avalanches and levitating pellets, which according to our scaling calculations are more effective transport processes under Martian gravity [7,8]. Among the two parameters tested, the sand temperature is the main driving parameter for transport via boiling while water temperature plays a minor role [8]. We highlight that if liquid water is present at the surface of Mars boiling could play an important role in understanding the recent changes in Martian gullies or RSL for which water is a candidate fluid [9]. It should not be neglected when analysing and modelling water flow features on Mars.

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