Boiling Water could Levitate Sediment on Mars – An Experimental Study. Jan Raack[1,2], Susan J. Conway[3], Clémence Herny[4], Matthew R. Balme[1], Sabrina Carpy[3], and Manish R. Patel[1,5], [1]School of Physical Science, STEM, The Open University, Milton Keynes, UK, jan.raack@open.ac.uk; [2]Institut für Planetologie, Westfälische Wilhelms-Universität, Münster, Germany; [3]Laboratoire de Planétologie et Géodynamique, Université de Nantes, France; [4]Physikalisches Institut, Universität Bern, Switzerland; [5]Space Science and Technology Department, STFC Rutherford Appleton Laboratory, Oxford, UK.

Introduction: We present laboratory studies of a newly recognized transport mechanism: "levitation" of sediment on a cushion of vapor released by boiling [1,2]. This mechanism can occur only under low atmospheric pressure with relatively 'warm' (for Mars) surface temperatures and can trigger dry avalanches. The combination of levitation and dry avalanches increases the amount of sediment transport per volume of liquid water, so should be considered when evaluating the formation of recent and present-day martian mass wasting features such as gullies and recurring slope lineae (RSL); less water may be required to transport sediment than previously thought [1].

While present-day activity of gullies is often explained with sublimation of CO_2 ice and dry avalanches [3,4,5], activity of RSL has been explained by either liquid briny flows [6,7] or dry mechanisms [8,9]. Gullies have formed over the last few millions of years [10,11,12,13] and their present-day activity may not be representative of the past; recent work suggests that CO_2 action alone, under any recent obliquity condition [14], cannot explain gullies found on equator-facing slopes. Hence, no proposed formation mechanism can be excluded. Previous experimental work has shown that transient liquid water under warm conditions behaves differently to water on Earth [15]. Also, remote sensing and climate models show that surface temperatures on Mars can reach ~300 K [6,16] at RSL sites [6,17], but although warm temperatures above the frost point are common on Mars, the origin of any inferred *liquid* water remains uncertain.

Method: The experimental apparatus comprises a 90 × 40 × 50 cm sediment bed (~63-200 μm grain diameter) inclined at 25°, housed in a Mars environmental chamber [1,2]. Pressure was maintained at ~9 mbar. For each experiment, pure water was introduced at the top of the slope, 1.5 cm above the sediment bed, and the flow behavior observed (Fig. 1). The water was pumped into the chamber from an external reservoir allowing the temperature to be maintained at ~278 K and the flow rate at ~11 ml s^{-1} [1]. Each run consisted of 60 s of water flow and was performed in triplicate; digital elevation models (DEMs) of the bed were created both before and after each run using multiview digital photogrammetry [1,2].

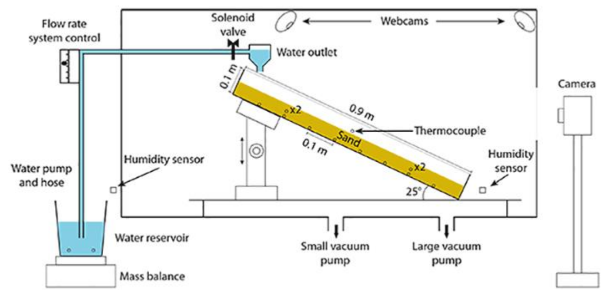

Figure 1: Experimental setup for low-pressure experiments as presented in [1,2]. From [2].

Results and discussion: Two types of experiments were performed: with "cold" (~278 K) and "warm" (~297 K) sediment [1]. Experiments with cold sediment were similar to flows under terrestrial pressure, but experiments with warm sediment showed completely different transport mechanisms (Fig. 2) which led to an increased amount of transported sediment. During the cold experiments most (~98%) of the sediment was transported by overland flow of water. Only very few wet sediment pellets were ejected by the slightly boiling water (~2%; Fig. 2,3) [1].

During the warm experiments the amount of transported sediment was nearly nine times greater than during the cold experiments [1,2]. This was caused by three processes: (1) transport of sediment by ballistic ejection of sediment and wet sediment pellets, (2) transport of sediment by "levitation" of mm to cm-sized sediment pellets with very rapid downslope motion, and (3) dry avalanches triggered by the other mechanisms [1]. The combined effect of these processes accounted for about 96% of the total sediment transport in contrast to the cold experiments [1].

We observed in the first seconds of warm experiments saturated sediment pellets detached from the source area and levitated down the slope triggering dry avalanches. The levitation of the pellets is explained by the release of gas at their base produced by boiling via a mechanism comparable to the Leidenfrost effect [1]. Extended experiments have shown that the intensity of this effect depends on the surface temperature, and not the temperature of the water [2].

Our calculations show that with reduced martian gravity, the effect of levitation will be enhanced and could last up to ~48 times longer [1,2].

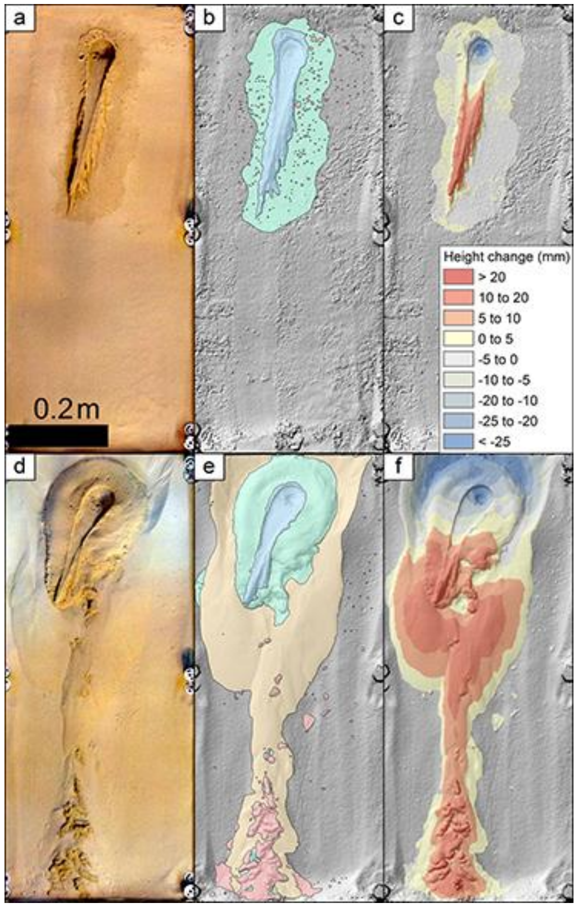

Figure 2: Image, map, and elevation data at the end-state of cold experiments [~278 K] (**a,b,c**) and warm experiments [~297 K] (**d,e,f**). The different transport mechanisms are: overland flow (blue), percolation (green), pellets (incl. levitation) (red), and dry avalanches/saltation (yellow). Flow from top to bottom, same scale for all images. From [1].

Conclusion: Our experiments show that the amount of transported sediment is 9 times greater when the effect of levitation is taken into account. This was caused by a surface temperature difference of only ~19 K under martian pressures. Although the availability of liquid water at the surface of Mars is hard to explain, our experiments show that the amount of water needed for sediment transport could have previously been overestimated when surface temperatures are high (~300K). This is not an explanation for the formation/activity of gullies and RSL, but is a process-observation that should be taken into account when studying these features. Furthermore, the exact temperature of the martian surface in the recent past is not precisely known due to large obliquity changes [18]. A slight increase in the maximum surface temperatures in the past on Mars would increase the scope for boiling and sediment levitation and hence the transport capacity of water-driven flows.

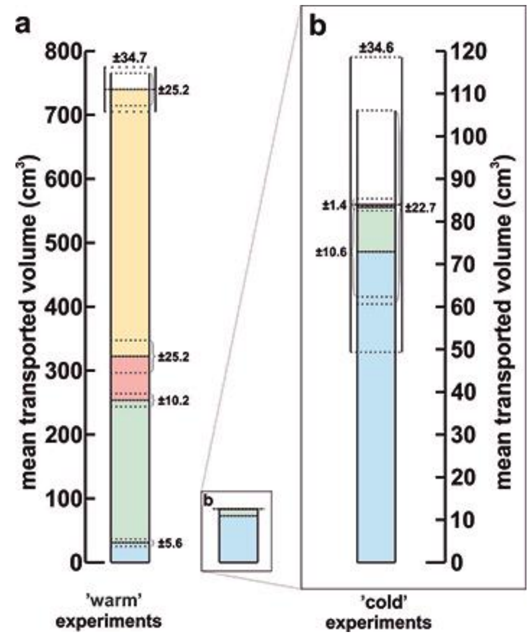

Figure 3: Mean volumes of transported sediment (**a** warm, **b** cold experiments) divided in different transport mechanisms. Same colors as in Fig. 2. From [1].

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