GRAIN SALTATION INDUCED BY BOILING ON MARS – EXPERIMENTS AND DEVELOPMENT OF A PHYSICAL MODEL. S. J. Conway[1], M. Massé, S. Carpy, T. Colleu-Banse and M. R. Patel[2], [1]CNRS/Laboratoire de Planétologie et Géodynamique, Université de Nantes, France (susan.conway@univ-nantes.fr), [2]School of Physical Sciences, Open University, Milton Keynes, UK.

Introduction: In our previous labwork we reported a new sediment transport mechanism relevant for Mars: sediment saltation through boiling [1]. We found seeping water was able to transport sediment downslope under martian conditions even though no sediment transport was observed under terrestrial conditions. This finding has important implications for inferring water reservoirs of recently active surface processes and hence for Mars' hydrosphere and habitability. However, in order to robustly transfer this finding to Mars we need to understand the physics behind this process. We can use this knowledge to define the limits of the process in terms of surface properties and/or environmental conditions found on Mars. In our previous work we inferred the physical mechanism behind the saltation [1], yet we had little empirical data to test this inference [2]. In this series of experiments we focused on the grain-scale processes involved in saltation via boiling with the objective of validating our physical model.

Experimental approach: Figure 1 shows the experimental set up. Two parallel confining walls 40 mm apart and 3.2 mm tall were adhered to an inclined roughened plane 0.4 m wide by 0.9 m long. This plane was placed inside the large Mars chamber and situated at the desired angle. Sediment was placed between the walls and levelled off. The water source was located at the top of the slope between the walls. A high speed camera was placed on the outside of the chamber but at a similar height as the plane in order to achieve a side-on viewpoint. Behind the wall furthest from the camera was placed a vertical calibration board allowing scale to be established in the high speed videos. Three markers were placed on this board at 51, 127 and 263 mm from the water source allowing the high speed camera to be aligned to the same position for each run. Lighting for the camera was provided by 3 lamps located above the apparatus corresponding to the marks on the calibration board. A source of heat for the sediment was placed at the top of the chamber (Fig. 1). A webcam was placed above the board in order to estimate the progression speed of the flow. Thermocouples were used to monitor the temperature within the sediment bed (Figure 1), on the exposed plane adjacent to the walls and two at the water source. The atmospheric pressure and humidity were monitored for each run.

Protocol: A total of 63 runs were performed. We varied both initial slope angle (5°, 15°, 25°) and grainsize (120, 250 and 500 µm). Each experiment was performed at least in triplicate. We used spherical glass ballotini beads. A typical run proceeded as follows: decompression of the chamber to 9 mbar, start of the water release, the acquisition of one or more high speed videos was performed at each marker aimed to capture the saltation occurring at the flow front. The camera focal length was set at 200 mm and kept level with the aid of spirit levels in all three planes attached to the tripod. Videos were captured at 4000 fps. The runs were stopped once the flow front passed the third marker, typically after 15 minutes.

Data analysis: We process the videos using an open source particle tracking code called tractrac developed by Joris Heyman (https://perso.univ-rennes1.fr/joris.heyman/trac.html). We extract particle trajectories (Figure 2) and an estimate of the initial ejection velocity for tens to hundreds of particles for the nine combinations of grainsizes and slope angles using

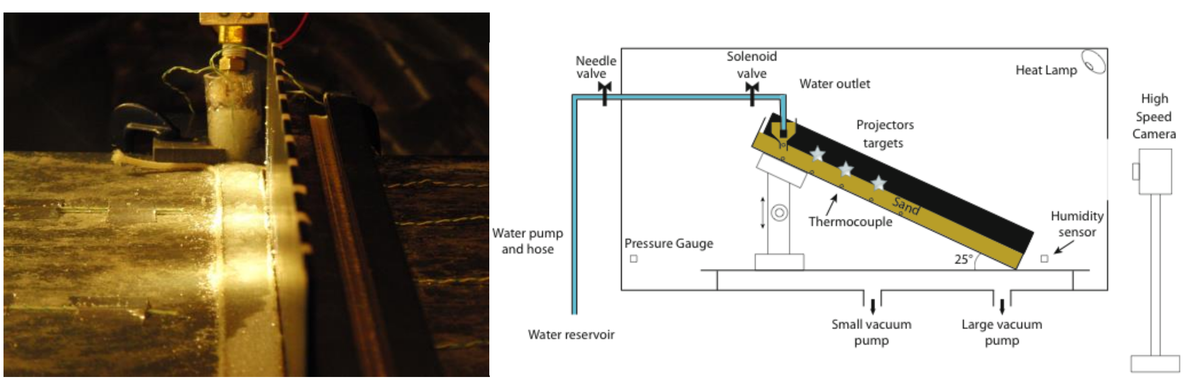

Figure 1: *left: front view of a typical experimental run with the calibration board to the right , the water source at the back and a flow which has progressed past the three spotlights. Right: diagram of set up. Note the camera is actually positioned with a side-on view.*

the 378 videos we collected. We can then compare our experimental trajectories and ejections speeds with those predicted by our physical model.

Physical model: For ejection of a particle to occur, the force exerted on the particle by the release of the gas has to overcome the weight of the particle. As a consequence, the velocity of the gas U_g must be greater than the threshold transport velocity to entrain the particle denoted by U_t. This threshold transport velocity can be estimated from the particle Reynolds number Re_p (Eq. 1), defined using the dynamic viscosity μ_v, the density of the gas ρ and the modal diameter of the grains D_{50}:

$$Re_p = \frac{\rho\, D_{50}\, U_t}{\mu_v} \qquad (1)$$

where ρ is the density of the water evaluated at the sand temperature and at the saturated vapour pressure, μ is the viscosity of the water vapour, D_{50} the mean diameter of the particles and U_t the mean threshold transport velocity value for the particles. The threshold value varies slightly depending on the temperature of the sand: the hotter the sand, the lower the value.

The gas velocity can be evaluated using the relationship given in [1]:

$$U_g = \frac{R_{eq}^2\, \Delta P}{8\, \mathrm{L}\, \mu_v} \qquad (2)$$

where μ_v is the dynamic viscosity of the gas, L is the path length through the sand surface layer with an equivalent radius R_{eq} and ΔP is the difference between the saturated vapour pressure P_{sat} and the chamber atmospheric pressure P_0. We can estimate the saturated vapour pressure P_{sat} using Antoine's equation which depends on the temperature of the sand. A minimum ΔP is required in the experiments to produce ejection. Since we assume that all of the kinetic energy of the gas is transferred to the particle movement, we can therefore calculate an initial velocity of ejection U_e of the particle from our estimated gas velocity U_g. For any given particle ejection angle we can predict the particle's trajectory using a ballistic path (as the atmosphere in the chamber is thin).

Preliminary results: We have performed an initial comparison between the results from six trajectories in one of our experiments to our physical model. The ejection angle was not the same for all trajectories because of the randomising effect of the path taken by the gas between the (shifting) particles, but for any given set of initial conditions we expect the ejection velocity to be of the same order of magnitude (independent of the ejection angle). In that experiment the sediment temperature, T_s was ~297 K and we calculated the corresponding threshold transport velocity U_t = 5.7 m s^{-1}. We estimate the gas velocity to be 227 m s^{-1} and hence the corresponding particle ejection velocity to be 0.66 m s^{-1}. We fitted ballistic trajectories to data obtained from the high speed camera (Figure 3) and from this we obtain an average ejection velocity of 0.62 m s^{-1}, which is in good agreement with our theoretical calculations.

Outlook: Our initial results are promising and we anticipate being able to successfully validate our physical model for a range of slopes and grainsizes. Once we have validated our model we can explore a wide parameter space to determine under what conditions grain saltation by boiling can occur on Mars and what magnitudes of motion it should be able to induce.

References: [1] M. Massé et al. (2016) *Nat. Geosci., 9*, 425–428. [2] C. Herny et al. (2018) *Geol. Soc. Lond. Spec. Publ., 467*, in press.

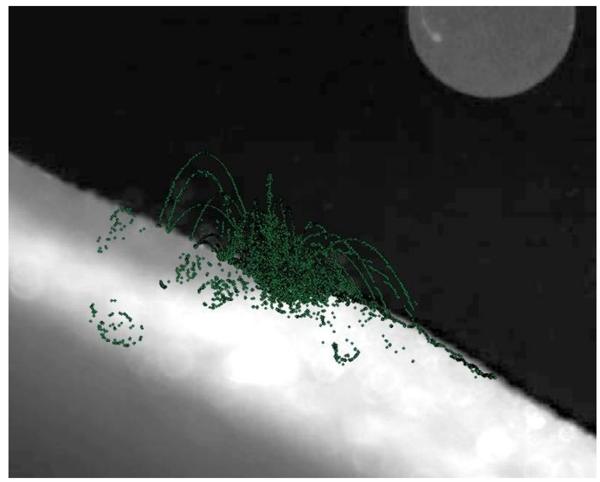

Figure 2. *A screen capture of one of the high speed videos superposed with the grain trajectories extracted using tractrac.Ciricle in top-right is 7 mm across.*

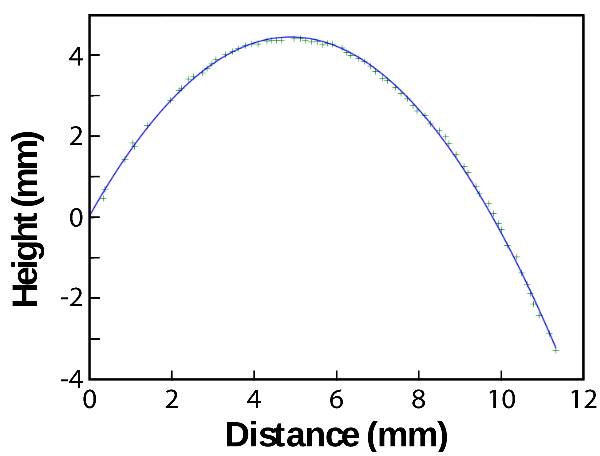

Figure 3. *Example of a trajectory of a sand grain particle extracted from the high speed video. The green crosses are the points used for the ballistic fit (fitted curve in blue).*