LABORATORY SIMULATIONS OF MARTIAN DEBRIS FLOWS OVER SAND DUNES. F. Costard[1], E. Védie[2], M. Font[2] and J.L. Lagarde[2], [1] UMR 8148 IDES Interactions et Dynamique des Environnements de Surface, CNRS-Université Paris-Sud 11, 91405 Orsay France, francois.costard@u-psud.fr, [2] UMR CNRS 6143 "M2C" Université de Caen, 2-4, rue des Tilleuls, 14 032 CAEN Cedex, France

Introduction: The recent discovery of groundwater seepage and surface runoff on Mars suggests the local occurrence of subsurface liquid water at mid and high latitudes during recent periods. They have been proposed to result of subsurface seepage of water [1], brines [2], near-surface ice melting at recent periods of high obliquity [3], snowmelt in more recent periods [4], geothermal heating [5] or liquid CO_2 breakout [6]. Among this large variety of surface runoff features, an unusual example of debris flows over sand dunes retains our attention. They are characterized by (i) their localisation over sand dunes, (ii) a typical morphology with long and narrow channels (Figure 1). Terrestrial analogs for these typical linear gullies are unknown justifying the use of laboratory experiments to try to understand the processes and conditions of formation of these Martian gullies over sand dunes.

Gullies over sand dunes : The SW flank of the megadune of the Russell crater (55°S and 347°W), exhibits various long and narrow linear gullies, first discovered by Mangold et al. [7]. Gullies are about 2.5 km in length and their mean slope is 10°. They start from regularly spaced small alcoves just under the crest of the dune (Figure 1). Individual gullies exhibit linear and narrow channels with levees.

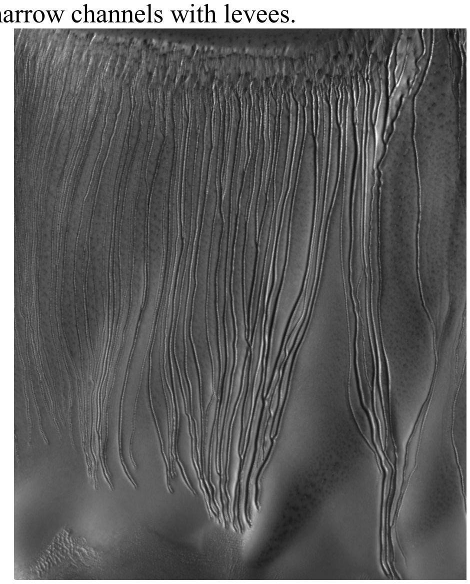

Figure 1 : Linear gullies over sand dune in the Russell crater on Mars. HIRISE image PSP_002904_1255 (25 cm/pixel). Width of the image: 2 km. Credit: NASA/JPL/University of Arizona.

From high resolution HIRISE image (Figure 2), most of the terminal deposits do not exhibit terminal lobes, but rather a concentration of small pits of unknown origin (thermokarst process ?).

Figure 2: Close-up over the terminal part of gullies on the megadune. HIRISE image PSP_002904_1255 (25 cm/pixel). Width of the image: 500 m. Light from the left. Credit: NASA/JPL/University of Arizona. One can note small thermokarst pits around the terminal lobes.

These dune gullies present sinuosity and connections with a geometry that allows the calculation of flow properties like the velocity and the viscosity [7]. But, the exact process of their formation over sand dunes still remains speculative.

Laboratory simulations: The experimental slope was designed to simulate debris flows over sand dunes with various slope angles, different granulometry and permafrost characteristics. In that experiment, we do not control the atmospheric pressure and we suppose the liquid water to be stable during the formation of debris flows.

Our small-scale experiment is composed of a rectangular box of 2.5 m by 0.55 m wide and 0.50 m depth in which reconstituted debris from fine sand or silt materials was saturated with water (figure 3). Morphologies are tested, with a median slope gradient of 15° whereas the top and bottom slope gradients are constant (50° and 8° respectively).

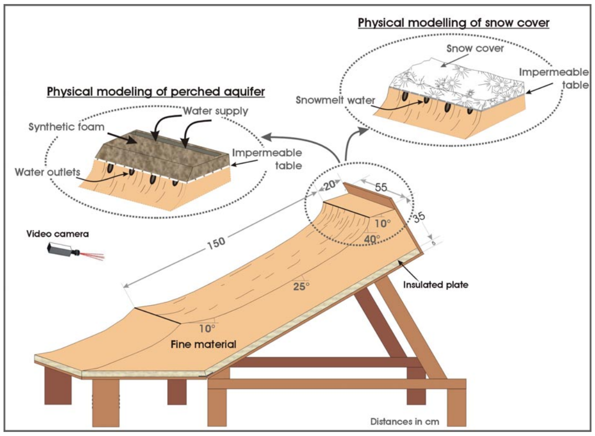

Figure 3. Close-up of the apparatus used in the physical modeling of debris flows.

Two types of water supply were tested :

1- To simulate perched aquifer, a solid and porous synthetic foam was placed on the top of the rim crest. Then during thawing, controlled water supply was injected into the foam.
2- Inflowing snowmelt water during thawing was simulated using fine particles of ice (< 1 mm) covering all the upper part of the slope.

Figure 4: Narrow gullies with lateral levees and relatively small terminal lobes. The morphological characteristics of these gullies on sand are similar to those found on Mars in the Russell crater. On the top : sinuous channels on the rim crest. In the middle : connections between gullies and variation of their growth by successive wave of debris due to several pulses of water from the rim crest. The analogy with Figure 1 is striking.

For each experiment, the material was initially saturated just before freezing. Frozen from the surface and permafrost was created at depth (0.50 m) with a temperature of –10°C. After freezing, the surface of the frozen soil is then progressively warmed to induce a controlled active layer formation. More than 40 laboratory simulations have been proposed in order to understand the formation of gullies over sand dunes on Mars. We used various materials (sand, silt), different slope angles and different depths of active layers.

Results : Preliminary results suggest that the typical morphology of gullies observed on Mars can be best explained by the formation of linear debris flows related to the melting of a near-surface ground ice with silty materials (see figure 4). This physical modelling highlights the role of the active layer during the debris flow formation. This preliminary work shows that a periglacial environment and the presence of a near surface permafrost could explain the formation of the Martian gullies. This hypothesis is consistent with some external process triggered by seasonal melting at high obliquity [3]. The implication for Mars is to suppose that martian dunes in the Russell crater are made of silty materials. This interpretation is in agreement with the low albedo, which should be volcanic sands. The composition of these debris flows over sand dunes supposes finer particles than usual terrestrial debris flows [7].

Conclusion: Our experiments suggest that morphology of gullies found on Mars implies the presence of ice rich permafrost with a relatively thin active layer. In any case (whatever be the origin of the water : melting of snow, perched aquifer, or melting of permafrost), the active layer together with the permafrost, controls the typical morphology of these linear gullies.

References:

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