LABORATORY SIMULATIONS OF MARTIAN GULLIES OVER SAND DUNES: IMPACT OF THE PERMAFROST TABLE 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] Laboratoire M2C, Université de Caen-Basse Normandie, UMR CNRS/INSU 6143 ; 2-4 rue des Tilleuls 14000 Caen

Introduction: It is know wellknown that many commonalities exist between the Martian and terrestrial periglacial climates and environments. The discovery of young gullies on Mars suggests the local occurrence of subsurface liquid water at mid and high latitudes. 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].

Some unusual linear gullies over sand dunes in the Russell crater are characterized by their long and narrow channels. There are no terrestrial analogs for those typical linear gullies.

This study focuses on the formation of that typical morphology by means of various laboratory simulations within a cold room. According to these experiments, we discuss the possibility to explain these gullies over sand dunes only due to surface and near-surface melt of volatile-rich material. In this study, we describe how the depth of the active layer helps to understand better the formation of Martian linear gullies observed in the Russell crater.

Gullies over sand dunes : Russell crater, a 200 km large crater located by 55°S and 347°W, exhibits various dune fields. One of them is relatively high (500 m) and covered by relatively low albedo volcanic sands. Gullies are about 2.5 km in length and their mean slope is 10°.

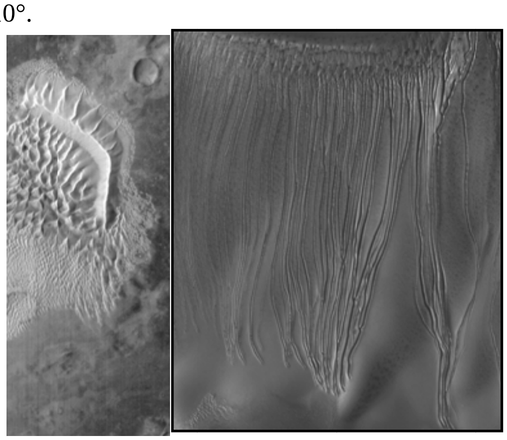

Figure 1 : Linear gullies over sand dune in the Russell crater on Mars. HIRISE image PSP_002904_1255 (25 cm/pixel). Width of the image: 2 km (for the right part). Credit: NASA/JPL/University of Arizona.

They start from regularly spaced small alcoves just under the crest of the dune (Figure 1). Individual gullies exhibit linear and narrow channels with levées.

Laboratory simulations: Physical modelling has been developed in order to simulate the development of typical gullies observed over Martian sand dunes in the Russell crater. The major purpose of the experiment was to examine the respective effects of slope angle, material, and permafrost.

We used the facility at the University of Caen/CNRS, France in a laboratory dedicated to physical modelling of periglacial processes [7]. To simulate the periglacial environment, our experiments were carried out in a cold room. 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 filled with saturated sand and silt materials (figure 2). Morphologies are tested, with a median slope gradient of 15° whereas the top and bottom slope gradients are constant (50° and 8° respectively).

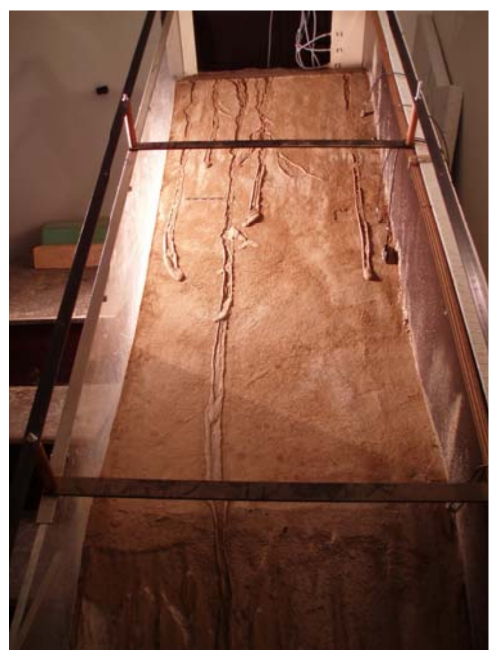

Figure 2. Close-up of the apparatus used in the physical modelling of debris flows.

To simulate the water supply, we used a porous synthetic foam placed on the top of the rim crest with a controlled water supply into the foam.

Effect of the permafrost table: 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 from the top to induce a controlled active layer formation. We used various materials (sand, silt), different slope angles and different depths of active layers. More than 40 experiments have been carried out over two years [8].

From various laboratory experiments, narrow gullies are preferentially formed by the water supply in the debris from the thawing of the ice rich permafrost and occurs along a significant length of the flow [8]. A relatively thin active layer strongly favours the formation of long and narrow linear gullies like those observed on Mars (figure 3). When active-layer thickness exceeded 5 mm, incision increases along the channel, resulting in a high quantity of transported material which then forms substantial accumulations (levées and terminal lobes).

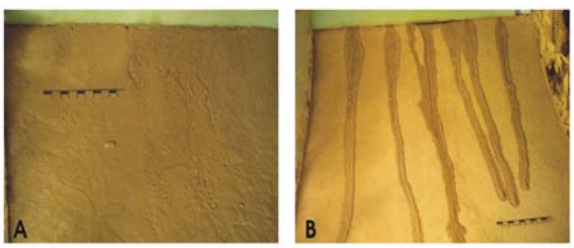

Figure 3. Effect of active layer thickness in a permafrost environment. A : diffused flow on surface with an active layer up to 10 mm thick. B : localized debris flows with an active layer of 1 mm thick.

Combined effects of particule size and permafrost table: The morphological change of the levees is related to the variation of velocities which results from the small change in slope gradient. This observation is in agreement with both characteristics of Martian gullies [9] and rheological properties of terrestrial debris flows [10].

We have observed 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 batween Figure 1 and Figure 3B is striking.

The best analogy have been observed with an experimental permafrost made of silty materials with a very thin active layer (higher length/width ratio and % of total length limited by levées. Table 1).

Material	Lenght/width	% of length incised	% of levées
Sand	23	34	26
Sand/silt mixture	41	34	48
Silt	86	32	66

Table 1. Morphological properties of experimental debris flows obtained by a thawing permafrost table.

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 control the typical morphology of these linear gullies. These results suggest that a periglacial environment was probably necessary for the formation of these linear debris flows over sand dunes on Mars [3].

References:

[1] Malin M. C., and K. S. Edgett (2000) *Science 288*, 2330-2335. [2] Andersen et al., 2002, *JGR 107*, doi:10.1029/2000JE001436. [3] Costard F. et al. (2002) *Science, 295*, 110-113. [4] Christensen, P.R. (2003) *Nature, 163, No. 8*, 116-. [5] Mellon M.T., and R.J. Phillips (2001) *JGR, 106*: 23165-23180. [6] Musselwhite D. S. et al. (2001) *GRL, 28*, 1283–1286. [7] Font et al. (2006) *Earth Surf. Process. Landforms*, Vol. 31, Issue 14, pp. 1731-1745. [8] Vedié et al. (2008) GRL, vol. 35, issue 21. [9] Mangold, N. et al. (2003) *JGR 108*. E4 10.1029/2002JE001958. [10] Johnson A. & Rodine J.R. (1984). Debris flows. *In Slope instability* edited by D. Brunsden & D.B. Prior, John Whiley and son. 257-361.

Acknowledgments : This program is supported by RELIEFS and PNP from INSU-CNRS, France.