Experimental Investigation of Gully Formation Under Low Pressure and Low Temperature Conditions

Conference or Workshop Item

EXPERIMENTAL INVESTIGATION OF GULLY FORMATION UNDER LOW PRESSURE AND LOW TEMPERATURE CONDITIONS. G. Jouannic[1,2], S.J. Conway[3], J. Gargani[1], F. Costard[1], M.R Patel[4], G. G. Ori[2], [1]IDES, Université Paris-Sud 11, CNRS/INSU UMR 8148, bât. 509, 91405 Orsay, France (gwenael.jouannic@u-psud.fr) ; [2]IRSPS, Università G. d'Annunzio, Viale Pindaro 42, 65127 Pescara, Italy ; [3]Laboratoire de Planétologie et Géodynamique, CNRS/INSU UMR 6112, Université de Nantes, 2 chemin de la Houssinière, BP 92205, 44322 Nantes Cedex 3, France ; [4]Planetary and Space Sciences Research Institute, The Open University, Walton Hall, Milton Keynes, MK7 6AA, UK.

Introduction: A large morphological diversity of gullies is observed on Earth and on Mars. Debris flow – a non-newtonian flow comprising a sediment-water mix – is a common process attributed to gully formation on both planets [1, 2]. Many variables can influence the morphology of debris flows (grainsizes, discharge, slope, soil moisture, etc) and their respective influences are difficult to disentangle in the field. Furthermore effects specific to the martian environment have not yet been explored in detail. Some preliminary laboratory simulations have already been performed that isolate some of these variables. Cold room experiments [3] were already perfomed to test the effect of a melted surface layer on the formation of linear gullies over sand dunes. Low pressure experiments [4] were performed to test the effect of the atmospheric pressure on erosional capacity and runout distance of the flows.

Our aim is to develop a new set of experiments both under Martian atmospheric pressure and terrestrial atmospheric pressure in order to reproduce the variability of the observed morphologies under well constrained experimental conditions.

Methodology: We have performed a parallel set of experiments under Martian atmospheric pressure (6 mbar, in the Open University Mars Chamber, Fig. 1a) and under normal atmospheric pressure in a cold room (Fig. 1b) at the IDES laboratory (Orsay, France).

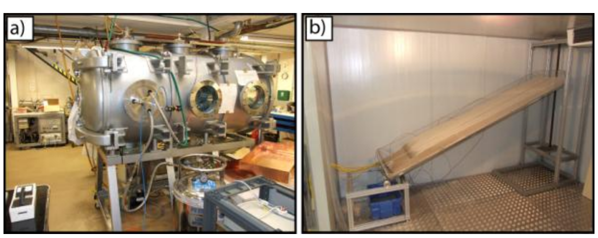

Figure 1: a) Mars Chamber in the Open University (Milton Keynes, UK) ; b) Experimental tray containing the permafrost in the Cold room (Orsay, France).

All experiments were performed with fine sand, which had been saturated in water, frozen, then the first millimeters of the permafrost were partially defrosted in order to create a fine active layer. We varied the discharge, the slope and the depth of melting of the ice rich permafrost. We measured the resulting morphology to quantify erosion and deposition. We have focused on the relative importance of these variables (rather than their absolute values) and their respective influence on the morphology. The Mars Chamber enabled us to perform these experiments at the low pressure and carbon dioxide atmospheric conditions experienced on the surface of Mars. The terrestrial cold room allowed us to perform reference experiments with an accurate control on experimental parameters (temperature of the room and of the water, discharge, active layer thickness).

Observations and Preliminary results:

Large apron: On Earth and on Mars, the morphology of many gully results from the superposition of several flow events and the progressive accumulation of sediments in the downstream part of the gully (Figs. 2a1 & 2a2). The experimental flow was performed using fine dry sand. The final large apron (Fig. 2a3) was obtained by the release of ~5 successive flow events.

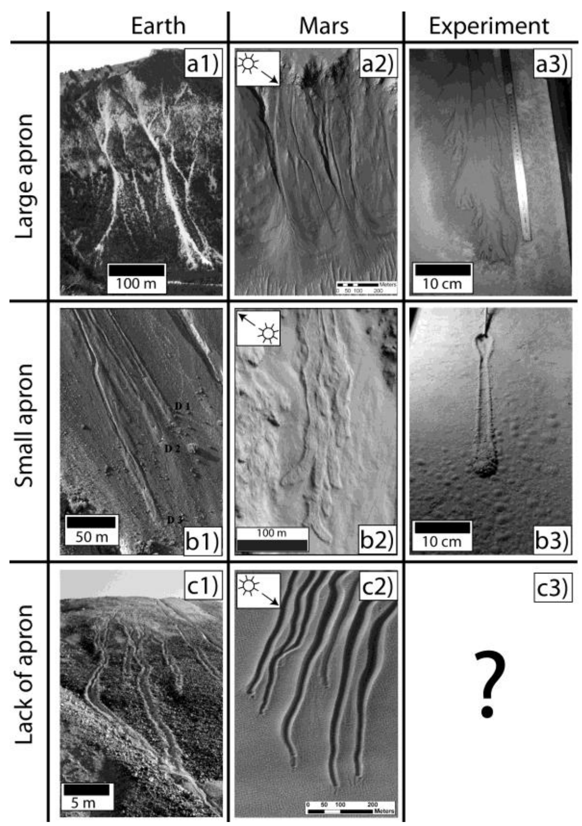

Figure 2: a1) Debris flows in the French Alps ; a2) Martian gullies on slope of an impact crater ; a3) Dry sand experiment resulting in large apron debris flow ; b1) View of debris flows at La Fossa Volcano (Italy) with small aprons[5] ; b2) Flow with small digitate aprons in the interior of Tooting crater [6] ; b3) Flow experiment in the Mars Chamber at low pressure (6 mbar) ; c1) Gullies without final deposit on Earth (Photo: O. Hungr, Canada) ; c2) Gullies without final deposit on the Russell megadune on Mars.

Small apron: On Earth, small terminal deposits can be found on debris flows in a cold, periglacial environments on talus deposits (French Alps) or on steep slopes of volcanoes with fine sediments (sand) [5] (Fig. 2b1, Italy). On Mars, small apron deposits have been found in Tooting crater, these flows could have been generated by the melting of ground ice (Fig. 2b2). Small apron gullies were recreated in an experimental run over permafrost using fine sand (230µm) under low pressure conditions (Fig. 2b3). The preliminary results of the experiments perfomed in the cold room (Orsay) highlight an increase in the levee thickness as a function of the slope (Fig. 3a, no clear trend can be deduced for the channel depth).

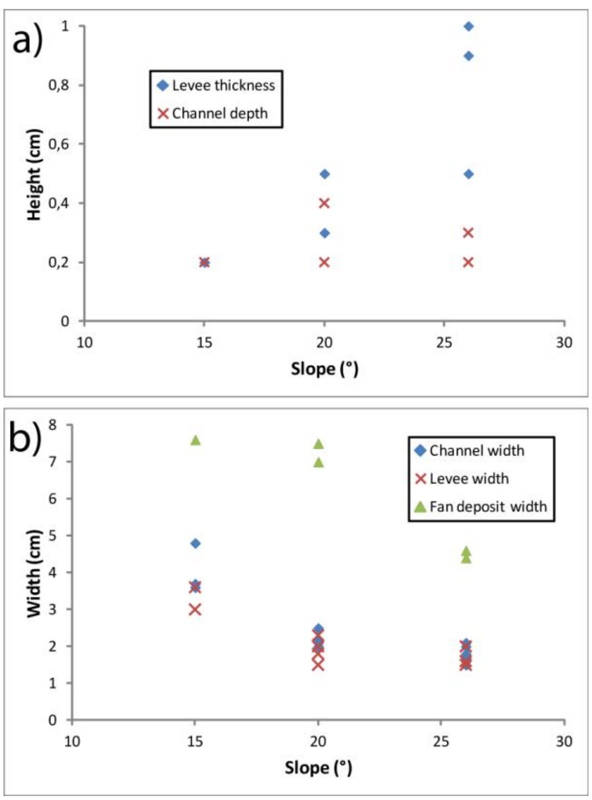

Figure 3: Preliminary results obtained from a set of small apron experiments in the cold room (Orsay). a) Channel depth and levee thickness as a function of the slope ; b) Channel, levee and fan deposit width as a function of the slope.

Three different slopes have been tested (15°, 20° and 25°) in these experiments using a constant flow rate of 2 ml/s, a water temperature of 20°C and a constant active layer thickness of 0.4 cm ± 0.1. A decrease in the channel, levee and fan deposit width is constantly observed as a function of the slope (Fig. 3b). In the future, these results realized in the cold room (Orsay, France) at low temperature and 1 terrestrial atmosphere will be compare with a set of experiment peformed in the Mars Chamber (Milton Keynes, UK) at low pressure (6 mbar).

Lack of apron: On Earth, gullies without final deposit are found in periglacial areas (Fig. 2c1, Canada). On Mars, this type of gully has been observed on sand dunes (Russell megadune, Fig. 2c2) or superposed on large debris aprons on the inner wall of impact craters. The processes that could explain this morphology still under study in the laboratory.

Conclusion: Our experimental investigations have allowed us to reproduce various different morphologies on a small-scale similar to terrestrial and Martian gullies at field-scale. Small debris aprons can be reproduced in the laboratory over permafrost with a thin active layer and this type of gully is sometimes observed on Earth (French Alps) and on Mars [6]. For high-discharge flows, the temperature seems to have greater influence over the final morphology than the atmospheric pressure. Nevertheless, including the effect of atmospheric pressure is essential for the understanding the initiation of the flows under Martian conditions.

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