DEBRIS FLOWS ON MARS: ANALOGY WITH TERRESTRIAL PERIGLACIAL ENVIRONMENT AND CLIMATIC IMPLICATIONS F. Costard[1], F. Forget[2], N. Mangold[1], D. Mercier[3] and J.P. Peulvast[1], [1]UMR8616, ORSAYTERRE, Equipe de planétologie, Université Paris-Sud, 91405, Orsay Cedex, France. fcostard@geol.u-psud.fr, [2] Laboratoire de Météorologie Dynamique, Université P. & M. Curie, Jussieu, France, [3] Université Paris-Sorbonne, UFR de Géographie et d'Aménagement, Paris, France

Introduction: The new discovery of recent runoff landforms on Mars [1] has renewed the question of liquid water stability in the surface and subsurface of Mars. Malin and Edgett [1] proposed a subsurface origin for the liquid flow. However there is a large variety of such landforms which are distributed in very different geological context and latitudes from 30° to 72°. We suspect that different processes could have played a role in the development of recent run-off features. According to terrestrial analogs in periglacial regions we discuss the possibility to explain some of these landforms by debris flows only due to surface and near-surface (<10 m) melt of volatile-rich material. Such interpretation has important consequences in term of recent climate change.

Observations on Mars: Debris flow is the term used by Malin and Edgett [1] to describe downslope flow of debris mixed with a significant amount of water within the walls of impact craters. They mostly occur in a latitudinal band higher than 30°. The upper part of the walls have a steep slope that is dissected by channels whereas thick accumulations of debris cover the bases of escarpments. The upper part of the slopes (mostly south facing slopes in the southern hemisphere) exhibits alcoves, with generally broad and deep runoff channels. They are characterized by their distinct V shaped channels with well-defined levees. Individual channels exhibit low sinuosity and deep erosion down to the fans that bury the lower parts of the crater walls (fig. 1). These debris fans corresponds to one or several lobes. As it was previously suggested, the morphology of these debris flows suggests several rapid mass movements of debris [1]. The accumulation of debris at the main channel terminations implies a relatively high solid and liquid discharge rates.

Terrestrial analogs: On Earth, debris flows occur in periglacial environments when soils begin to be heavily saturated with water after the melting of the snow cover and/or the ground ice [2]. The initiation process of flow is still not yet fully understood. This initiation can be either due to water saturation by a peak intensity of rainfall events, or to a rapid snowmelt (or melting of ground ice) with subsequent saturation or to a seismic event [3, 4]. Rock fall can also generate a debris flow activity. Indeed, the incorporation of even a small percentage a water content (<10% of H_2O in weight) [5] or vibrations during the initiation of the rockfall can changes the flow [6]. Liquefaction process is also proposed. Field observations indicate that snow covers play an important role on the dynamic of these debris flows. Materials in the regolith are generally coarser and poorly sorted. The duration of these debris flows is extremely variable and may occur as a single or multiple events. The deposition occurs along the narrow channel in levees of very coarse materials with boulders. The end deposits are lobate form

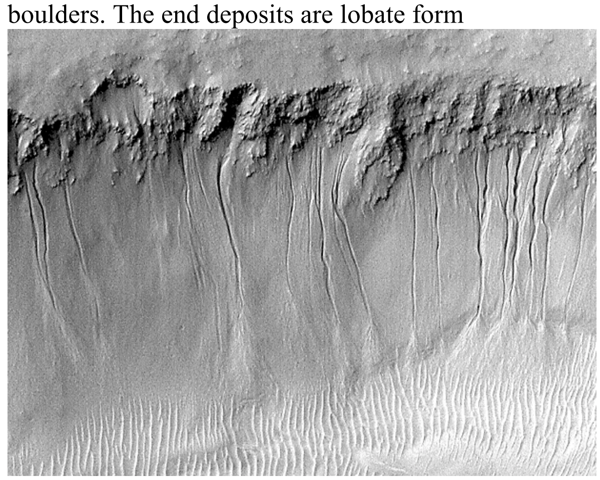

Figure 1: Debris flows on Mars (29°S and 39°W). MOC image, MSSS. Total length of debris flows is 900 m.

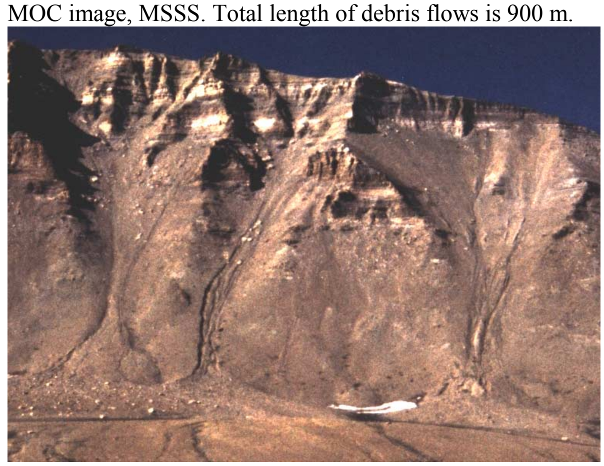

Figure 2: Debris flows in Jameson Land (East Greenland). The mean length of the transport zone is about 500 meters.

Debris flows were observed by two of us (F. Costard and J.P. Peulvast) in East Greenland (Jameson Land) during a field trip in 1987 and 1989 [7]. Jameson Land (70 to 71°N) is located north of the

Scoresby Sund fjord and comprises wide plateaus of 600 to 1000 m high mainly composed of clastic sediments (sandstones, mudstones and shales from Permian to Lower Cretaceous age). The mean annual temperature is –10°C, so the ground is permanently frozen. This implies that no water sources were observed on the field. Summer maximum and winter minimum temperatures are +20°C and -43°C.respectively. Rain is likely to exist and produce some of these landforms though this region is submitted to a dry climate and showers are not frequent.

Several debris flows were studied on the eastern slope – a cuesta - of the 500 m elevation plateau. Below simple or multiple channels, their deposits form fans whose top is found up to 60 m above the base of the slope. The source areas of the flows corresponds to deep alcoves of about 15 m to 60 m high and 20 to 100 m wide. The mean length of the transport zone is a about 300 to 500 meters, on a slope of about 25-30° (fig. 2). The sediments are relatively cohesionless, coarse and easily removable. This is a particularly favourable condition for the initiation of debris flows. Distal-lobes are found lower down at the end of the channels at the foot of hill slopes. Levees are observed on both side of these channels as a continuous and narrow ridges rising 10 to 50 cm above the surrounding slope. These levees correspond to depositional of coarse materials.

Seasonal snow covers occur in the alcoves. Interstitial ice is found within the soil. It occurs under the surface and can be seen to a depth of several meters. When the snow and the interstitial ice melts, the saturation level is reach within the layer of weathered debris. The decrease of the shear strength of the debris by water saturation is probably responsible for repeated debris flow episodes. These landforms all result from surface processes due to snow melting and permafrost melting near the surface.

Stability of liquid water and climatic implications. The comparison between Martian and terrestrial landforms leads to the conclusion that surface processes could explain many of the described features. Such processes imply that liquid water can appear in the first meters of the Martian subsurface. Every landforms are located at latitudes higher than 30°. Therefore, they are located in regions where the Martian permafrost is supposed to contain ground ice in the near-subsurface, less than 10 meters deep [8]. This ground ice may represent one source of liquid water for the debris flows. However, this conclusion is contradictory with the usual consideration that liquid water can not exist at the surface because of the low pressure and temperatures [8]. However, pressure conditions are different in the subsurface. The lithostatic pressure due to several meters of rock increases the pressure at the ice/rock contact in comparison to the atmospheric pressure. For example, about 200 hPa for 3 meters of debris with density of ρ=2000 kg/m^3. Nevertheless melting can occur only if temperatures cross the melting point, i.e. 273K for pure water ice. Assuming that water is chemically pure, the temperatures conditions are not reached at the present time. Indeed, at latitude of 35° where these landforms are the most numerous, the annual mean temperature is about 215K. Surface temperatures reach an average of 255K at surface in the mid-summer, with diurnal maximum of 295 K. However the diurnal maximum only affects the first centimeters of the ground. Therefore, only the seasonal effect can be considered. However the increase of temperature in subsurface is limited to the surface mean temperature of 255 K which does not allow pure ice to melt. This implies either that the water ice is not pure or that climatic conditions were warmer in the recent past.

Water ice doped with salts or CO_2 clathrates has been reported in different ways [9]. However, the occurrence of such components is difficult to explain in the near-surface of different kinds of hillslopes. At least, it could explain gullies of the south polar regions, at 70°S, where temperatures are very cold, i.e. 190 K of mean annual temperatures. The second possibility, recent climatic changes, may be possible considering the large pseudo-cyclic variations of the obliquity and excentricity of the planet at the scale of 100,000 years. An obliquity of more than 40° would increase both maximal temperatures in polar regions and atmospheric pressure due to CO_2 sublimation (see Clifford, LPSC 32, this volume). Recent martian landforms produced by liquid flows are rare and only associated to hillslopes. They probably represent transient processes that might occur when climatic conditions were at one extremity of the possible ranges of conditions in the recent past.

Conclusion : The analogy between debris flows in Greenland (Jameson Land) and debris flows on Mars suggest that some of these landforms are only due to the presence of liquid water in the first meters of the Martian subsurface. Such interpretation involves some recent climate changes.

References: [1] Malin M.C. and Edgett K.E. (2000) *Science 288*, 2330-2335. [2] French H. M. *The periglacial environment* (1988) 341 p. [3] Innes J. L. (1983) *Progress in Phys. Geogr. 7*, 469-501, [4] Boelhouwers et al. (2000) *Earth Surf. Proc. Landforms 25*, 341-352. [5] Iverson R.A. (1997) *Review of Geophysics 35*, 245-296. [6] Dikau R. et al. (eds), Wiley (1996) *Landslide Recognition*,.251 p. [7] Peulvast J. P. *Physio-Géo 18*, 87-105. [8] Fanale F. P. et al. (1986) *Icarus 67*, 1-18. [9] Hoffman N. (2000) *Icarus 146*, 326-342. **Acknowledgements:** This work is supported by Programme National de Planétologie de l'Institut National des Sciences de l'Univers (CNRS, France).