NARROW GULLIES OVER HIGH SAND DUNES ON MARS: EVIDENCE FOR FLOWS TRIGGERED BY LIQUID WATER NEAR SURFACE.

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Background:
The observation of recent gullies on Mars was one of the more unexpected discoveries of the Mars Observer Camera (MOC) aboard Mars Global Surveyor [1]. The characteristics of these landforms suggest the local occurrence of a fluid emanating from alcoves located mostly in the upper part of poleward-facing slopes at mid and high latitudes [1]. However, observations of gullies originating from the top of peaks and dunes question this scenario [2]. Most gullies are more likely to result from the melting of liquid water in the first meters of the Martian sub-surface at high obliquity. This is suggested by the analogy between the martian gullies and terrestrial debris flows observed in Greenland which are known to result from the thawing of near-surface ground when above-freezing temperatures are reached [2]. Numerical simulations show that above-freezing temperatures can occur at high obliquities in the near-surface of Mars, and that such temperatures are only predicted at latitudes and for slope orientations corresponding exactly to where the gullies have been observed on Mars. In this work, we focus on gullies observed on the flanks of high dunes.

Analysis of channel tracks:
Narrow gullies interpreted as the result of liquid flows on frozen dunes are observed on 6 MOC images in the latitudes of 40 to 60°S. Among these dunes, a large scale sand dunes reaching an elevation of 600 m above surrounding plains covers the floor of Russel crater (Fig. 1). The close-up on MOC19-01170 shows that the flank of this dune is striped by narrow channels less than 20 m wide and 1 to 2 km long (Fig. 2). Using MOLA data we find that the flank of the dune is of about 10°, with exception of the steeper part of the crest. All channels have their sources in small alcoves at the crest of the dune. No source exists in the middle of the dune, that is an argument in favor of slides formed at the dune crest. Nevertheless, the fact that they keep the same width along the whole flank of the dune favors liquid flows better than dry granular flows. Furthermore, several channels show sinuous tracks and no granular flows can present such geometry. Channel tracks are mainly straight without crossing themselves. Several exceptions exist left of the picture where channels organized in networks of coalescent tracks. Such junctions are also typical of liquid flows. Lateral ridges, also called "levées", are observed on every channels. They demonstrate that the liquid of the flow is a viscous slurry with a given shear strength. Indeed, terrestrial debris flows formed by a slurry of mud, rock and water display usually such lateral ridges [3]. The rapid stop of the channel in the lower part of the slope is also consistent with a viscous slurry. Using clinometry we determine the thickness of lateral ridges as being several meters or less. This gives shear strength equivalent to terrestrial ones supporting the fact that the liquid involved in the slurry is H_2O water like on Earth. The sinuousity of several channels also shows that the flow is not very fast (less than 10 m/s) and inconsistent with CO_2 driven flows. Indeed, flows triggered by CO_2 would give high velocities strictly larger than 20 m/s like pyroclastic flows on Earth [4]. These observations therefore support the interpretation that a viscous slurry due to liquid water formed the channels observed on the flank of the dune.

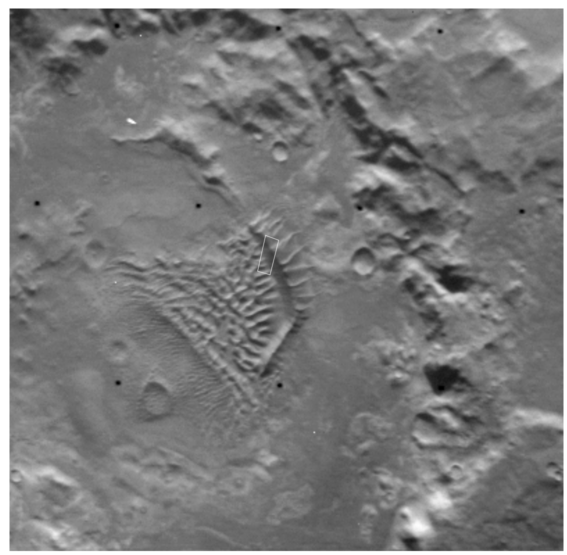

Fig. 1: Dune field in Russel crater (347°W, 54.5°S). The white square shows the close-up of figure 2. Image about 100 km wide.

Implications:
The occurrence of liquid water close to the surface of this dune is questionable. Where does the water come from? Dunes formed by sand can represent a porous reservoir for ground ice. The storage of ground ice in dunes is possible by condensation of water vapor from the atmosphere during cold season or upward diffusion and condensation of water vapor [5]. Condensation from atmosphere is possible at low latitudes if the obliquity is higher than at the present time. During such period of high obliquity, about 40-45°, melting can

occur during summer explaining the formation of flows [2]. This favors an external cause for the condensation of water ice and its subsequent melting inside near-surface layers of dunes. The fact that gullies over dunes are still observable at the present time does not mean that they formed only few years ago. Dunes may be frozen and inactive for thousand years explaining the conservation of these landforms. On the other hand, the presence of large inactive dunes has also implications on the global survey of eolian process on Mars. Wind action should have been higher in the past to explain the formation of such huge dunes. This is possible especially if the atmospheric pressure was higher. Such increase could have been a consequence of high obliquity period in agreement with previous conclusions.

References: [1] Malin and Edgett, *Science*, 2000 [2] Costard et al., *Science*, in press. [3] Johnson and Rodine, in "*Slope instability*" Wiley, 1984 [4] Stewart and Nimmo, JGR, *in press*. [5] Clifford, JGR, 10973, 1993.

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Fig. 2: Part of MOC image M19-01170 in Russel crater. Channels are nearly 2 km long.