GEOLOGICALLY RECENT EARTHFLOW-LIKE LANDSLIDES ON MARS. A. Guimpier[1], S. J. Conway[1], A. Noblet[1] and N. Mangold[1], [1]Laboratoire de Planétologie et Géodynamique CNRS UMR6112, Université de Nantes, France. anthony.guimpier@univ-nantes.fr

Introduction: Given the hyperarid climate that is believed to dominate the late Amazonian on Mars, landslides are generally interpreted as forming without liquid water [e.g., 1,2]. This study focuses on four small martian landslides of less than 20 Ma [3] with volumes <10^7 m^3 located in a crater in the Nilosyrtis Mensae region at 27°N, 76°W (*Figure 1*). We compared the morphology and inferred rheology of these landslides with terrestrial analogues and identified similarities between them and terrestrial earthflows. Earthflows need liquid water to form, so we then assess the potential role of volatiles in the formation of these four landslides on Mars.

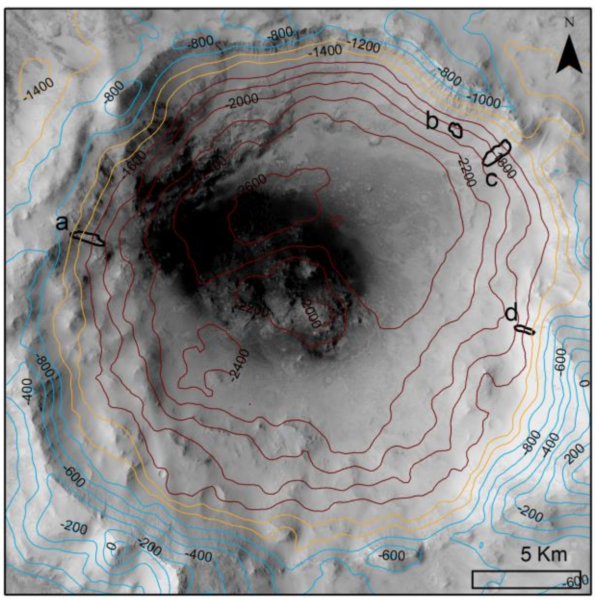

Figure 1: Locations of landslides inside the impact crater in the Nilosyrtis Mensae region. Landslides a and c are shown in detail in Figure 3. The contour lines are plotted with a 200-m interval. MOLA/HRSC elevation data and mosaic of CTX images D01_027480_2076 and J22_053457_2076. NASA/JPL/MSSS

Methodology: We used images from the ConTeXt camera (CTX) at 6 m/pix, Colour and Stereo Surface Imaging System (CaSSIS) at 5 m/pix and High Resolution Imaging Science Experiment (HiRISE) at 25-50 cm/pix. From HiRISE stereo images, we produced Digital Elevation Models (DEM) at 1-2 m/pix using the Ames Stereo Pipeline [4] and SocetSet [5] to make morphometric measurements (e.g., *Figure 2*).

If we assume a Bingham rheology, we can estimate the yield strength (Y) of the materials making up the martian landslides using the morphology of the deposit [e.g., 6,7]. We used the following two relations:

$$Y = hg\rho \sin(\alpha) \quad (1)$$

$$Y = \frac{\rho g h^2}{W} \quad (2)$$

Where ρ is the material density, h is the levee height, α the slope inclination, g the gravitational acceleration and W the width of the landslide cross-section. We can then compare these estimated values to terrestrial analogues which share morphological features with the martian landslides.

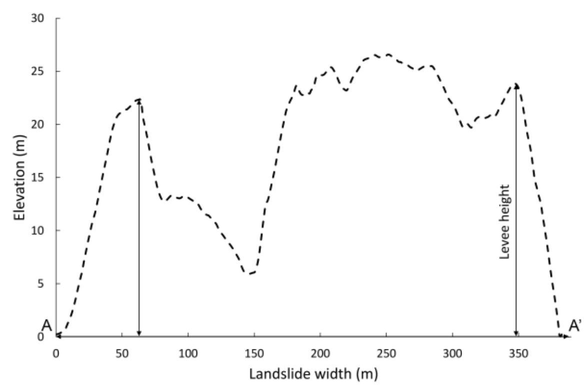

Figure 2: Cross-section A-A' of a martian landslide b in figure 3 showing the structure of the levees.

Morphological results: The four martian landslides are located inside an impact crater 25 km in diameter (*Figure 1*). The crater is characterised by the presence of well-defined fractures on its walls and by presence of more than 300 rockfall tracks [e.g., 8]. The landslides are also located at approximately the same topographic level (*Figure 1, orange contour line*). If we compare this elevation with the general elevation outside the impact crater (*Figure 1, blue contour lines*), and this elevation is in general lower than the elevation of the surrounding terrain. All four landslides are within the same smooth material, which appears draped on the topography.

These landslides have the following characteristics: (1) a lobate flow front, (2) lateral levees, (3) a sinusoidal longitude profile implying the absence of residual material in the landslide erosion zone and its accumulation in the deposition zone (*Figure 3 b & d*), (4) they occur mid-way down hillslopes between 20 and 25° in inclination, and (4) compression ridges are present on their deposits (*Figure 3a & c*).

These morphological characteristics are also expressed by terrestrial earthflows. Earthflows propagate over a wide range of slopes between 15° and 40° [9]. These martian landslides also share at least one morphological characteristic with mudflows (irregular scars and ridges perpendicular to the direction of propagation).

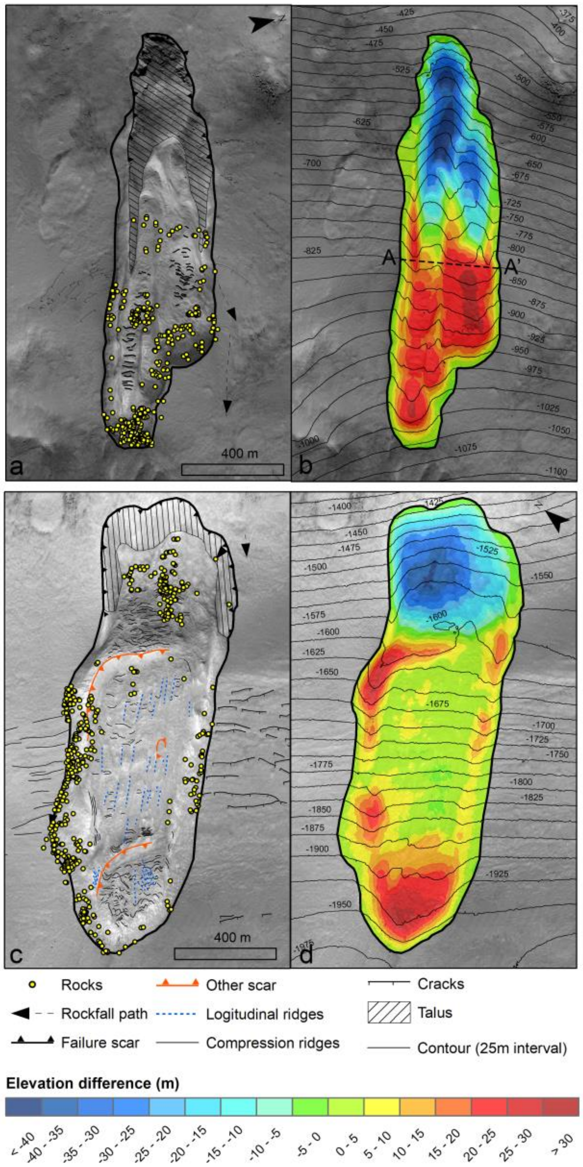

Figure 1: Structural and elevation map of martian landslide. (a) and (b) is the located at the west in the impact crater and (c) and (d)is located at the east in the impact crater. HiRISE images (a & b) ESP_026781_2075; (c & d) ESP_057110_2075. NASA/JPL/UofA.

Rheological results: We estimate a yield strength between 11 and 97 kPa for the martian landslides. We compared these yield strength estimates with values from the literature for earthflows (1 to 100 kPa [10]), mudslides (0.01 to 0.8 kPa [11,12]). Our estimated values are of the same order as those of earthflows and andesite lava flows. The relatively high yield strength values are consistent with the steep inclination of the lateral levees indicating strong material cohesion.

Discussion: Terrestrial earthflows require liquid water to form. The similarities observed between these late Amazonian martian landslides and terrestrial earthflows, raises the question of the potential origin of liquid water to mobilise these landslides on Mars in such a recent period, when Mars is believed to be hyperarid. The presence of more than 300 rockfall tracks indicates general slope instability of the crater walls, but the landslides are not located on the highest slopes inside the crater. This is further evidence of an external factor, in this case water, playing a role in their formation. There are two reasonable possibilities: 1) the water comes from an underground aquifer or 2) the water comes from the local melting of ground ice under previous favourable climate conditions.

Our working hypothesis is a blend of these two hypotheses. These landslides are located at the southernmost limit of the icy latitude dependant mantle, and we have identified sublimation surface textures indicative of the former presence of ice on pole-facing slopes in this region. These deposits cannot be directly involved in the formation of the landslides. The fact that these landslides occur at the same topographic level - below the elevation of the surrounding terrains - opens up the possibility of migration of water in the subsurface, which then initiated these failures. We also consider the possibility that the clays that have previously been detected in this region [3] may have favoured failure via swelling on contact with water.

Conclusions: (1) The morphological and rheological comparison between martian landslides and terrestrial analogues reveals they are similar to earthflows. (2) Earthflows involve liquid water, implying the involvement of volatiles in the formation of the martian landslides. (3) These volatiles could have a surface origin associated with local ice melting and subsequent migration in the subsurface.

Acknowledgments: This thesis is funded by a ministerial grant. We are grateful for the support of the Programme National de Planétologie and the French Space Agency CNES.

References: [1] C. Quantin et al. (2004) *PSS*, *52*, 1011–1022. [2] V. Soukhovitskaya and M. Manga (2006) *Icarus*, *180*, 348–352. [3] A. Guimpier et al. (In review) *PSS*. [4] M.J. Broxton and L.J. Edwards (2008) *LPSC, 2008*. [5] R.L. Kirk et al. (2008) *JGR*, *113*. [6] D.M. Pyle and J.R. Elliott (2006) *Geosphere*, *2*, 253–268. [7] J.A. Hunt et al. (2019) *G3*, *20*, 1508–1538. [8] P.-A. Tesson et al. (2020) *Icarus*, *342*, 113503. [9] D.K. Keefer and A.M. Johnson (1983) *U.S. G.P.O., Professional Paper*. [10] A.L. Nereson and N.J. Finnegan (2015) *AGU 2015*, EP41C-0943. [11] D. Craig (1981) *Engineering Geology*, *17*, 273–281. [12] L. Jing et al. (2018) *JGR*, *123*, 2004–2023.