INVESTIGATING MARTIAN LANDSLIDES ON A GLOBAL SCALE. Fabio Vittorio De Blasio[1], Giovanni Battista Crosta[1], Paolo Frattini[1], Elena Valbuzzi[1]
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Introduction:

During a long-term project, we have identified and classified a large number (>3000) of Martian landslides especially but not exclusively from Valles Marineris. This database, which will supplement other databases from different authors, will contribute to a more comprehensive basis for a statistical study of landslides on Mars.

The database is beginning to reveal a series of trends than may assist understanding landform processes on Mars and its past climatic conditions. Perhaps one of the most interesting aspects of our data is the presence of a population of landslides whose particularly long mobility deviates from average behavior. Here, we report our ongoing research on a few of these aspects of Mars morphology.

Materials and methods:

Landslides have been mapped according to standard geomorphological criteria, delineating both the landslide scar and accumulation limits, associating each scarp to a deposit, and using the program ArcGis. Multiple accumulations from the same source area or from different sources have been differentiated where possible to obtain a more complete dataset. Each landslide has been classified according to a number of criteria such as type, degree of confinement, possible trigger, elevation with respect to datum, geomorphological features, degree of multiplicity, and so on. The runout, fall height, and volume have been measured.

Peculiarity of landslide flows:

Moreover, landslides are also studied in relation to i) morphologies created by the landslide itself, ii) mounds, barriers or upslopes than have affected the movement of the landslide mass.

While some landslides have travelled unimpeded on a usually flat area, others have travelled against obstracles or mounds; in some extreme cases, the landslide was capable of travelling for several tens of km along the whole valley and upon reaching the opposite side it travelled against slope for several hundreds of meters, which is indication of high travelling speed (Fig. 1). In other cases, the high speed is revealed by dynamical deformations of the landslide body such as pressure ridges due to the impact of the landslide against a mound (Fig. 2).

Another observation valid at least for the landslides in Valles Marineris especially at the boundary with the dichotomic level, is their resemblance with landslides on terrestrial glaciers [1]. Indications that ice may have influenced the flow of Martical landslides is also revealed by icy conditions that are well-known in the chaos regions and that we find also in Valles Marineris, especially at Coprates Chasma (Fig. 3). Here, we have observed fluted morphologies at the front of the Coprates Labes landslide as well as concentric grooves indicating a glacial or periglacial regime when the landslide took place. Considering the absence of clearly glacial features in Valles Marineris (rouches mountaunee, cirques, trimlines, moraines), we suggest, however, that the glacialism in Coprates was not as strong as proposed in ref. [2], but sufficiently robust to influence the flow of landslides sliding on the icy surface. Moreover, even if most of the landslides are morphologically similar to those on terrestrial glaciers, their undistorted appearance indicates that if a glacier was present in the valley bottom, it was not flowing. The superposition of several stacked landslides still exhibiting linear furrows shows that either ice was continuously renewed, or another source of ice (not meteoric) was present to lubricate the landslides. Our observations make us suggest that a layer of sub-surface ice could better explain these features, and also elucidate the creation of the chaotic terrain at some places of Valles Marineris and other locations of Mars.

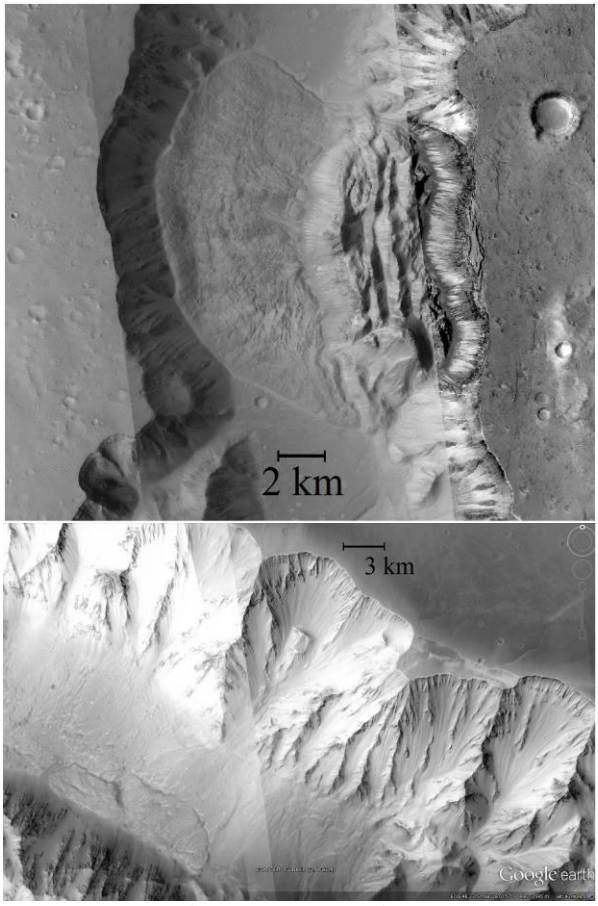

Figure 1. Examples of landslides travelling for a long distance along a flat area and them impacting against the opposite side of their valley. Top image: the landslide ran up on the opposite side (Shalbatana Vallis, CTX mosaic). Bottom: after perhaps a phase of run-up, the landslide fell back depositing on its previous deposit. Candor Chasma, Courtesy Google Mars (mosaic based on CTX images). North in both images points at the top.

Long-runout landslides:

To characterize landslide mobility, we made use of the H/L ratio, also known as the Heim's ratio, or the tangent of the *Fahrböschung*, expressing the ratio between vertical displacement to maximum horizontal distance for a landslide and representing a proxy to the effective friction met by the landslide along its path. On Earth, the ratio H/L decreases with landslide volume [3]. Our database confirms with a much more robust statistics this trend noticed long ago also for Mars [4]. It also confirms that Martian landslides are on the average less mobile than their terrestrial counterparts. In some areas, the ratio is above or below the best fitting line for all the sampled landslides, indicating respectively lower and higher mobility.

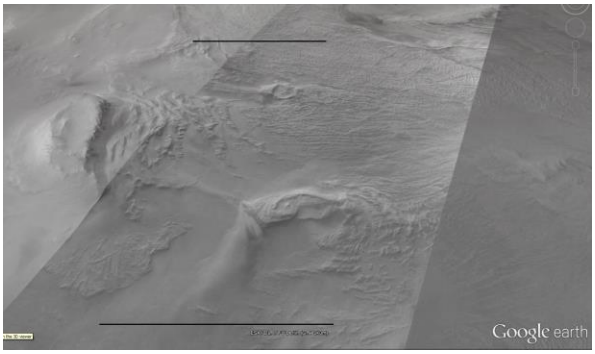

Figure 2. Example of pressure ridges originated by the impact of a landslide body against a mound in Melas Chasma. Each line is 10 km long. North approximately pointing to the right.

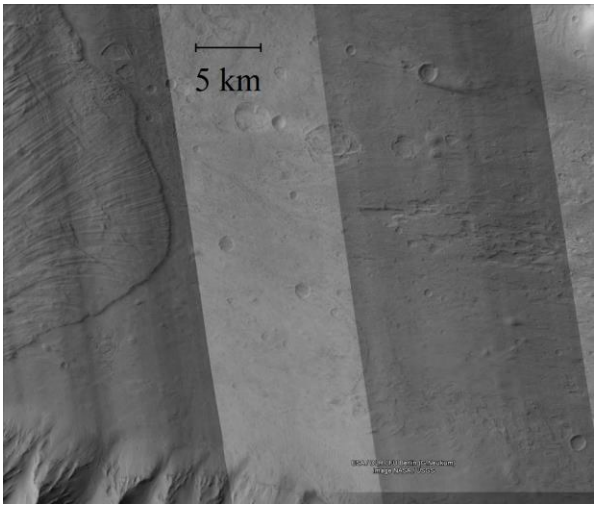

Figure 3. The bottom of Coprates Chasma reveals past glacial and periglacial conditions, including glacier-like furrows that may have affected the flow of the landslides such as the one visible on the left. This very large landslide (called Coprates Labes) shows, like many other landslides in Valles Marineris, longitudinal furrows typical of many terrestrial landslides which travelled on top of glaciers. North top of figure.

By analyzing the residuals (i.e., deviatios of the H/R value with respect to the best fit curve) we find that high mobility is associated with four kinds of landslides:

1) Landslides appearing in conjunction with morphologies of suspected glacial or periglacial environments, as explained earlier. A series of numerical simulations are then put forward to address basic questions concerning the possible role of ice as a natural lubricant at the moment of flow.
2) Landslides triggered by meteoroid impacts.
3) Landslides evidently related to Toreva blocks.
4) Olympus Mons aureoles.

Each of these long-runout landslides requires special mechanism to explain the flow to the observed long distances. We are investigating the dynamic conditions as to how the excess mobility occurs for each of the 1-4 cases.

Concluding:

A large database of Martian landslides is providing indications of the behavior of these mass flows on Mars. Among the observations made during the completion of the database, we have documented some peculiar features in large landslides on Mars. Based on imagery and a comparison to glaciated landscapes on Earth, we show that the glacialism in Valles Marineris, where most of the landslide took place, was very peculiar, both for the kind of erosive and depositional features, and their distribution and abundance.

References: [1] De Blasio, FV. 2011. PSS 59, 1384–1392. [2] Gourronc M., et al. 2014. Geomorphology 204, 235-255. [3] Lucchitta, B. 1979. JGR 84, 8097-8113. [4] Scheidegger, A.E. 1973. Rock Mech. 5, 231-236.