New Methodology for Initial Volume Estimation of Martian Landslides from DTM and Imagery.

A. Lucas[1,2], A. Mangeney[1], D. Mège[2], K. Kelfoun[3]. 1 - Institut de Physique du Globe de Paris, UMR CNRS 7154, Université Paris Denis Diderot, France. 2 - Laboratoire de Planétologie et de Géodynamique, UMR CNRS 6112, Université de Nantes, France. 3 – Magma et Volcans, UMR CNRS 6524, Observatoire de Physique du Globe de Clermont-Ferrand, France. (lucas@ipgp.fr).

Abstract: We propose a new method for the reconstruction of slided materials in large Martian landslides, and we take the large Coprates Chasma landslide as an example.

Introduction: Large Martian Landslides (LML) were studied by many authors [1-3]. Studying these landslides contribute to an understanding of the dynamics of the landscapes and is expected to provide insight into the climatic conditions during emplacement at Amazonian Time [4] due to the possible presence of groundwater in liquid or solid phases.

Many studies highlight a much higher mobility of Large Martian Landslides compared to terrestrial cases [1,2,5] (*see also Lucas at al., workshop on Martian Gullies, 2008*). A few parameters allow us to characterize the dynamic of those catastrophic events such as runout, velocity, surface area of deposits, and the volume involved in mass spreading. In order to understand the behavior of Large Martian Landslides, numerical simulations have been performed in [5]. A major problem when simulating real flows is the reconstruction of the pre-event DTM (Digital Topographic Model). Initial mass volume and bottom topography reconstruction are thus needed so as to reproduce the observed final deposits in the simulations.

Sato et al. [7] have already proposed a LML volume measurement method. We focus here on a method developed for numerical simulations [5].

Data used: Using infrared and panchromatic imagery from from THEMIS, HRSC, MOC, andMOLA DTM,we compile data in ENVI®. Correct deposit identification deposits is a key element in our approach. Thermal IR data obtained by THEMIS during night time make it possible to distinguish between the deposits and the surroundings.

DTM processing:

Two steps are needed in the topography reconstruction.

1. After deposit identification on the images, the Region Of Interest (ROI) is used as a mask in the DTM altimetric grid. Deposit thickness within the ROI is removed using a vectorial mapping software (e.g. Didger®). In several cases on Mars (e.g. Coprates Chasma), the deposits are made of a faulted area overhanging debris aprons [3] (fig. 1). The floor topography below the faulted domain is not well constrained. We perfomed here two reconstructions using two floor topographic slopes.

This removal generates dispersion of the altimetric information in the initial grid. The altimetric grid is then rebuilt by kriging [8], defined by the equation:

$$Z^*(x_0) = \sum_{i=1}^{N} \lambda_i Z(x_i),$$

where the estimation of $Z^*(x_0)$ is calculated for $x = x_i$ at x_0 (where x_0 are known points) of the plane starting from known values; λ_i is the ponderation coefficient in $x = x_i$. Kriging is appropriate because it takes both the geographical position and variability of the data into account. This interpolation method of interpolation minimizes the errors if information is not spacially regular. The new altimetric grid obtained by this method has the same spacial resolution as MOLA.

2. The second step is reconstruciton of the initial landslide volume. At first order, we interpolate the wallslope using the each edge of the scarp. Afterwards, we perform a topography modeling so as to get the second order of the wallslope shape. The morphometric features are determined by calculating the slope and the curvature of the surface using ENVI® (fig. 2). This step allows us to determine the initial wallslope geomorphology. Our calculation of the missing spur-and-gully volume does not exceed 3% of the total ridge's volume at MOLA resolution (*Further work is in progress using a HRSC DTM. More significant volume is expected due to the better spatial DTM resolution*).

Finally, reconstruction of the initial slided volume is done using the same vectorial method as that used for floor topography retrieval (fig. 3).

Discussion: Volume estimates for Large Martian Landslides have been previously calculated by [3,7] using the same data. Similar to *Sato et al.* [7], our volume estimates are based on floor topography reconstruction, whereas *Quantin et al.* [3] proposed a simple estimate from MOLA data. Nevertheless, we find a volume similar to the volume found in [3], and more importantly, our volume balance has the same sign with [7] (table 1). Moreover, our calculations differ from [7] in the interpolation algorithm used. Whereas *Sato et al*. [7] obtain non physical oscillations in their

DTM (fig. 4-a), the algorithm we use gives a non undulated, more realistic DTM (fig. 4-b), a constraint that we initially imposed because of the requirement of having a smooth topography for subsequent landslide development simulation.

Coprates Landslides:	[3]	[7]	Topo-1	Topo-2
Initial Vol. (km^3)	500	249	300	300
Final Vol. (km^3)	346	472	390	410
Vol. Balance: (Vf-Vi)/Vi	-0.31	0.90	0.30	0.36

Table 1 – Volume estimates for Coprates Chasma landslide in the litterature and in our study. Topo 1 is steeper than Topo 2.

Conclusion: Despite floor topography unknowns, our results are in broad agreement with [7]. In addition, as we mentioned below, our method of reconstruction is suitable to 3D numerical simulations due to an optimal geostatistic algorithm.

Our method may be applied on more recent datasets such as HRSC and HiRISE DTMs, an evolution that is currently in progress.

Finally, given that the intial geometry of VM is a graben structure [9], Our methodology is applicable to estimate the mass wasted by weathering processes.

References: [1] Lucchitta, *JGR*, 1979; [2] McEwen, *Geology*, 1989; [3] Quantin et al., *PSS*, 2004; [4] Quantin et al., *Icarus*, 2004; [5] Lucas and Mangeney, *GRL*, 2007; [6] Lucas and Mangeney, *1st EPSC*, 2006; [7] Sato et al., *7th Int. Conf. Mars*, 2007; [8] Stein et al., Springer ed. 2002; [9] Mège et al., 1996.

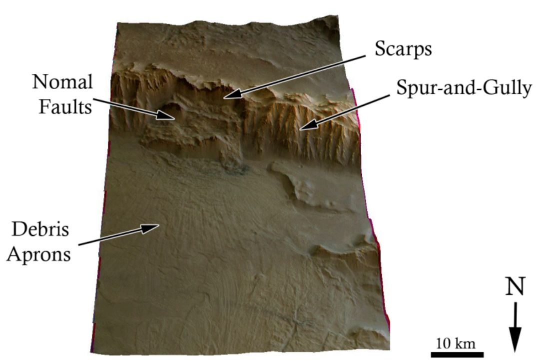

FIG. 1 – HRSC image in Coprates Chasma (12°S, 67°W). Spur-and-Gully features are not present at landslide Scarps. The equivalent missing volume is 3% on MOLA DTM.

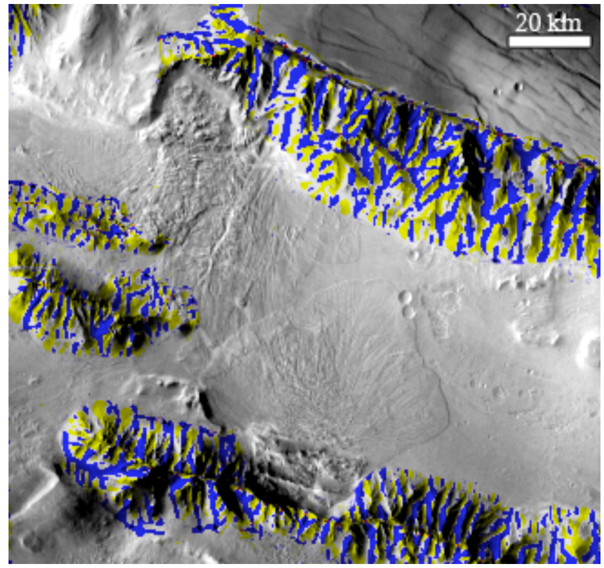

FIG. 2 – Topographic features from modeling (see DTM processes section) over IR-THEMIS mosaic. Yellow areas are spur, blues areas are gullies. Spurs have a convex cross-section and convex longitudinal curvature while gullies have concave curvatures. Mean spur-and-gully morphology wavelength is ~4km in this region.

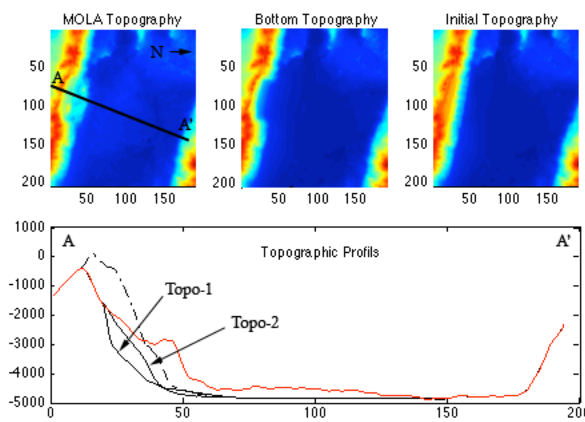

FIG. 3 – (Top) Respectively, MOLA, bottom (floor) and intial topographies. (Bottom) Topographic profiles along the black line. MOLA is in red, initial topography is dashed-dotted , bottom topography is in black.

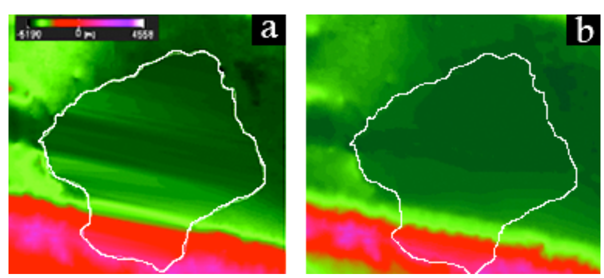

FIG. 4 – (a) Topography reconstruction from [7]. (b) Our reconstruction with the same color chart.