A NEW INSIGHT ON THE DYNAMICS OF MARTIAN GRANULAR FLOWS IN VALLES MARINERIS.

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Introduction: Morphologies related to granular flows (landslides, debris flows, gullies...) were identified on Mars on orbital imagery [1, 2, 3]. Some of these granular flows may still active today such as gullies in Centuri Montes region [4]. Former work highlights a higher flow mobility on Mars compared to terrestrial cases [1, 2, 5, 6]. Water often takes part in the dynamics of these events on Earth [5, 7].

We propose to study the behavior of large Martian landslides using a long wave approximation (LWA) numerical model that takes the topography prior to the flow into account [8]. Therefore, this study is a contribution to the identification of the influence of liquid or solid water on Martian landscape dynamics during the Amazonian [4, 9].

Scaling laws: Experimental studies of dry granular column's spreading on a horizontal plane have shown a scaling law relating the initial landslide aspect ratio ($\alpha = H_i/L_i$ with $H_i$ initial height and $L_i$ initial length) and runout ($\Delta L/L_i$) [10].

Runout is defined as $\Delta L/L_i = 2aK/\varepsilon$ [11] where $K$ is the Rankine coefficient (depending on internal and bed friction angles), and $\varepsilon = \tan \delta - \tan \theta$ where, $\delta$ is the dynamic friction angle and, $\theta$ the local slope. In addition, we proposed to use $1/\mu_e = \Delta L/H_i = 2K/\varepsilon$ to characterize the mobility of the flows [12]. This new parameter appear to be independent of any geometric parameters (volume, initial aspect ratio and mass) neither gravity.

Comparaison between Martian and laboratory data: Similar correlation between initial aspect ratio and runout were observed for Martian landslides observed in Valles Marineris (VM) as well (fig. 1) [13]. It is thus tempting to deduce that large Martian landslides occurred in VM were dry.

Nevertheless, the normalized runout of the VM landslides is twice longer than in laboratory (fig. 1). The trend observed on Mars suggests that all the major parameters have not been taken into account in experimental studies.

The normalized runout does not depend on gravity [8] and should thus be comparable on Mars and on the Earth. Only the time of spreading is gravity-dependent.

In addition, the new mobility $1/\mu_e$ of large Martian landslides is close to 10 whereas it is equal to 1.24 for dry granular spreading flows in laboratory [12].

The geological processes and physical parameters that may explain this discrepancy include topography, granulometry distribution [14], and fluid pressure. We discuss the effect of topography below, especially in the case of an inclined canyon floor topography prior to landsliding on Mars as it was not the case in former experiments and simulations on granular collapse.

Numerical simulation: Numerical model based on Saint-Venant equations implying a depth-averaged continuum model (LWA) and a Coulomb-type friction law with a constant friction $\mu$ ($\mu = \tan \delta$) can reproduce the basic behavior of granular flows [8]. To fit experimental results (spreading of dry granular column on a horizontal plane), it is needed to deal with $\alpha < 1$ and $\delta = 32^\circ$.

Furthermore, this model is able to take the curvature effect of the topography into account [8]. Simple simulations on inclined plane (using the slope range observed on Mars) could not fit the Martian observations with $\delta = 32^\circ$. On the other hand, values of $\delta$ below 10° are necessary to reproduce the high mobility in order to fit Martian values [12].

This model makes it possible to study the influence of the topography in a geophysical context. Using MOLA Digital Topography Model (DTM) given by spaceprobe Mars Global Surveyor (MGS) our work aim to simulate large Martian landslides occurred in Valles Marineris.

Simulations of Ophir Chama landslide: A simulation was performed for one of the Ophir Chasma landslides. The chasma topography prior to landsliding needs to be reconstructed first. In order to remove the landslide deposits, we first identified them using visible and IR images from THEMIS, HRSC and MOC. Then we thus performed a geomorphological mapping of landslides deposits at a resolution better than MOLA. Computation with topography grid was done using GIS software.

In order to remove the topographic signal of the landslide deposits from the MOLA altimetric grid, we used a vectorial mapping software coupled with a geostatistic kriging method in order to rebuild a new, regularly spaced altimetric grid. The new altimetric grid obtained has the same spatial resolution as MOLA (~463 m/pixel). Figure 2 shows the results of the topographic processing steps. Subsequently, a simple linear interpolation between two side profiles was
used for the reconstruction of the initial wallslope. In this manner, weathering morphologies (such as spur-and-gully) could not be taken into account in the reconstruction.

We designed our simulations so as to fit runout length and the extent of the deposits observed on Mars (fig. 2c). In Ophir Chasma, their extent is close to 3 416 km² and we get 3 450 km². But both these results (runout and extent fits) required friction angles lower than 10°. Although the slope effect has been accounted for a very low value of friction angle compared to the 32° needed to reproduce laboratory dry granular flows.

The very high mobility required by the very low friction coefficient may be due to the existence of fluid/gaz pressure. Sublimation of ice lenses or overpressured groundwater during landsliding could also contribute to increase the mobility.

**Conclusions:** This study shows that the topography effect has a significative increase on the mobility. Although this effect has been taken into account in our simulations, the friction coefficient used to fit Martian data has to be much smaller than the friction coefficient used to reproduce laboratory experiments of dry granular flow. The new mobility defined in this study is higher for large Martian landslides than one observed in laboratory.

The influence of a fluid in dynamics of these large landslides thus remain an open question and will be discussed in a fellowing study. Nevertheless, large Martian landslides are more akin to fluid than dry granular flows.