DISCRETE ELEMENT MODELING OF LANDSLIDE DYNAMICS: THE INFLUENCE OF FRICTION AND ASPECT RATIO. Timur Borykov[1], Anne Mangeney[2], Daniel Mège[1,3], Patrick Richard[4] and Joanna Gurgurewicz[1,5], [1]Institute of Geological Sciences, Polish Academy of Sciences, Research Centre in Wrocław, Podwale 75, 50-449, Wroclaw, Poland, timur.borikov@twarda.pan.pl, [2]Équipe de Sismologie, Institut de Physique du Globe de Paris, [3]Laboratorie de Planétologie et Géodynamique, UMR CNRS 6112, University of Nantes, France, UMR 7154 CNRS, France,[4] LUNAM Université, IFSTTAR site de Nantes, France, [5]Space Research Centre, Polish Academy of Sciences, Warsaw, Poland

Introduction: Landslides and debris flows sculpt the surface morphology on Earth as well as on other planets. They constitute one of the most efficient mass wasting processes on Mars [1]. Recent researches have studied the fundamental physics of the collapse of granular columns in experimental and numerical approaches [2, 3, 4]. Our work presents a 3D discrete element simulation (DEM) of the axisymmetric and planar (sidewalls) spreading of initially vertical granular columns, in which the runout of the grains and their dynamic motion are continuously monitored during the course of collapse, in order to understand better detailed processes of landslide propagation on Earth and Mars.

Numerical model and results: Simulation is performed using the numerical model and code MODY-GS [5]. This integrates Newton's equations of motion for each of a large number of colliding grains. It is performed using the Velocity-Verlet scheme. This scheme is very stable and has become the perhaps most widely used Molecular Dynamics algorithm.

Here we systematically study the role of both the effects of the initial condition and input parameters related to the material properties in the spreading of the granular mass. The most important factors that can influence the granular flows properties are: particle-wall, inter-particle (Coulomb) and rolling friction, number of particles, size of grains, coefficient of restitution, aspect ratio and inclination angle. The collapse dynamics is shown to be dependent on the initial geometry of the planar or cylindrical column, and quite independent on the inter-particle (Figure 1) and particle-wall friction, as well as the number of grains for a grain number > 1000 (Figure 2).

We also observed that the coefficient of restitution considerably changes the behaviour of the systems for the coefficient of restitution $\rightarrow 1$; in particular, this dramatic change is expected to become more important for increasing values of the aspect ratio. On the contrary, for the coefficient of restitution ≤ 0.85, the influence of the coefficient of restitution becomes negligible.

The results from the previous granular collapse experiments are characterized by the scaling laws which emerged for the final runout and the maximum height of the deposit [2, 4]. We look for similar behavior by varying the aspect ratio a from 0.9 to 50. Our scaling for the runout distance showed both a linear and a power-law dependence on the aspect ratio of the initial column, in agreement with the previous studies [2, 4].

In order to understand the dynamic behavior better, we analyzed velocity profiles (Figure 3) as a function of the runout and height. We have also shown that the value of the inter-particle friction μ deeply affects the internal structure of the flow. In particular, large inter-particle friction leads to the gradual growth of a static layer at the base of the flow, while small inter-particle friction does not allow this static layer to build up, and the flow freezes in a very short time. If the aspect ratio is large enough for an initial episode of free fall of the column to occur during the axisymmetric or planar collapse the behavior of the spreading will be dominated by free-fall (Figure 4). And in fact, almost the whole column becomes involved in the downward movement. This was studied in some detail by Staron and Hinch [3] in their 2D DEM. Although high aspect ratios are difficult to find in nature, many rock falls or slope destabilizations involve a strong acceleration, which is a key aspect of the material ejection. The main effect of the sidewall friction on the flow is to steepen the slope of the interface and to decrease the thickness of the flowing layer at a given time in the collapse.

The simulation results are in good agreement with previous experimental work (Figure 5) carried out in 3D and quasi-2D configurations [2, 4].

Discussion: Scaling laws for the runout and final deposit height as a function of the initial aspect ratio have been found. We reconfirm the dependence of final deposit shape on the colunm's initial aspect ratio, and that inter-particle frictional effects play a significant role in the dynamics of spreading. Several different patterns were observed, dependent on the initial aspect ratio, particle-wall, inter-particle and rolling friction. Collisional motions dominate and the runout mechanics is sensitive to the coefficient of restitution. Our analysis of axisymmetric and planar granular flows reveal the subdivision into three regimes of flow behavior dependent on the initial aspect ratio. An intermediate situation is characterized by its upper moving free surface and the lower static interface which delineates the growing deposit.

Perspectives: Many impact crater rims on Mars display evidence of recent gravitational movements, in which the three flow modes identified in this work can be identified in different proportions. This work will help understanding the propagation of these movements and the physical properties of the involved rock debris

References: [1] Lucas, A., Mangeney, A., Mège, D. (2011) J. Geophys. Res. Planets, 116, E10001. [2] Lube, G., Huppert, H.E., Sparks, R.S.J., Hallworth, M.A. (2004) J. Fluid Mech. 508, 175–199 [3] Staron, L., Hinch,: E.J. (2005) J. Fluid Mech. 545, 1–27. [4] Lacaze, L., Phillips, J.C., Kersewell, R.R. (2008) Phys. Fluids 82, 063302. [5] Richard, P ,Valance, A, Metayer, J.-F., Sanchez, P., Crassous, J., Louge, M.Y. and Delannay R. (2008): Physical Review Letters, 101, 248002

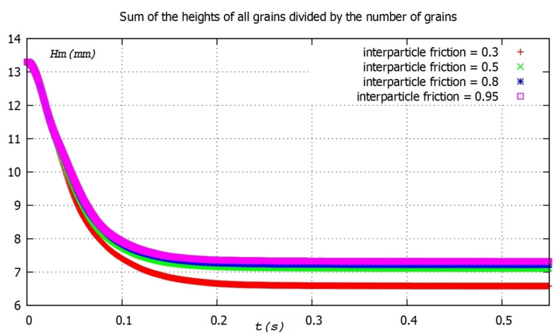

Figure 1: Average grain height as a function of time profiles (sidewalls case) for various values of inter-particle friction.

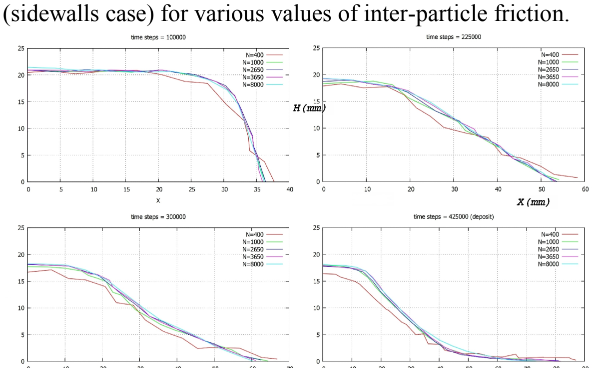

Figure 2: Snapshots of the collapse in numerical simulation: thickness of the granular mass at various times obtained witha different number of grains. We can see that 1000 is the probably lower safe limit for DEM modeling

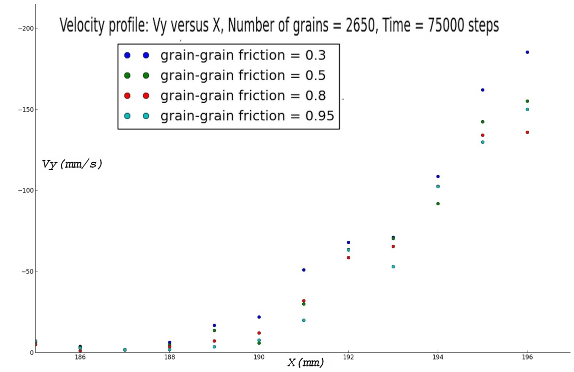

Figure 3: Vertical velocity profiles in the sidewalls case of granular columns. The simulations do not show significant changes in the velocity profiles when the inter-particle coefficient of friction increase.

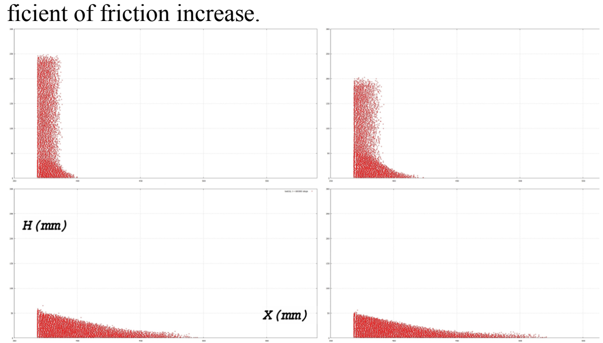

Figure 4: Snapshots of the collapse of a column of initial aspect ratio $a = 40$

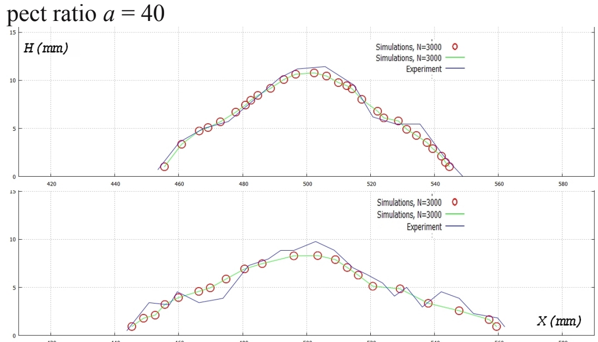

Figure 5: Numerical simulation of spreading of an initially cylindrical granular mass (grain-grain friction coefficient = 0.4, coefficient of rolling resistance = 0.133) at two different times for 3000 grains, compared to experimental results obtained in another work (Maxime Farin, IPGP).