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Trial to make ramparts: Granular flow model of fluidized ejecta on Mars

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Ejecta deposits of Martian craters show evidence for extensive surface flow not typically seen at other craters on the Moon and Mercury. The exact mechanism for why such surface flow occurs remains unclear, but it must be indicating some unique surface environmental condition. Typically fluidizing agents such as water or an atmosphere have been proposed to be responsible for the formation of these deposits.

Simple granular flows can explain a wide range of flow features at landslides including their long run-out distance and lineaments, without necessarily invoking any volatiles. They might also explain fluidized deposits, with their long run-out, circumferential lineaments, thin deposit layers, and ramparts, also without necessarily invoking any volatiles or an atmosphere. In order to investigate simple granular flow models for such ejecta deposition, we use the three dimensional distinct element method (DEM). This method calculates the motion of each individual ejecta grain, taking into account mechanical interactions between grains. Our initial study showed that the surface condition is important: smooth plains with a low coefficient of friction, or readily erodible plains can produce long run-out ejecta flow (Wada & Barnouin-Jha 2006, MAPS 41, 1551). Such smooth or readily erodible Martian surfaces could be the result of sedimentary processes associated with large amounts of water that existed on Mars.

While our initial model showed that ejecta surface flow was fairly easy to achieve, it possessed too many simplifications that did not permit the formation of ramparts at the distal end of the ejecta deposits. One of the obvious simplification was that all the grains in our model were true spheres without any rolling resistance. As a consequence, grains kept rolling on flat surfaces even if the surface had a finite friction. A necessary condition to make a rampart is that the distal ejecta must stop advancing. In the DEM, this implies giving the ejecta grains rolling resistance that reflects their natural angularity. This study, thus, investigates how giving ejecta grains rolling resistance in the DEM might generate ramparts, and impact the overall emplacement and flow of granular ejecta.

In our DEM model, the mechanical interaction forces and torques between spherical grains in contact (and the floor) are expressed by the Voigt-model, which consists of a spring and dash-pot pair, in both normal and tangential directions. The spring gives elastic forces based on the Hertzian elastic contact theory. The dash-pot expresses energy dissipation during contact to realize energy dissipation with a given coefficient of restitution. For the tangential direction, a friction slider is introduced to express Coulomb's friction law with a given coefficient of friction. In this study, we introduce a rolling resistance between grains (and also the floor), which models the difficulty of rolling due to the grain angularity, expressed by a critical rolling displacement.

As an initial condition of our DEM calculations, we consider a 5-degree wedge of an ejecta curtain composed of 2958 grains with a radius of 35 m, each traveling on ballistic paths prior to deposition. This initial condition was obtained by using the ejecta scaling relationship, assuming a transient crater with a radius of ~5 km.

By introducing rolling resistance in our granular flow model, we have succeeded in stopping ejecta motion effectively. However, we have not yet succeeded in making an obvious rampart. This may be due to other simplification of our model such as the small number of grains considered, and their fairly large size. Secondary cratering of the surface material and their subsequent flow might also play a role. Further studies will explore all these factors.

Keywords: rampart, crater, Mars, granular flow, simulation, DEM