DISCRETE ELEMENT SIMULATIONS OF TEST SCENARIOS FOR STUDYING LANDSLIDES ON ASTEROIDS. M. Sachse[1] (manuel.sachse@dlr.de), D. Kappel[1,2], D. Haack[1], K. Otto[1], [1]German Aerospace Center (DLR), Institute of Planetary Research, Berlin, Germany, [2]University of Potsdam, Institute of Physics and Astronomy, Potsdam, Germany

Introduction: Our overall aim is to investigate the physics of volatile-related surface features on asteroids and comets. One form of mass wasting are landslides – the fast movement of a large mass of regolith and rock down a slope – as observed on the large asteroids Vesta and Ceres by NASA's Dawn spacecraft [1,2]. Here we focus on numerically simulating landslides under the physical conditions on asteroid Vesta. This study complements and continues a previous work [3], where we have been investigating dynamical processes that are implied by surface features on comet 67P/Churyumov-Gerasimenko. Studying asteroids and comets is most important to a better understanding of the formation and evolution of our Solar system as these bodies formed from the early Solar nebula [4,5] and their material underwent only little alteration since then. Asteroids and comets are also the main source for interplanetary dust created by mutual collisions and the erosion of their surfaces by impacting meteoroids [6].

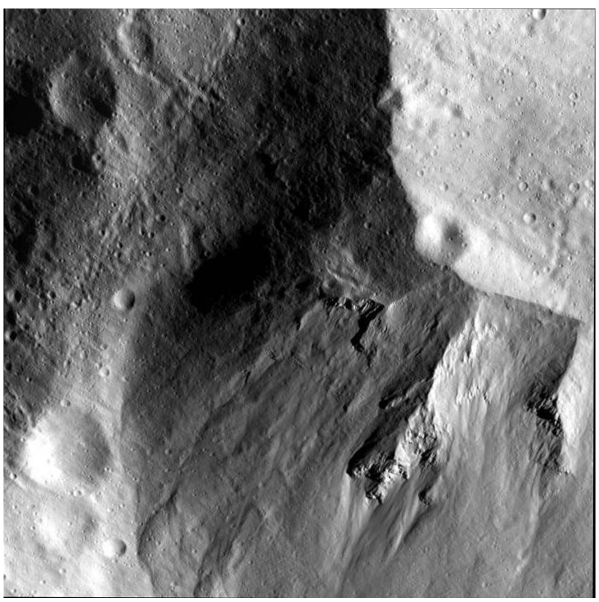

Fig. 1: Close-up view of the wall of the Rheasilvia impact basin on asteroid Vesta, image credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA, PIA15494.

Methods: We treat the material on the surface of the asteroid as granular material. The dynamics of the particles are modeled with the open source Discrete Element Method (DEM) simulation code LIGGGHTS [7]. Generally, we assume that the grains are small polydisperse spheres with sizes in the micro- to millimeter range, which – in case of the dry asteroid Vesta – consist primarily of silicates and interact according to the Hertz contact model. Additionally, we consider friction, rolling friction and cohesion as well as the ambient surface acceleration on the asteroid. The large number of simulated particles needed to make up macroscopic structures is reduced by applying the method of 'coarse graining' [8]. Here a group of physical particles is replaced by a computational parcel, whose contact force parameters are scaled in a way that the parcels have statistically the same dynamics as the original particles. The model and its parameters are calibrated by comparing its results to small-scale laboratory experiments [9,10].

Test scenarios and results: We present a series of three test scenarios designed to numerically study landslides on asteroids.

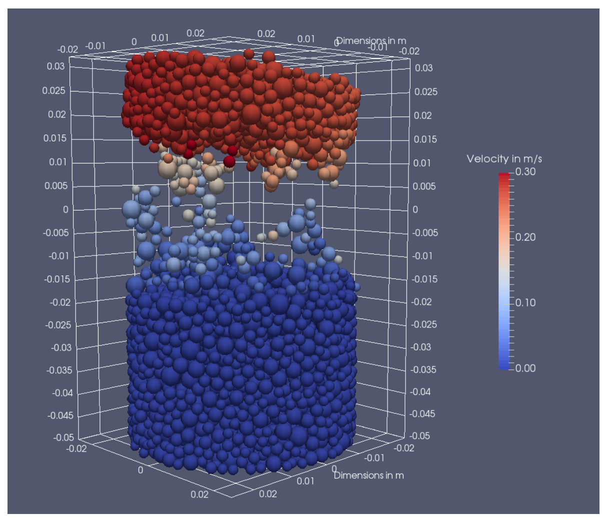

Fig. 2: DEM simulation of a 5 cm-sized cylinder mounted to a wall on its bottom side shortly after breaking apart due to pulling on its top side.

Coarse graining test. Landslides on Vesta have occurred from cliffs as high as several kilometers. Simulating such large structures requires coarse graining factors that are much larger than the typically applied and tested values (<10). To this end we have designed a test scenario to check the scaling of the coarse graining over several orders of magnitude. In this scenario we mount one side of a cylinder made up of small particles to a wall and measure the tensile strength of the material by pulling on the opposite side with an increasing force until the cylinder breaks apart. We investigate the scaling of this break-up force with the parcel size and for different boundary conditions, and its dependence on the size of the cylinder, the particle size, and the contact force parameters. The results help us to understand how to correctly apply coarse graining to the following scenarios.

Brazilian disc test. In order to calibrate the mechanical parameters of the material, we compare laboratory measurements of a well controlled Brazilian disc test, which can be used to determine a material's tensile strength, to corresponding results of DEM simulation. Here, a centimeter-sized cylindrical disc of compacted polydisperse micrometer-sized silica and optionally unsintered water ice particles is exposed to increasing pressure against its curved side [10]. The force at which the disc cracks can be used to estimate the material's tensile strength [9], which mainly depends on the inter-particle forces and the geometrical configuration of the original particles. Like in the previous scenario, the coarse graining scaling is studied, now with the additional advantage of the direct comparability between measurements and simulations. While the formation and morphology of the crack formation can be qualitatively compared, already constraining the orders of magnitudes of the friction and cohesion parameters, the evolution of the force with time and the tensile strength can be quantitatively compared, leading to further constraints that improve our understanding of how to apply the DEM model, coarse graining, boundary conditions, and valid parameter ranges in addition to literature values, which is needed for the following scenario.

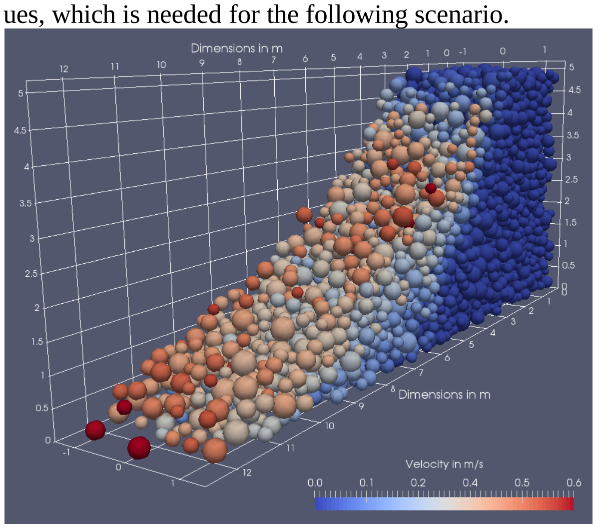

Fig. 3: DEM simulation of a landslide from a 5 m high cliff triggered by seismic activity.

Landslides triggered by seismic activity. Finally, we test the stability of a cliff and simulate its collapse caused by seismic activity due to a nearby impact of a meteoroid onto the asteroid [11]. For this purpose we construct a cliff of a given height and front face slope angle using the coarse graining factors and material properties as constrained in the previous two test scenarios. Then we expose the cliff to an oscillating acceleration of increasing magnitude. Here we investigate how the stability of the cliff against the local gravity and against the induced acceleration depends on various model parameters including the size of its constituents, the contact force parameters, and the height and angle of the cliff. Additionally, we investigate the dependence of the run-out length after the collapse of the cliff on the same parameters. Eventually, we want to compare our simulation results with the different observed morphologies of landslide runouts on Vesta [1,12].

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