ANALOGUE MODELING OF IMPACT CRATER FORMATION USING GLASSBEAD-FLOUR MIXTURES. J. Aschauer[1], T. Kenkmann[1] and M. Rudolf[2], [1]Institute of Earth and Environmental Sciences, Albert-strasse 23-B, 79104 Freiburg, Germany; Johannes.aschauer@uranus.uni-freiburg.de, [2]GFZ German Research Centre for Geosciences, Section 3.1, Telegrafenberg, Potsdam D-14473, Germany; Michael.rudolf@gfz-potsdam.de

Introduction: Analogue modeling is used in various fields of geology to understand the kinematics of geological processes. If the physical properties of analogue materials (e.g. sand, clay, glass beads, floor, silicone, paraffin wax) are known these models may be precisely scaled to allow processes that take significant time on a geological timescale to be studied in the laboratory. Here we use different mixtures of glass beads and flour to understand how the composition of the target affects the formation and morphology of craters.

Methods: The experimental setup consists of a vertical spring driven air gun shooting at a plexiglass box (40 x 40 x 20 cm) filled with the different types of target materials. For quarter-space experiments which are used to determine the dimensions of the craters and to observe the crater flow field perpendicular to the target surface, the box is reduced to its half-size and the projectile enters the box right behind the front glass. The cylindrically-shaped (6,35 x 10 mm) PVC projectiles have a mass of 0.416 g and a density of 1.355 g/cm^3. The projectile hits the target with a speed of 180.4 m/s and a kinetic energy of 6.7 J.

As target materials we use glass beads of 420-840 μm grain size and mix them in different proportions with flour up to 25 wt%. The target is dumped loosely and not packed. To test reproducibility, each experiment was repeated 5 times. In total 55 experiments were conducted. In order to illustrate the finite strain in the target we conducted several experiments with thin horizontal layers of colored glass beads embedded in the target.

The bulk densities of the target mixtures vary from 1.31 to 1.54 g/cm^3. Cohesion and the angle of repose are measured with a ring shear apparatus. While the angle of repose ranges between 22-28°, cohesion reaches a maximum at 10% floor content, and systematically decreases with both increasing and decreasing floor content. Cohesions vary from 57 to 233 Pa.

Two ImagerCMOS Cameras record the impact at 50 fps. They are imaging the impact experiments from either above or, in case of quarter space experiments, from the side perpendicular to the front glass. Depth and diameter are determined for the transient and final craters and the displacements are computed with a particle image velocimetry (PIV) software for each frame.

Results: In Figure 1 the scaled depths π_h of all experiments are plotted against the scaled radius π_R. Both terms are normalized on target density and projectile mass [1]. Two different types of crater morphologies are observed in the experimental series.

In target materials with little flour contents (<12.5 wt%) funnel shaped craters are forming. After the formation of the parabolic transient crater, the flanks are collapsing and subsequently the final crater has slope angles corresponding to the angle of repose of the target materials. There is no upward motion recognizable in the center of the crater. Depth-diameter ratios of the final craters are ~0.2.

With flour contents of more than 15 wt% the morphology of the final craters changes. The craters become less deep whereas the diameters remain more or less constant. The depth-diameter ratios decrease to values of 0.15. The built-up of a central uplift due to radial slumps which surge from all sides is recognizable. To some extent we also observe the uplift of originally deep-seated grains, probably as a result of an elastic rebound, 20-40 ms after the formation of the transient crater (Fig. 3). This upward motion is not meant to be induced by buoyancy forces.

With further increasing flour content we observe a trend to slightly decreasing diameters while the depths remain roughly constant. The change in the behavior of the target material is interpreted to correspond with the loss of grain-to-grain contact of the glass beads. The glassbead-flour mixtures become matrix supported from a flour content of ~15 wt% and the material properties are governed by flour instead of the glass beads.

In targets with flour contents exceeding 7.5 wt% ring structures outside the final crater rim are observable (Fig. 2). Those rings are usually embossed about 1 mm to the initial target surface; sometimes the area inside the ring is only sagged. The rims contain of ejecta as well as target material. The processes which leads to the formation of those rings is not completely understood yet and needs further research.

Discussion: In the experimental series we can see a transition from simple craters to more complex crater morphologies. As impact energy, projectile mass, and gravity are kept constant we could demonstrate that the simple-to-complex transition also depends on strength of the target.

References: [1] Holsapple, K. A. (1993) *Annual Review of Earth & Planet. Sci., 21*, 333-373.

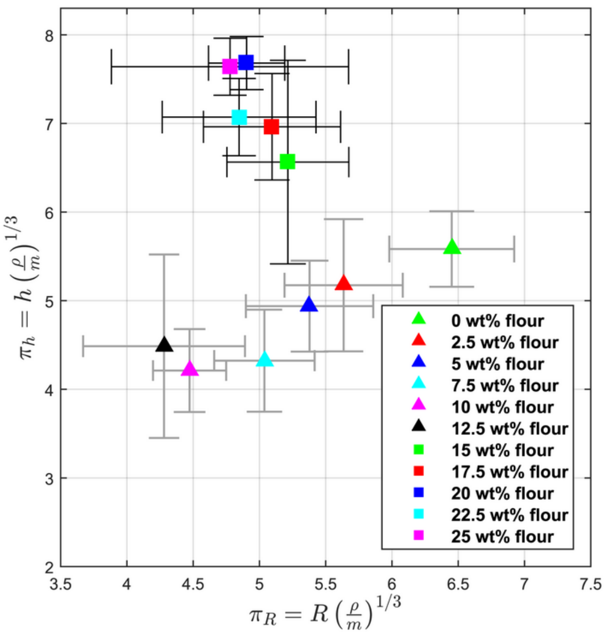

Fig. 1 Scaled depth π_h and scaled radius π_R of the final craters with different flour contents. The craters with flour contents less than 15 wt% form a bowl-shaped cavity, those with ≥ 15 wt% flour result in complex crater morphologies.

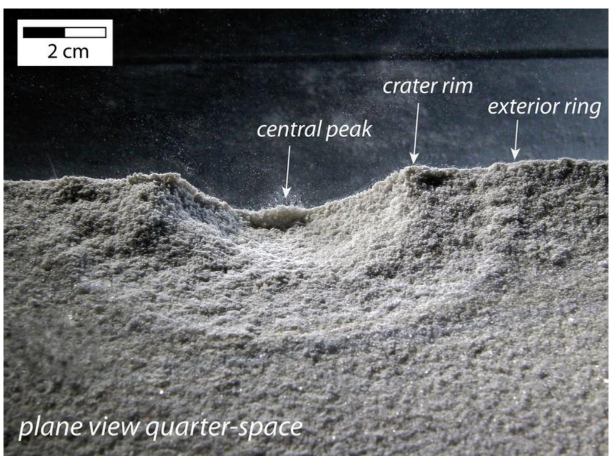

Fig. 2 Plane view image of a quarter-space experiment. Rim structure in a quarter space experiment with 22.5 wt% flour content of the target material. The outer rim has a radius 3 cm larger than the final crater rim. The area in between the crater rim and the exterior ring is slightly sagged. A central peak in the crater center is also visible.

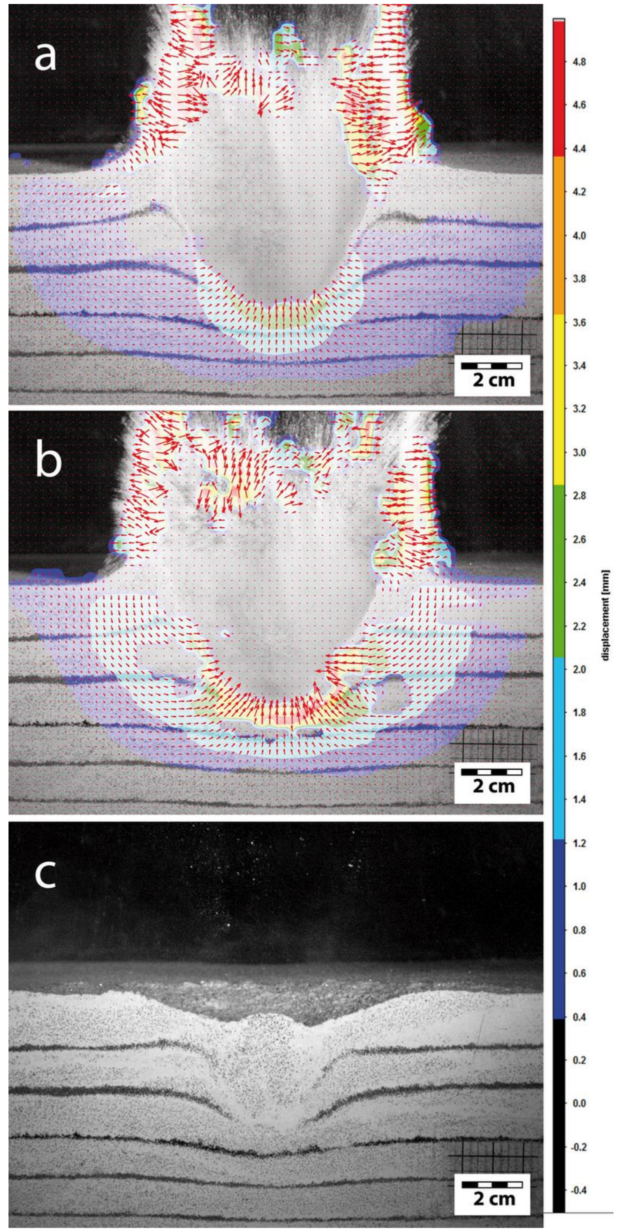

Fig. 3 Snapshots of a quarter-space experiment at (a) 40 ms, (b) 60 ms and (c) 260 ms after the impact of the PVC-projectile in a target with 25 wt% flour content and embedded colored glassbead layers. (a) and (b) Upward motion of the central crater floor, illustrated with PIV-software. (b) Continued upward motion and the beginning of inward collaps of the transient cavity. (c) The colored layers are downward deflected below a depth of 7 cm. Above material is a mixture of both near-surface material that moved from the steep slopes into the cavity and material that got uplifted.