IMPACT CRATER COLLAPSE: FIRST EXPERIMENTAL RESULTS FROM ANALOGUE MODELING USING PARTICLE IMAGE STRAINOMETRY (PIS). Thomas Kenkmann[1] and Patrick Burgert[1]; Institute of Geosciences, Geology, University of Freiburg, Albertstrasse 23-B, 79104 Freiburg, Germany; Thomas.kenkmann@geologie.uni-freiburg.de

Introduction: The modification stage of impact cratering comprises all types of mass movements that modify the shape of the transient cavity that form at the end of the excavation stage. The driving force for crater modification is gravity. To understand the kinematics of crater wall collapse in simple craters we conducted experiments with analogue materials and traced displacements using particle image strainometry (PIS).

Methods: The experimental setup consists of a box (40 x 30 x 13.5 cm) with a mixture of 80% sand and 20% starch (Fig.1; Table 1). Cohesion and friction coefficient of this material are determined in a ring shear apparatus (Table 1). A paraboloid cavity with radius Ri and depth Di (Table 1) is created artificially during the filling procedure by using a replica that is removed upon completion of the filling. Instability of the cavity is induced by moving a piston beneath the cavity at constant velocity of 0.19 cm/min (Table 1). Two cameras (*La Vision*), installed at high angle to the target surface, film the flank collapse of the cavity at a frequency of 3.5 Hz. Headlights illuminate the setup. We use the *Strain Master 3D* software package by *La Vision* to record changes in the position of material points. Particle imaging strainometry (PIS) provides an accurate measure of the instantaneous displacement field of laboratory flow and is adapted for strain monitoring in analogue sandbox experiments. PIS is an optical, non intrusive method for non-linear flow and deformation visualisation by optical image correlation techniques. In granular-flow experiments, optical image correlation enables spatial resolution of the displacement data in the range of the particle size of the sand material [1]. The deformation is recorded by sequential digital images and the corresponding displacement field is computed by cross-correlation from the translation and distortion of the sand particle pattern in successive images with a given time interval.

Results: First results of our experiments are illustrated in Figs. 2 and 3. Flank collapse of the cavity starts in the western sector at the uppermost part of the cavity slope (Fig. 2a). Slumping creates a steep fault scarp that is slightly curved in plan view. The first scarp formation and slump initiates a cascade of subsequent neighboring mass movements into the cavity. With increasing time slumps occur in all sectors of the cavity wall (Fig. 2b-d). While the majority of the initial slumps reaches the cavity center and flows superimpose onto each other, the runout path length of mass movements formed at later stages is reduced. These mass movements halt before approaching the center as the slope angle decreases downslope due to stacking of several slumpings. The distance of the fault scarps to the cavity center decreases with time (Fig. 3). This is caused by the formation of concentrical faults that start to develop after ~160 s at ~1.6 Ri (Fig. 2b; Fig. 3). Concentric ring faults first develop in segments where slumps did not occur, but they grow quickly, interconnect, and branch into subsystems. Extension perpendicular to the concentric fissures allows for slow creeping of the entire mass between the

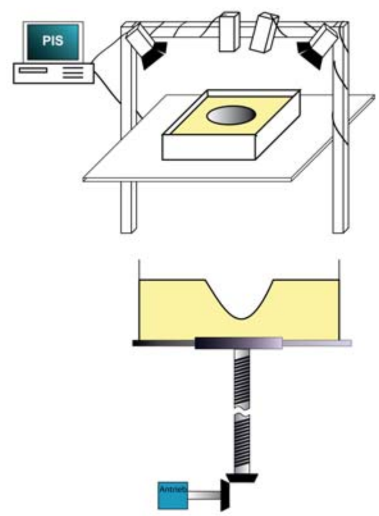

Fig. 1 Experimental set-up. A piston beneath the box moves at constant velocity and causes instabilities of the cavity in the granular medium. Two cameras film the movements of flank wall collapse of a paraboloid cavit.
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Table 1. Details of the experimental set up	
Initial cavity depth Di:	8 cm
Initial cavity radius Ri:	5 cm
Vertical piston displacement:	0.65 cm
Piston diameter:	10 cm
Image rate:	3.5 Hz
Resolution:	9 px/mm
Error:	0.025 Px
Number of frames:	1500
Sand/starch mixture 8:2:	
Static friction:	0.56
Static cohesion:	50 Pa

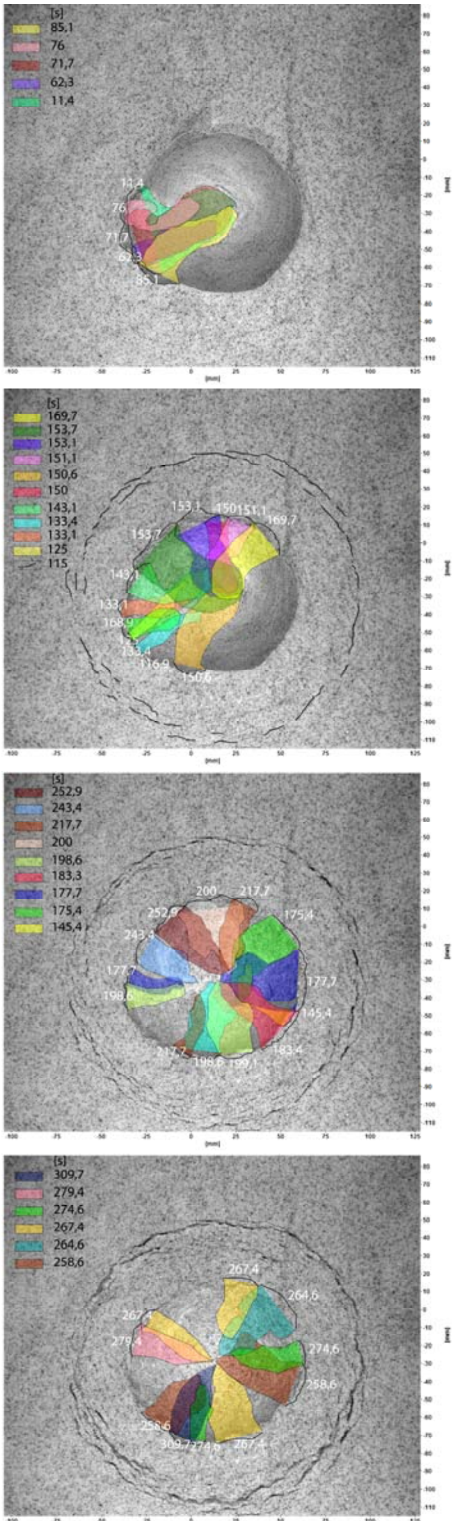

Fig. 2 a-d. Four snapshots of cavity collapse at 86, 170, 253, and 310 s, shown in plan view. Individual slumpings are color-coded. Numbers give the time of activation.

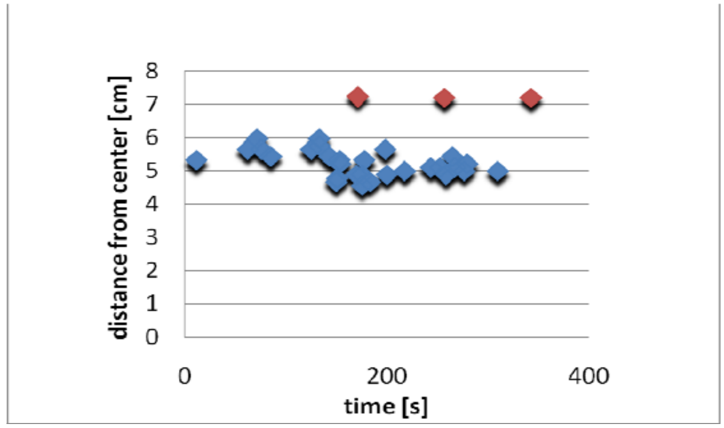

Fig. 3. Activation time for slump events (blue) and fissure formation (red) versus their distance from the crater center.

concentric ring fissures and the cavity. Thus the edge of the cavity to the target shifts slightly inward. Ring fissures finally coalesce and broaden.

Discussion: A new experimental set-up and the application of 3D particle image strainometry allows us to quantitatively measure time, displacement, particle vectors, and strain of the collapse of a paraboloid cavity. The cavity is aimed at mimicking a transient crater that forms dynamically at the end of the excavation stage of impact cratering and that is affected by gravity collapse. The scaling factor, *S*, for analogue models is given by: $S = (C \rho_m a)/(C_m \rho g)$, with C and C_m are cohesion in nature and model, ρ and ρ_m are material density in nature and model, and g and a are gravity in nature and model, respectively. If a reduced strength (damaged rock, e.g., 5 MPa) and equal gravity in model and nature is considered the scaling factor *S* is $\sim 10^3$, thus the model is analogue to the failure of a cavity of 100 m diameter. Despite the deficits of the experiment (static cavity, instability created by piston motion, Ri/Di ratio) we believe that the approach is useful to understand the kinematics of crater collapse. Striking similarities, e.g. exist to the 108 m Snowball crater (500 tons TNT, [2]). This crater likewise shows circumferential fissures at a distance similar to that in the analogue model. The lensoid breccia infill of simple craters such as Brent and Barringer can be correlated with the analogue model.

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References: [1] Adam, J. et al. (2005) J. Struct. Geol. 27: 283-301. [2] Jones G.H.S. (1977) In Roddy, D. J. (1977) Impact and Explosion cratering, 163-183.