EJECTA DYNAMICS DURING HYPERVELOCITY IMPACTS INTO DRY AND WET SANDSTONE.

T. Hoerth[1], F. Schäfer[1], K. Thoma[1], M. Poelchau[2], T. Kenkmann[2] and A. Deutsch[3], [1]Fraunhofer-Institute for High-Speed Dynamics, Freiburg, Germany (tobias.hoerth@emi.fraunhofer.de), [2]Institute of Geosciences, University of Freiburg, Germany, [3]Institute of Planetology, University of Münster, Germany.

Introduction: We report on several hypervelocity impact experiments into porous Seeberger sandstone. The impact excavation process was recorded using a high-speed camera. The dynamics of the ejecta particles were analyzed quantitatively by measuring the velocity of different ejecta particles at a defined position as a function of time. Furthermore the temporal development of the ejecta cone angle and the crater diameter were investigated.

Experiment: The impact experiment presented here was performed in the framework of the MEMIN program [1, 2] (Multidisciplinary Experimental and Modeling Impact Research Network). This test campaign was conducted at a two-stage light gas accelerator at the Ernst-Mach-Institute (EMI) in Freiburg, Germany: The Space Light Gas Gun (SLGG). In the experiment a projectile with a diameter of 2.5 mm weighing 0.067 g made of alloyed steel D290-1 was shot into a sandstone cube with an edge length of 20 cm at a velocity of 4.8 km/s. The pressure in the target chamber was 100 mbar.

Measuring Technique:

High-speed recording. The high-speed recording was conducted with a frame rate of 10^5 fps. The exposure time was 1 µs. The image size of the frames was 192 x 192 pixels. Incident and transmitted flash light was used for illuminating the ejection process.

Velocity measurements. The velocities of individual ejecta particles at a fixed point in the ejecta flow field close to the impact point were measured using a software tool operating with a cross-correlation algorithm [3]. In this software package the individual frames which have to be converted into grey scale images are compared to each other by means of the grey value pattern of small submatrices around a certain ejecta particle. If a certain grey value pattern is found again at a different place in the ejecta flow field the center of this pattern is determined to be the ejecta particle. Displacement-time-curves for about 10 consecutive frames are generated and best fit straight lines are used for determining the velocities.

Preliminary Results:

High-speed recording. In figure 1 four selected high-speed video frames at different time steps are shown. In the first frame, which shows the ejecta state at about 38 µs after the impact, a cone with high-speed ejecta has formed. The second frame, about 258 µs after the impact, shows the fully developed ejecta cone with a characteristic kink in its slope, about 4 cm above the target surface. The lower part of the ejecta cone is very steeply inclined with respect to the target surface and eventually developes into a "tube". In the third frame, about 928 µs after the impact, the ejecta tube has increased in length and has developed a "neck". A ring vortex has caused turbulences in the upper part of the ejecta cone. This atmospheric effect exists due to the fact that the experiments were conducted in low vacuum (100 mbar) instead of high vacuum. The vortex is most likely due to recovery winds caused by reduced pressures behind the "upwards" moving ejecta cone. In our experiment the vortex is outside the ejecta cone as opposed to [4] and [5] where the vortex is inside the cone because of an "outwards" moving ejecta curtain. In the fourth frame, about 2768 µs after the impact a long "ejecta tube" can be seen. In the third and fourth frame spallation fragments are visible as well.

Velocity measurements. In figure 2 the ejecta velocities, measured at a defined position (red line in figure 1) about 1.6 cm in front of the target surface, are plotted versus time after the impact. The velocity values are scaled to the impact velocity. The later the ejecta particles leave the target the slower they are. This decrease roughly obeys t^{-1}. The first point which has by far the highest velocity resulted from a measurement of the ejecta front velocity.

Further measurements. Ejecta cone angles and crater diameter developments were measured as a function of time. The angles were measured between the ejecta nearby the target and the target surface. As can be seen in figure 3 the angle between the ejecta cone and the target surface changes with time. A first plateau is reached at about 50 µs when the angle between the ejecta cone and the target surface is about 57°. A second plateau can be seen at about 200 µs when the ejecta cone is separated from the developing "tube", which is shown in the second frame in figure 1. Before the angle reaches its final value of about 90° ("tube") it increases to more than 100°. The reason for that is a "neck" which can be seen in the third picture in figure 1. In figure 4 the crater diameter values are plotted versus time. Crater diameter values could only be measured up to about 100 µs. These values converge in time to constant values of about 42 mm. The kink is associated with the end of the transient crater formation process at about 50 µs and correlates with development of the first plateau measured in the ejecta cone angles.

Outlook: Several hypervelocity impact experiments into water saturated sandstone have recently been conducted at the Ernst-Mach-Institute [2]. The ejecta behavior is currently being evaluated and will be compared to the ejecta behavior of the dry sandstone. Impact experiments into wet sandstones were also part of the MEMIN pilot study [1, 6]. Furthermore spallation velocities will be measured and compared to published values.

References:

[1] Kenkmann T. et al. (2011) *Meteoritics & Planet. Sci.*, in press [2] Poelchau M. H. (2011) *LPSC 2011 this volume.* [3] Dost M. et al. (2003) *Proceedings of SPIE*. [4] Schultz P. (1992) *Jour. Geoph. Research*, Vol. 97, 11,623-11,662. [5] Barnouin-Jha O. S. and Schultz P. H. (1996) *Jour. Geoph. Research*, Vol. 101, 21,099-21,115. [6] Schäfer F. et al. (2006) *Proceedings of 40th ESLAB Symposium*

Acknowledgements: The MEMIN-project (research group FOR 887 and TH 805/4-1) is funded by the German Research Foundation (DFG). We also wish to thank the EMI technicians for their support.

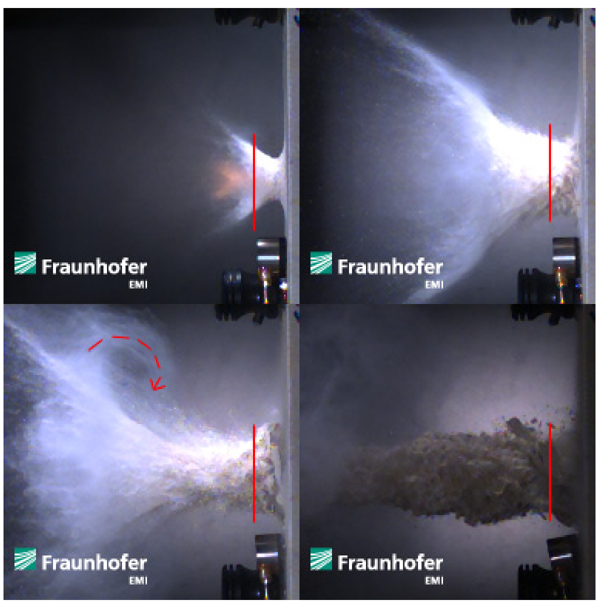

Figure 1: Ejecta at several different time steps. The time steps are 38, 258, 928 and 2768 µs after the impact. Ejecta cone and fireball are visible in the first image. In the later images, an ejecta tube develops, and a ring vortex is formed (dashed arrow). Red line denotes the position at which ejecta speeds were evaluated.

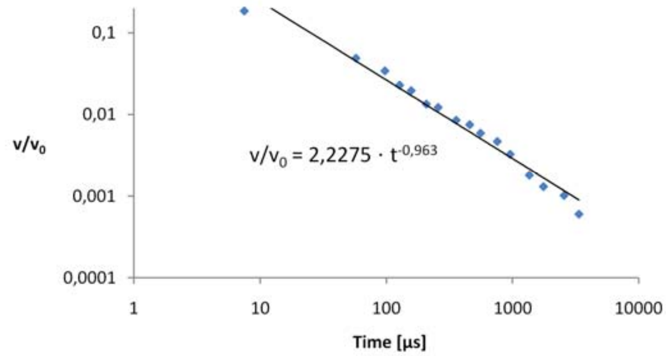

Figure 2: Logarithmic plot of the scaled velocities (logarithmic) versus time (logarithmic).

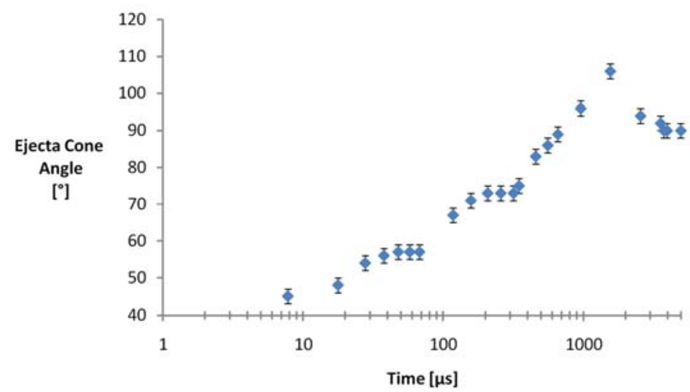

Figure 3: Ejecta cone angle versus time (logarithmic). Plateaus at 50 and 200 µs correlate to ejecta cone formation after completion of the transient crater, and the formation of an ejecta tube, respectively.

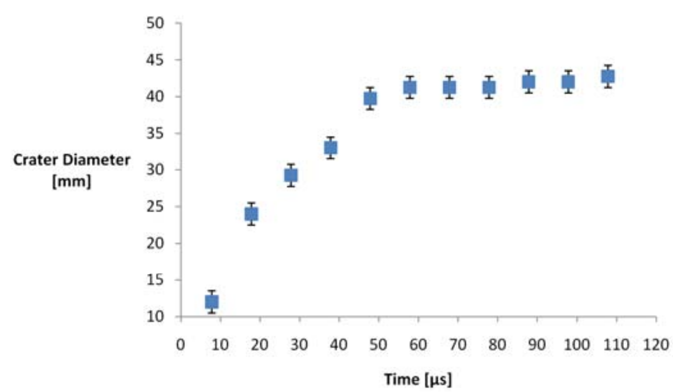

Figure 4: Crater diameter versus time. Values level out after 50 µs, indicating the end of transient crater cavity formation.