FRAGMENTATION AND EJECTION BEHAVIOR IN IMPACT EXPERIMENTS – THE MEMIN PROJECT. F. D. Sommer[1], T. Hoerth[2], M. H. Poelchau[1], T. Kenkmann[1], and A. Deutsch[3]. [1]Institute for Earth and Environmental Sciences, Albert-Ludwigs-Universität Freiburg, D-79104 Freiburg, Germany (Frank.Sommer@geologie.uni-freiburg.de), [2]Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut D-79104 Freiburg, Germany, [3] Institute of Planetology, Westfälische Wilhelms-Universität Münster, D-48149 Muenster, Germany.

Introduction: The MEMIN (Multidisciplinary Experimental and Modeling Impact Research Network) project is focused on the formation processes of experimental impact craters into geologic materials. The aim of this study is to comprehensively understand the characteristics and the behavior of the material ejected during experimental impact cratering by applying postmortem analyses in addition to real-time measurements. A series of four mesoscale cratering experiments on dry and 50% water-saturated sandstone was conducted to examine the evolution of the different stages of the ejection process in detail.

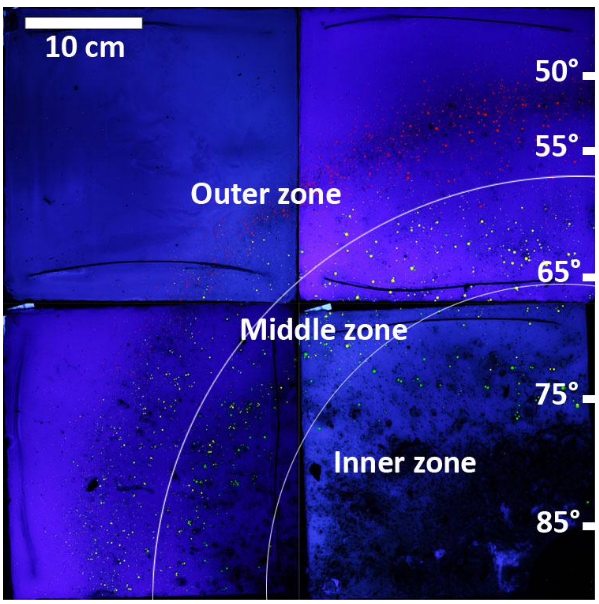

Fig. 1: Vaseline catcher of a dry sandstone experiment under ultraviolet light.

Experimental setup: Three steel projectiles and one iron meteorite (Campo del Cielo IAB) projectile, all with 12 mm diameter, were accelerated to ~4.6 km/s at the two-stage light-gas gun facilities of the Fraunhofer Ernst-Mach-Institut, Germany. The sandstone targets (Seeberger sandstone) consist of about 90% quartz and 10% clay minerals; the average grain size is 86.1 µm (d_{50}), and the porosity amounts to 23.1±0.5 % [1,2]. Ejecta fragments were collected in a custom-made catcher of Vaseline installed opposite to the target surface at a distance of ~50 cm [1]. Three concentric rings of different colors were painted on the target surface around the point of impact to allow tracing of the origin of discrete particles in the catcher. A high-speed video camera was installed to record the impact process. The recovered material was investigated with high spatial resolution, and the ejection angles were reconstructed with tracer paint mapping from catcher imprints. For an overview of MEMIN experiments see [3,4].

Catcher mapping: Mapping of standard and ultraviolet tracer paint particles allows tracks of the particles around the impact point to be reconstructed. It can be shown that on dry targets the tracer paint colors show an inverted sequence in the catcher, i.e. particles that originated close to the point of impact preferentially occur in the outer zone, while those ejected from more distal areas landed in the middle and inner zones of the catcher (Fig. 1). On water-saturated targets the different colors do not show this inversion, but instead build overlapping bands of colored particles. For dry targets particle sizes increase with increasing distance from the point of impact.

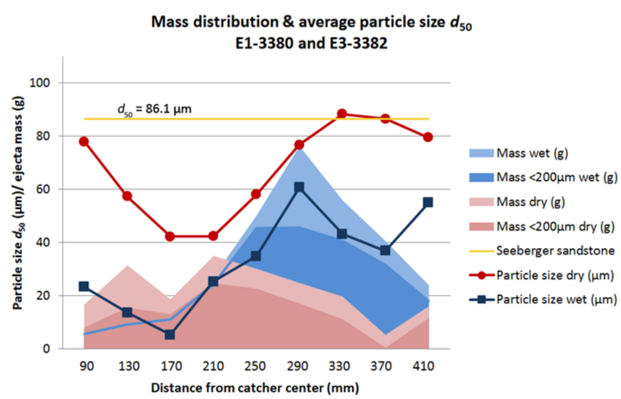

Fig. 2: Comparison of mass distribution and particle size distribution (d_{50}) between dry and water-saturated targets. The mass <200 µm represents the cone material whereas larger particles are part of the tube phase.

Catcher analysis: For this analysis the catcher surface was divided into nine concentric rings of 40 mm width around the central opening. From each area a representative sample (40 mm x 50 mm) was taken for ejecta mass determination, particle size distribution, projectile and melt content and particle characterization. For the mass determination the results were converted for the complete circle. Catchers of experiments on dry sandstone targets display three mass peaks with very fine material (crushed quartz and projectile fragments) and highly shocked material around the inner zone, coarse material and spall in a middle zone and fine particles (single quartz grains) in the outer zone (Fig. 2). Water-saturated targets display one mass peak with a zoned composition; very fine and shocked material near the center and fine material in the outer zone is overlain by coarse particles and spall (Fig. 2).

Discussion: In former examinations of experiments on dry sandstone targets, a characteristic set of four stages of the ejection process were characterized: plume and fireball, cone, kink and tube [1,3]. The analysis of the ejecta material from dry sandstone experiments reveals a continuous degradation starting with molten quartz, followed by highly shocked quartz, crushed quartz and fragmented sandstone (single quartz grains to large spall fragments). The distribution of the material on the catcher implies a relation of damage type and ejection stage.

i. Plume stage: About 2% of the ejecta consist of crushed quartz grains ejected with high speed in the first stage after the impact. This material, mixed with a small amount of projectile fragments, is concentrated in an area between 65° and 80° around the catcher center. Molten silica and projectile fragments, and highly shocked quartz represent less than 0.5% of the ejecta and can be found between 70° to 80° [2].

ii. Cone stage: The cone material consists mainly of single quartz grains. It represents about 12% of the ejecta mass at the beginning ejected at an angle of 50°. With increasing distance to the impact point the velocity decreases rapidly while the ejecta angle increases.

iii. Kink stage: Atmospheric turbulence and ring vortices start to influence the particle tracks, winnowing out finer material, therby changing the shape of the originally straight cone. On the catcher the stage is characterized by depletion of very fine particles between 55° and 60° (Fig. 3).

iv. Tube stage: About 85% of the ejecta consist of fragmented sandstone larger than single quartz grains. This material is ejected in the tube stage with velocities below ~150 $m\ s^{-1}$. The ejection angle is nearly perpendicular.

In comparison the ejecta pattern of dry target material can be described as a broad thin blanket with a distinct rim of fine material, a concentration of coarse material around the center, and a mix of melt, shocked and crushed quartz as well as sandstone fragments in the center. The water-saturation of the pore space changes the fragmentation and ejection behavior considerably by inducing an explosive component into the system. Water-saturated targets display a pattern with a material mix concentrated in a narrow, thick wall around the center whereas the center displays only a thin layer of molten, shocked and crushed quartz together with remains of the projectile.

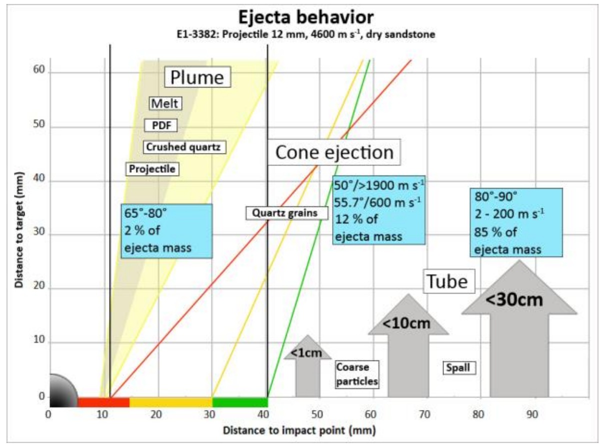

Fig. 3: Overview of the ejecta behavior with increasing distance from the impact point.

Outlook: Currently the initial velocities of the different ejecta stages are calculated by analyzing the high-speed videos. By measuring the position of single particles and fragments from frame to frame the initial velocity can be calculated. Further on an experiment on quartzite will be included into the study as an example for non-porous target material.

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References: [1] Sommer F. et al. (2013) MAPS 48 in print. [2] Ebert M. et al. (2012) LPS 47, 1400. [3] Kenkmann T. et al. (2011) MAPS 46, 890-902. [4] Poelchau et al. (2013) MAPS 48 in print.