THE SURFACE STRUCTURE OF SHATTER CONES IN EXPRIMENTAL IMPACT CRATERS. J. Wilk[1] and T. Kenkmann[1], [1]Institute of Earth and Environmental Sciences – Geology (Albert-Ludwigs-Universität (ALU) Freiburg, Alberstraße 23B, 79104 Freiburg, Germany, jakob.wilk@geologie.uni-freiburg.de).

Introduction: Shatter cones are the only known macroscopic feature considered as evidence for shock metamorphism. Conveniently identifiable in the field, they play an important role for the discovery and verification of impact structures. Still the occurrence of shatter cones is heterogeneous throughout the crater record and evidently bound to material parameters and physical boundary conditions.

Most authors align the formation of shatter cones with the passage of the shock front or the release from shock loading [1-3]. However, none of the existing models provide a satisfying concept that explains all relevant aspects of shatter cones, namely, their (i) conical to hyperbolic shape, (ii) the presence of diverging striations and grooves, and (iii) their hierarchical bifurcation that leads to the horsetailing effect.

In our study we aim at a better qualitative and quantitative understanding of the geometrical parameters of shatter cones. Here we present the findings of shatter cone like features found in MEMIN cratering experiments. In this MEMIN project we are attempting to constrain the physical boundary conditions necessary for the formation of shatter cones.

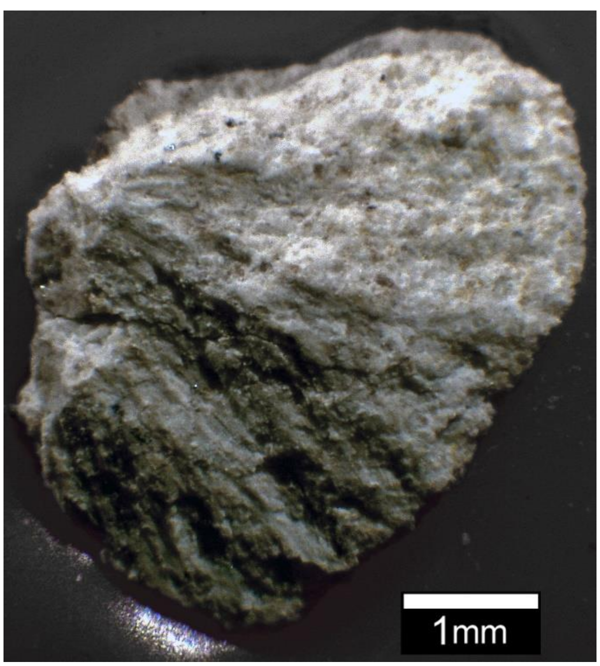

Figure 1: Fragment recovered from the ejecta of a 20 cm sized sandstone cube impacted by an aluminum projectile.

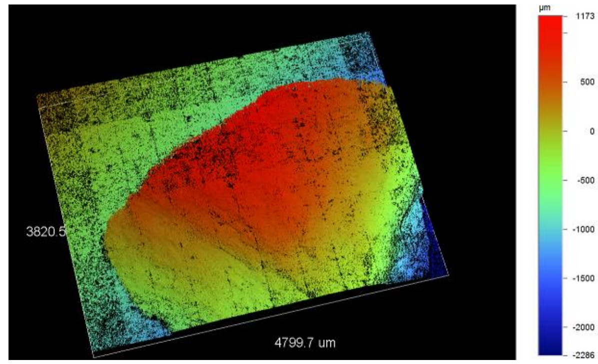

Figure 2: WLI scan with the Bruker AXS Contour GT-K0 of the fragment shown in figure 1, note the curved fracture surface and fine diverging striae.

Methods: By hand picking and soft stimulated fracturation of the crater's subsurface we thouroughly examine the ejecta of our experiments and the crater itself. A morphometric analysis of each specimen is carried out with a Bruker AXS Contour GT-K0 white light interferometer (WLI). We use this optical non-contact, non-intrusive technique with nm-µm spatial resolution for characterizing surface topographie, in particular to measure (i) apical angles of master cones and their sub-cone apices, (ii) the groove-ridge wavelength and amplitude of striated cone surfaces, (iii) the bifurcation distance of fractures and (iv) the curvature of cones.

Results: So far millimeter to half centimeter sized cones had been recovered from the ejecta of sandstone and limestone blocks impacted by aluminum and steel projectiles. The 20 cm sized cubes of sandstone were impacted by aluminum projectiles with the diameters of 5 and 2.5 mm, with impact velocities ranging from 6.97 to 7.75 km/s [4]. In addition an impact experiment with a 20 cm sized limestone cube that was impacted by a 2.5 mm steel projectile at 5.32 km/s was investigated.

We found fracture surfaces of distinctly conical geometry and slightly curved surfaces, marked by fine striations (Figs.1, 2). SEM analysis of the recovered fragments showed vesicular melt films alternating with smooth polished surfaces [5]. The vesicular melt films predominantly form at strain releasing steps and suggest that shatter cones are probably shear fractures or mixed mode fractures. The fragments are found in the material with intense grain crushing and porosity reduction.

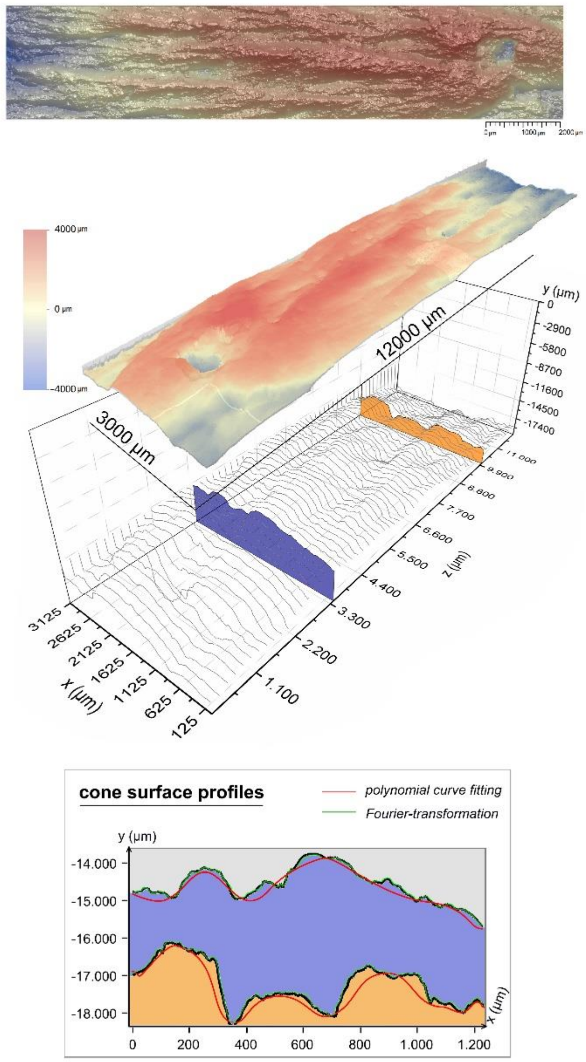

Figure 3: WLI surface meassurement of a shatter cone in micritic limestone from Steinheim crater and surface approximation of two shatter cone profiles taken perpendicular to the cones axis with the software Origin 9.1.

Prelimenary results of the extracted shatter cone surfaces show that the subparallel arrangement of longitudinal ridges and grooves of shatter cones can be described by multi-harmonic or multi-frequency wave analysis (Fig.3). The sinusoidal topology perpendicular to the shatter cones symmetry axis can conveniently be descibed by standardized parameters, enabling a more sophisticated and quantitative description of the alternating groove striae wave patterns and may offer a critical test for further model development.

In comparison by scale-invariant parameters the recovered fragments show surface characteristics comparable to shatter cones e.g. from the Steinheim impact crater. With the WLI method we can easily extract values e.g. for the spikiness of a scale limited surface (curtosis). In the measured fracture surfaces we also observe a qualitative self-affinity comparing the surface roughness from fractals of the primary surface.

Continuing Work: We will extending our search for shatter cones in the MEMIN experiments into the crater subsurface to better constrain the physical boundary conditions for their formation. Whereas a thorough morphometrical analysis of shatter cone fragments found in the ejecta is carried out to quantitatively describe the hierarchical structure of shatter cone patterns, the surface roughness and their structure on different scales.

References: [1] Gash P.J.S. (1971) *Nature Phys. Sci.*, 230:32-35. [2] Baratoux D. and Melosh H.J. (2003) *Earth & Planet. Sci. Letters*, 216:43-54. [3] Sagy A. et al. (2004) *JGR*, 111: 1-20. [4] Poelchau M.H. et al. (2013) *Meteoritics & Planet. Sci.*, 48:8-22. [5] Kenkmann T. et al. (2012) *MetSoc 75*, Abstract #5092.