ANATOMY OF YOUNG METEORITE CRATERS IN A SOFT TARGET (CHIEMGAU IMPACT STREWN FIELD, SE GERMANY) FROM GROUND PENETRATING RADAR (GPR) MEASUREMENTS.

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Introduction: GPR is a widely used geophysical method for the exploration of near-surface structures and has also been successfully used in the investigation of some meteorite impact structures. In the larger craters investigated (Bosumtwi, Barringer, Mistastin, [1-3]), the depths of the crater floors can hardly be reached even at very low antenna frequencies (e.g. 25 MHz at Bosumtwi), so that the measurements are usually limited to the marginal areas and their geological structures (ejecta, layer deformations). The situation is different with smaller craters (e.g. Haviland crater [4]) or with small structures for which an impact is discussed [5, 6]. We report here on a program of GPR measurements over some craters of different size in the soft Quaternary target of the Chiemgau impact strewn field in southeast Bavaria (Germany).

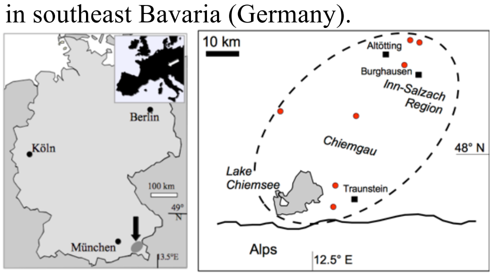

Fig. 1. Location map for the GPR measurements over craters (red circles) within the roughly elliptically encircled Chiemgau meteorite impact strewn field.

The Chiemgau impact event: In a roughly elliptically shaped strewn field (Fig. 1) more than 100 mostly rimmed craters with diameters between a few meters and a few 100 meters occur. Apart from the craters and their distinct morphology as revealed from precise Digital Terrain Model analyses (DGM 1; 1 m x 1 m grid, vertical resolution 0.2 m; see e.g., Fig. 2) [7], the impact strewn field shows all and abundant evidence of impact signature as is required within the impact research community (impact melt rocks, impact glasses, strong shock metamorphism like PDFs and diaplectic glass - quartz and feldspar, shatter cones, geophysical anomalies, and meteoritic matter [8, 9, and references therein]). The event happened in the Bronze Age/Iron Age as revealed from impact catastrophe layers and their archeological inventory [9].

Field work: So far, a total of seven craters of the Chiemgau strewn field have been investigated with GPR (Fig. 1), whereby two further smaller craters accompanying the large Lake Tüttensee crater have also been included in the measurements. A larger program was dedicated to this Lake Tüttensee crater, and a parallel campaign was carried out by a research team from the Czech Republic with special, very low-frequency equipments, which will be reported on separately. The measurements reported here used different antenna systems with 200, 300 and 400 MHz.

Results: From the amount of data collected so far we select typical radargrams for the #004 Emmerting, Aiching, Punzenpoint, Lake Tüttensee and Eglsee craters (Fig. 2).

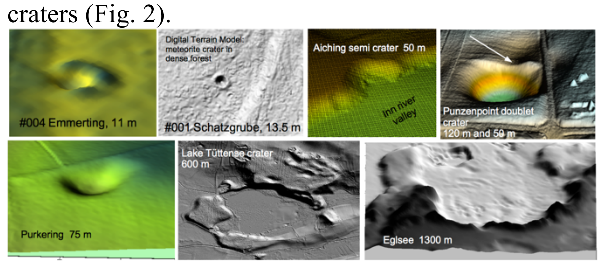

Fig. 2. Chiemgau impact craters for GPR measurements. Surface 3D images are from the Digital Terrain Model (in Germany: DGM 1). Note the strong exaggeration. Meter specifications are rim wall diameters.

#004 Emmerting is the early and so far best investigated small crater. It is characterized by an impressive impact inventory with extreme temperature and pressure effects (melt rocks, shock effects PDF, diaplectic glass). Until today its exact formation has not been clarified, since the extreme temperature effects on the rocks, >1,500°C, within a 20 m measuring halo cannot be attributed to the impact of a projectile, but suggest a near-surface heavy impact explosion [8]. The strong radar reflections (Fig. 3), which are good with a drill core in the center of the crater that has proven horizons of extreme sintering of the subsurface, fit well with this assumption.

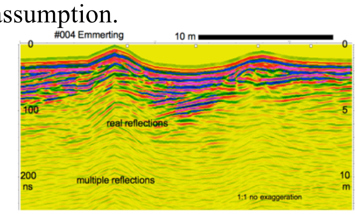

Fig. 3. Radargram across the #004 crater; see text. (25 MHz center frequency with modulated 200 MHz; data from P. Kalenda and R. Tengler).

Aiching: The semi crater Aiching appears punched into the embankment of the Inn river valley, and the data of the DGM 1 show its unmistakable contours of a 50 m diameter crater with a ring wall (Fig. 2). The radargram in Fig. 4 reveals in beautiful resolution the structure of the crater below its second half eroded and leveled by the Inn river, which allows an exemplary reconstruction of the formation of a meteorite crater with the diameter of some decameters in a soft target.

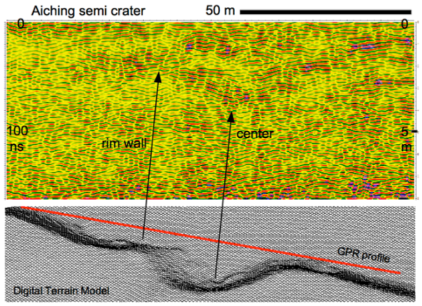

Fig. 4. Radargram across the hidden half of the Aiching semi crater in the Inn river valley. 300 MHz.

Punzenpoint was conspicuous as a flat depression in the Quaternary gravel subsoil but had become a candidate for an impact genesis only after a data analysis of the DGM 1. In the DGM 1, but only in this high resolution, it becomes clear that it is a walled doublet structure in which a smaller, 50 m measuring crater has dug itself into the ring wall of the larger, 120 m measuring circular structure, i.e. a tiny time later (Fig. 2, upper right). An ice age formation (e.g. a dead-ice hole) could therefore be ruled out, and the most recent GPR measurements (Fig. 5) have definitely excluded such a formation and taught a meteorite impact as the most plausible explanation.

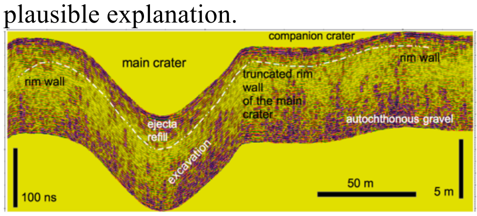

Fig. 5. Radargram crossing the Punzenpoint doublet crater. 300 MHz.

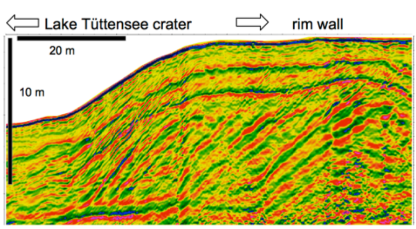

Fig. 6. Radargram (data superposition of 25 MHz and 200 MHz antennae; 25 MHz data from P. Kalenda and R. Tengler) across the Lake Tüttensee crater rim wall.

Lake Tüttensee: From the very beginning there was a fierce dispute between the local and regional authoritative geologists on the one hand (proponents of the textbook dead-ice formation) and the impact researchers on the other hand (as advocates of a meteorite crater) about the origin of the 600 m-diameter Lake Tüttensee depression. For years, extensive geological-geophysical-mineralogical-petrographic impact findings [8, 9] have been permanently ignored by the ice age geologists without ever having presented their own evidence. The latest brilliant results of the GPR measurements (Fig. 6) should also cause basic problems to explain the structure of the crater as a dead-ice depression. Note the distinct imbricate layering reflecting the excavation and ejection in the impact cratering process. The top horizontal layering is interpreted as a deposit from the Lake Chiemsee impact tsunami [10] that finally overrun the crater.

Eglsee: The impact nature of the Eglsee crater, which has a comparable size as the famous Barringer (Arizona) crater (Fig. 2), was originally suspected by a group of astronomers after having visited the Chiemgau impact strewn field and then studied a satellite imagery. Their suggestion fell into oblivion and was reanimated by the study of the now available Digital Terrain Model, a subsequent gravity survey, geological field work, and the here presented GPR campaign (Fig. 7).

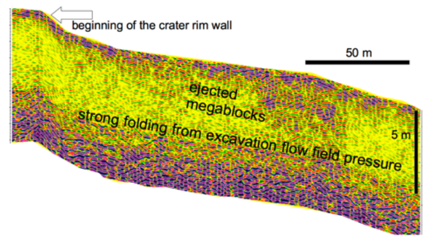

Fig. 7. Radargram (300 MHz) across the ejecta curtain of the Eglsee crater, which connects to the ring wall.

Conclusion: The here presented results of the GPR measurements over meteorite impact craters of various size in the young soft target of the Chiemgau impact strewn field exemplify the enormous potential of this high-resolution geophysical tool of underground exploration, which may lead to a much better understanding of impact cratering processes even on remote planetary bodies. This knowledge adds to the conviction that a combination of GPR and high-resolution DTM data may also help to identify new meteorite craters (or dismiss their impact origin), apart from the often overworked mineralogical expertise.

References: [1] Boateng, C.D. et al. (2012) *IJSRA*, 1, 47-61. [2] Russel, P.S. et al. (2013) *JGR Planets*, 118, 1915-1933. [3] Beauchamp, M. et al. (2011) *42th LPSC*, Abstract #2147. [4] Click, K. et al. (2007) *GSA*, 39.3, pp. 71 (abstract). [5] Spooner, I. et al. (2009) *Met. Planet. Sci.*, 44, 1193-1202. [6] Heggy, E. & Paillou, P. (2006) *Geophys. Res. Let.*, 33, L05202, 4 p. [7] Ernstson, K. (2017) http://www.impact-structures.com/wp-content/uploads/2017/01/DGM-1-final.pdf, (accessed 25/12/18) [8] Ernstson, K. et al. (2010) *J. Siberian Federal Univ., Engin. & Techn.*, 1, 72-103. [9] Rappenglück, M.A. et al. (2017) *Z. Anomalistik*, 17, 235-260. [10] Ernstson, K. (2016) 47th LPSC, Abstract #1263.