

NOT JUST A RIMMED BOWL: GROUND PENETRATING RADAR (GPR) IMAGERY OF SMALL CRATERS IN THE HOLOCENE CHIEMGAU (GERMANY) METEORITE IMPACT STREWN FIELD.

J. Poßekel¹, K. Ernstson². ¹Geophysik Poßekel Mülheim, Germany, jens.possekkel@cityweb.de ²University of Würzburg, D-97074 Würzburg, Germany, kernstson@ernstson.de

Introduction: The cratering of earth media by surface explosions is a complex process of combined effects that are difficult to treat. Some 40 years ago, the so-called Maxwell Z-model was a first analytical approach to describe the formation of craters with excavation flow and ejecta for a vertical impact (Fig. 1). The plausibility of the Z-model has not yet been investigated, because the movement of the target material cannot be directly observed in the laboratory [2] and only the present final state is visible in nature, which can be explored with single drillings or with geophysical measurements. For simple bowl-shaped craters, depth-to-diameter ratios, and possibly the thickness of a breccia lens on the ground may be determined. We report here on a program of high-resolution GPR measurements over some craters of different size in the soft Quaternary target of the Chiemgau meteorite impact strewn field in southeast Bavaria (Germany), which provides an unusual insight into structures and movements during crater formation.

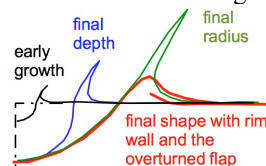


Fig. 1. Selected phases of crater formation in the Maxwell Z-model [1].

The Chiemgau impact event: In a roughly elliptically shaped strewn field (Fig. 2) more than 100 mostly rimmed craters with diameters between a few meters and a few 100 meters occur.

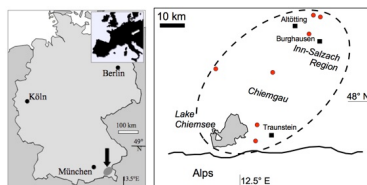


Fig. 2. Location map for the GPR over craters (red circles) within the roughly elliptically encircled Chiemgau impact strewn field.

Apart from the craters and their distinct morphology as revealed from precise Digital Terrain Model analyses (1 m x 1 m grid, vertical resolution 0.2 m; [3]), 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, shatter cones,

geophysical anomalies, and meteoritic matter [4, 5, and references therein]). The event happened in the Bronze Age/Iron Age 900 - 600 B.C. as revealed from impact catastrophe layers and their archeological inventory [5].

Field work: So far, a total of 9 craters of the Chiemgau strewn field have been investigated with GPR (Fig. 2). A special program was dedicated to the larger 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 has been reported on separately [6]. Our measurements 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 crater and the Aiching semi crater.

#004 Emmerting (Fig. 3) is the early and so far best investigated small crater. With a diameter of 11 m 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-related explosion [4].



Fig. 3. The 11 m-diameter #004 crater near Emmerting and its 3D surface of the Digital Terrain Model DTM.

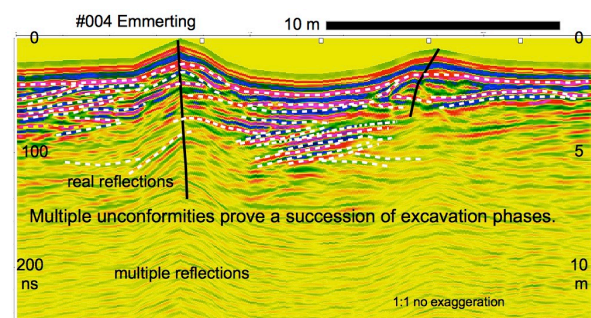


Fig. 4. Radargram across the #004 crater (25 MHz center frequency with modulated 200 MHz; data from P. Kalenda and R. Tengler) and interpretation.

The radargram in Fig. 4 corresponds in a certain way to the unexplained formation mechanism. Extreme reflectivity down to a depth of 5 m with an outward moving wall projection also to this depth, are the special features. With the high GPR resolution, abundant unconformities are also shown, revealing a whole sequence of movement phases during excavation. The simple approximate Z-model does not do justice to this structure.

Aiching. The semi crater appears punched into the embankment of the Inn river valley (Fig. 5, 7), and the data of the DTM show its unmistakable contours of a 60 m- diameter crater with a weak ring wall (Fig. 7, 8).



Fig. 5. The Aiching semi crater. The arrow points to the gravel excavation outcrop in Fig. 6.

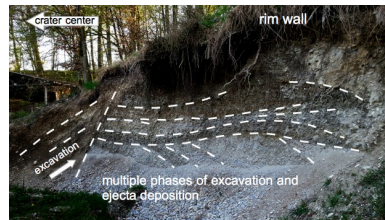


Fig. 6. The gravel excavation outcrop in the rim wall revealing a complex structure that reminds of the overturned flap in Fig. 1.

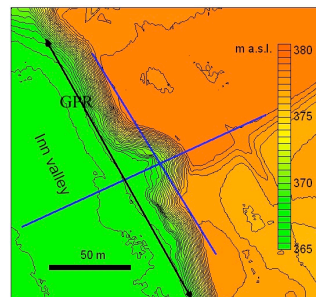


Fig. 7. The Aiching semi crater in the DTM with the location of the GPR profile and the radial and rather tangential DTM profiles in Fig. 8.

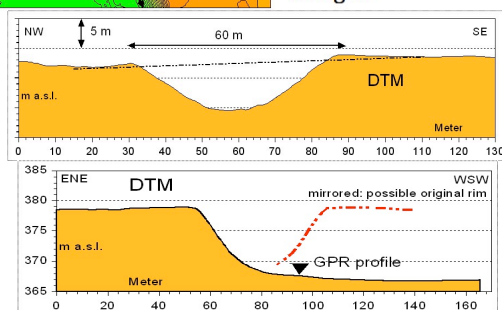


Fig. 8. The DTM profiles for the Aiching semi crater. The assumed reconstruction of the original full crater shows that the GPR profile is located roughly midway between crater center and rim.

While the erosion of the Inn river has exposed a very coarse section of the crater in the past, a gravel excavation, certainly unintended, has recently made an exceptionally fantastic cut through the crater rim with a ring wall (Fig. 6).

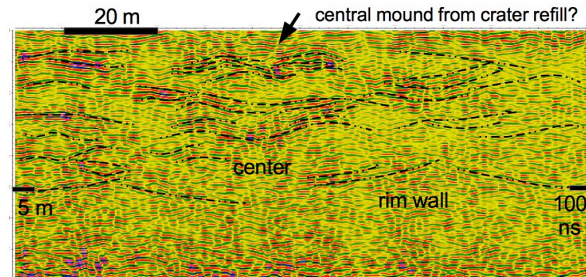


Fig. 9. Radargram across the hidden half of the Aiching semi crater in the Inn river valley. 300 MHz antenna. Note the wavy deformations and unconformities.

The radargram in Fig. 9 reveals in beautiful resolution the structure of the crater below its second half eroded and leveled by the Inn river. Similar to the radargram of the #004 crater (Fig. 4) a replication of structures with wavy deformations downwards implying layer unconformities are most suspicious. A doublet mound of higher reflectivity in the very center may have formed from crater refill with coarser material from rim wall collapse. In this respect, today's very flat ring wall of the Aiching crater (Fig. 8) could have been the remains of an originally much higher wall, which may well have been part of a Z-model overturned flap (Fig. 1)

Conclusion: The results of a high-resolution GPR presented here are not singularly selected two examples of an exploration of the crater bedrock. Very similar results of a complex subsurface with prominent wave-like movements and multiple layer unconformities are also found in the other craters in the Chiemgau meteorite crater strewn field surveyed with the GPR. These results should not be generalized or applied to impacts on other targets, but they show to what extent GPR can contribute to getting to the bottom of impact processes, at least for impact craters in the decameter range and in the range of some 100 m diameter [6].

References: [1] Maxwell, D. E. (1977) in *Impact and Explosion Cratering*, pp. 1003-1008. [2] Wada, K. et al. (2004), LPSC XXXV, Abstract #1520. [3] Ernstson, K. and Poßekel, J. (2020) This meeting. [4] Ernstson, K. et al. (2010) *J. Siberian Federal Univ., Engin. & Techn.*, 1, 72-103. [5] Rappenglück, M.A. et al. (2017) *Z. Anomalistik*, 17, 235-260. [6] Poßekel, J. and Ernstson, K. 50th LPSC, Abstract #1204.pdf.