HIGH-RESOLUTION DIGITAL TERRAIN MODELS DTM: RAYLEIGH-TAYLOR AND KELVIN-HELMHOLTZ INSTABILITIES AND IMPACT CRATERING IN UNHARDENED LOOSE SEDIMENTS - THE HOLOCENE CHIEMGAU AIRBURST IMPACT CASE. K. Ernstson[1], J. Poßekel[2] and A. West[3], [1]University of Würzburg, 97074 Würzburg (Germany) kernstson@ernstson.de, [2]Geophysics Poßekel Mülheim (Germany) possekeljens@gmail.com, [3]Comet Research Group, Prescott, Arizona 86301, USA

Introduction: Special features in impact craters, often seen in lab experiments, may be caused by Rayleigh-Taylor (RT) and Kelvin-Helmholtz (KH) fluid instability related to viscosity/inertia/density/velocity differences, with RT occurring from density inversion during deceleration, forming plumes, while KH happens with velocity shear creating wave-like deformations, both generating complex mixing layers. RT in impact cratering (mushrooming) happens when a denser impacting liquid or solid ejecta hits a less dense target fluid or surface, and the deceleration causes the interface to become unstable, lifting the denser matter up and pushing the lighter matter down. This creates mushroom-shaped plumes or fingers growing outward from the impact site. While this process is commonly observed in lab experiments of liquid impacts, it is less common in large terrestrial craters where it may happen due to different physics like vaporization or shock waves. KH occurs at the interface between two layers with different velocities, creating a velocity shear forming wave-like patterns. While RT may drive the mushroom shape in impacts to form central uplifts (besides e.g., rebound) KH can occur in turbulent impact ejecta or mixing zones, contributing to complex dynamics. Hence, RT produces mushroom and finger structures, while KH instability is velocity-driven and may produce wavy impact phenomena.[1]. It is understandable that both processes can interact in the formation of impact structures. Here we report on obvious RT and KH instabilities that can be observed regularly in the extremely high-resolution digital terrain models with the aforementioned crater features (fingers, mushrooms, waves, splashing) related to the low-altitude touchdown airburst impact of the Chiemgau impact strewn field.

The Chiemgau impact and the DTM: The Chiemgau meteorite impact, suggested some 20 years ago, is now established as the world's currently largest Holocene impact site, which has been dated to 900-600 B.C. in the Bronze Age/Celtic era. The Digital Terrain Model DTM (in Germany the DGM 1 [2]) maps the topography of the earth's surface with a dense data network obtained from laser scanning (LiDAR) from an airplane. The DTM data used here for a 1 m x 1 m grid at a vertical resolution of 10 cm (even lower with interpolation) capture the bare ground without buildings and vegetation, even in dense forests and swamps. We have been using the DGM 1 for several years to systematically search the Chiemgau impact strewn field for new impact findings applying this extremely high-resolution method, which has now led to well over 100 new structures with diameters up to 1,300 m [3-6]. In addition, the DTM has led to the Chiemgau crater strewn field being now understood as the result of a low-altitude "touchdown" airburst impact with associated crater shapes, some of which are highly complex [4].

KH and RT relevant Chiemgau impact target rocks: Typical Quaternary layered deposits consist of loess loam, silt, clay, sand, gravel, and any mixture of these fractions, e.g., sandy loam, sandy silt, clayey sand, sandy gravel, in addition to special formations such as interbedded layers of highly consolidated conglomerates (Nagelfluh).

Densities: Densities of involved rocks may vary considerably and are (in g/cm^3) dry sand 1.5-1.6, dry gravel 1.3-1.7, groundwater-saturated sand 1.9-2.0, clay 1.9-2.2, Nagelfluh 2.4, dry silt down to 1,0-1,2.

Viscosities: The viscosities of the unconsolidated rocks affected by the touchdown impact differ by many orders of magnitude, with the pre-impact viscosities of the target rock, such as composition, grain size, texture, and water content, but also the impact parameters, such as temperature, pressure, and strain rate, are playing an important role.

Selection of RT and KH features in Chiemgau impact structures: In the case of the Chiemgau impact, we generally contrast the predominant number of simpler, walled, bowl-shaped craters with the complex structures (Fig. 1), for which we show the RT and KH instabilities in maps and profiles (Figs. 2-7).

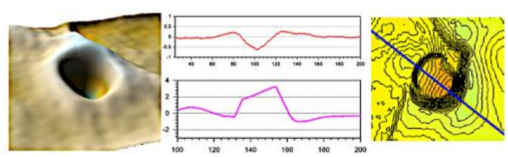

Fig. 1. Contrasting impact structures: wall-lined bowl-shaped crater (DGM 1 surface m and RT mushroomed hillock (DGM 1 contour map).

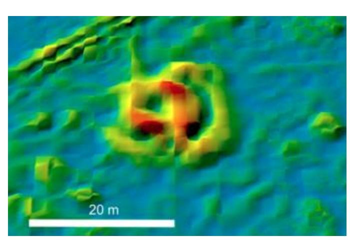

Fig. 2 Emmerting 004 crater, DGM 1 surface. Wavy crater rim.

Fig. 1 and Fig. 2 show the DGM 1 maps and profiles after a removal of a general terrain trend by strong low-pass data filtering (2D moving average) and thus centering the data to a zero level, which applies also to the following maps and profiles.

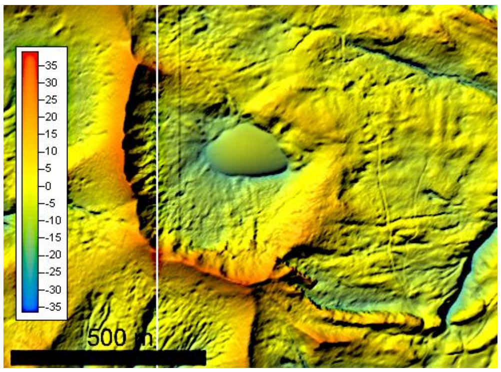

Fig. 3. Lake Grünsee crater, DGM 1 surface. RT crater fingering.

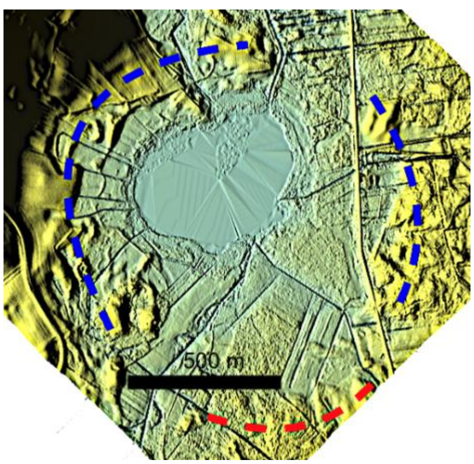

Fig . 4. Lake Eschenau crater, DGM 1 surface. Blue: splashed crater rim; red: fingered crater rim.

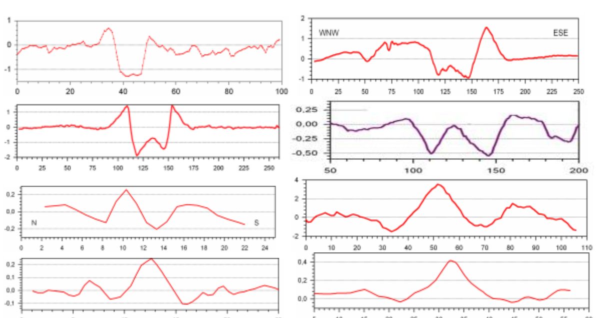

Fig. 5. Various stages of increasing mushrooming from bowl-shaped impact.

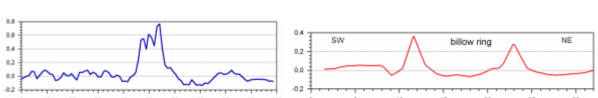

Fig. 6. Exotic mushrooming in flat depressions.

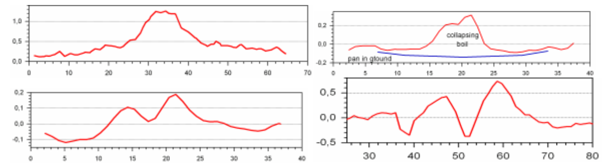

Fig. 7. Increasing collapse of mushroom impacts.

Discussion and Conclusions: The Chiemgau impact is an impact crater field measuring at least 60 km x 30 km with well over 100 craters in a Quaternary loose sediment substrate. <>The discovery of this new, very large number of craters is thanks to the new possibilities offered by the LiDAR Digital Terrain Model DGM 1, which, with an extremely high resolution of 1 m (interpolated decimeter) horizontally and 0.1 m (interpolated centimeter) vertically, even detects craters in dense vegetation (e.g., in forests) and reveals complex crater morphologies in the highest possible detail. <>The DGM 1 show that the craters created by the impact are largely bowl-shaped with walls, but also have some very complex structures such as mushroom shapes, finger shapes, multiple rings, wave patterns, and fragmented edge zones. <>The formation of such complex shapes can be explained, as here, by impacts known primarily from experiments with liquids, through so-called Ryleigh-Taylor (TM) and Kelvin-Helmholtz (KH) instabilities. <>We apply these TM and KH processes to the layers in the Chiemgau impact area, which consist of alternating beds of loose sediment with greatly varying densities and viscosities of the rocks involved. <>Based on these very complex crater shapes, we conclude that they rule out a normal geological origin such as sinkholes or other collapse structures, as well as relics of the last ice age in the form of dead ice holes, as is still claimed by some people, even by official sources. <>The large accumulation of these very special, sometimes exotic crater structures in the roughly elliptical strewn field of the Chiemgau impact proves once again the reality of the existence of this currently largest Holocene impact event worldwide. <>It also shows that databases and statistics on currently established terrestrial impacts, to which the impact literature consistently refers, are no longer relevant.

References: [1] Modified and shortened from Google Chrome AI [2] Geodaten Bayerische Vermessungsverwaltung. [3] Ernstson K. and Poßekel J. (2025) *MetSoc. Meeting 2025*, Abstract #5312. [4] Ernstson K. and Poßekel J. (2024) *LPSC 2024*, Abstract #1658. [5] Ernstson K. and Poßekel J. (2020) *11th PPC 2020*, Abstract #2019. [6] Ernstson K. and Poßekel J. (2024) *AGU 2024*, Abstract #EP01-29.