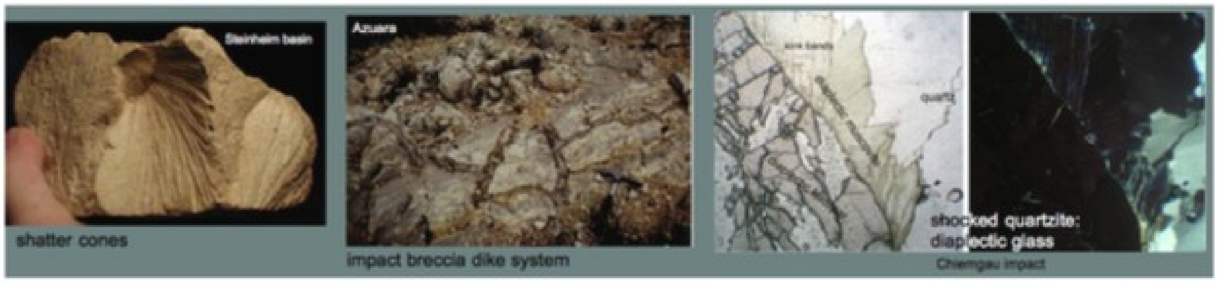
ERNSTSON CLAUDIN IMPACT STRUCTURES – METEORITE CRATERS

Research on impact geology, geophysics, petrology, and impact cratering



The Chiemgau Impact (Germany) meteorite crater strewn field. Model craters, Part 1: the small #004 Emmerting, Kaltenbach and Mauerkirchen craters, and the role of Digital Terrain Models

K. Ernstson, H.-P. Matheisl, J. Poßekel and W. Mayer

September 2024

The Chiemgau Impact (Germany) meteorite crater strewn field. Model craters, Part 1: the small #004 Emmerting, Kaltenbach and Mauerkirchen craters, and the role of Digital Terrain Models

K. Ernstson[1], H.-P. Matheisl[2], J. Poßekel[3] and W. Mayer[4]

Abstract

The article is the first part of a treatise on the large impact crater strewn field of the Holocene Chiemgau impact with a focus on the now huge number of craters, and a model description of typical examples, for which the craters #004 Emmerting, Kaltenbach and Mauerkirchen were selected here in the first part of addressing the small craters. The selection is justified by the fact that they were already at the beginning of research into the remarkable impact event with geological, geophysical, geochemical, and mineralogical-petrographic investigations and today, some 20 years later, demonstrate how the application of extremely high-resolution digital terrain models down to the decimeter and centimeter range has changed impact research almost in a paradigm shift. This is also a key aspect of this article, which will be followed by two more for the medium-sized and larger craters.

Keywords: Chiemgau impact, impact crater strewn field, Digital Terrain Model, impact rocks, shock metamorphism, Bavaria, Germany

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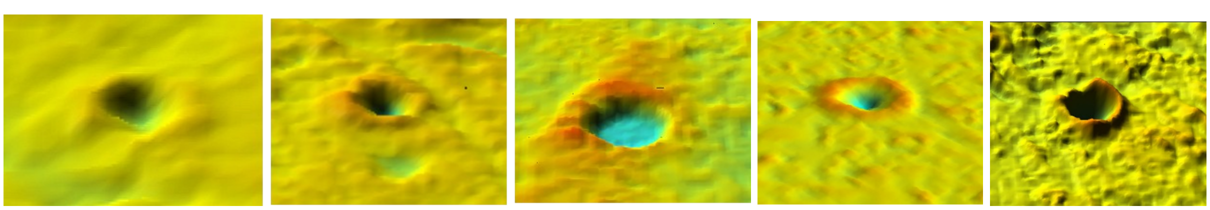
1 Introduction

The Chiemgau strewn field discovered and established in the early new millennium (Schryvers and Raeymaekers, 2004; Schüssler et al., 2005; Rösler et al. 2005, Rappenglück, M. et al., 2005, Hoffmann et al., 2005, 2006; Yang et al 2008), extensively investigated in the following decade until today (Ernstson et al. 2010, 2011, 2012, 2013, 2014, 2017, 2020, 2023, 2024, Hiltl et al. 2011, Isaenko et al. 2012, Rappenglück, B. et al. 2010, 2020 a, b, c, 2021, Rappenglück M.A, et al. 2013, 2014, Bauer et al. 2013, 2019, 2020, Shumilova et al. 2018, Ernstson and Poßekel 2017, 2020 a, b, 2024, Ernstson and Shumilova 2020, Poßekel and Ernstson 2019, 2020), and dated to 900-600 BC in the Bronze Age/Iron Age (Rappenglück, B. et al. 2023) comprises far more than 100 mostly rimmed craters scattered in a region of about 60 km length and ca. 30 km width in the very South-East of Germany. The crater diameters range between a few meters and 1,300 m. The doublet impact at the bottom of Lake Chiemsee is considered to have triggered a giant tsunami evident in widespread tsunami deposits around the lake (Liritzis et al. 2010, Ernstson 2016). Geologically, the craters occur in Pleistocene moraine and fluvio-glacial sediments. The craters and surrounding areas are featuring

heavy deformations of the Quaternary cobbles and boulders, impact melt rocks and various glasses, strong shock-metamorphic effects, and multiple geophysical (gravity, geomagnetic, electromagnetic, GPR and seismic) evidence. Impact ejecta deposits in a catastrophic mixture contain polymictic breccias, strongly shocked rocks, melt rocks and artifacts from Bronze Age/Iron Age people. The impact is substantiated by the abundant occurrence of metallic, glass and carbonaceous spherules, accretionary lapilli, microtektites and of strange, probably meteoritic matter in the form of iron silicides like gupeiite, xifengite, hapkeite, naquite and linzhite, various carbides like, e.g., moissanite SiC and khamrabaevite (Ti,V,Fe)C, and calcium-aluminum-rich inclusions (CAI), minerals krotite and dicalcium dialuminate. The impactor is suggested to have been a roughly 1,000 m sized low-density disintegrated, loosely bound asteroid or a disintegrated comet to account for the extensive strewn field. A touch-down airburst (Moore ...) is currently being discussed for the Chiemgau impact event (Ernstson...)

A new situation for impact research on the Chiemgau impact has arisen in recent years in that the Digital Terrain Model DGM 1 is available online free of charge for the whole of Bavaria and thus for the entire Chiemgau impact field in the form of tiles measuring 1 km x 1 km, which can be downloaded in a matter of minutes as ASCII (x, y, z) files. The mesh size of the DGM 1 is 1 m with a vertical resolution of the terrain surface of 0.1 m, which can be interpolated into the decimeter and centimeter range using the SURFER program. SURFER data processing can be used to generate topographic maps with isolines of any density, shaded relief maps and pseudo 3D models of the surface in any view orientation and color scaling (Fig. 1). In the same extremely high resolution, profiles of any orientation can be extracted from the generated maps, which enables a completely new approach to the analysis of crater morphologies (Fig. 2). A further step towards a completely new approach to impact crater research is made possible by the DGM 1, which eliminates buildings and all vegetation, including the densest forests, in the LASER processing of the digital terrain model, so that only the bare ground is registered and included in the data. These new possibilities for impact research have led to the gradual systematic examination of the tiles for promising morphological signatures. While the original documentation of the discoverers of the Chiemgau impact around 20 years ago already included around 80 craters, the number has been multiplied several times with the help of DGM 1 and the "thinning out" of the widespread forests and inaccessible swamp areas.



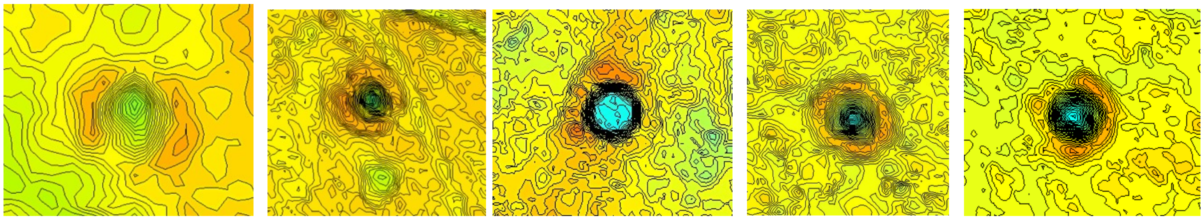


Fig.1. A selection out of several dozens of similarly shaped craters in the Chiemgau strewn field processed from the DGM 1 data as 3D surface maps (upper; exaggerated) and topographic maps with contour intervals of 5 and 10 cm (lower). Diameters (rim to rim) are between 10 m and 30 m.

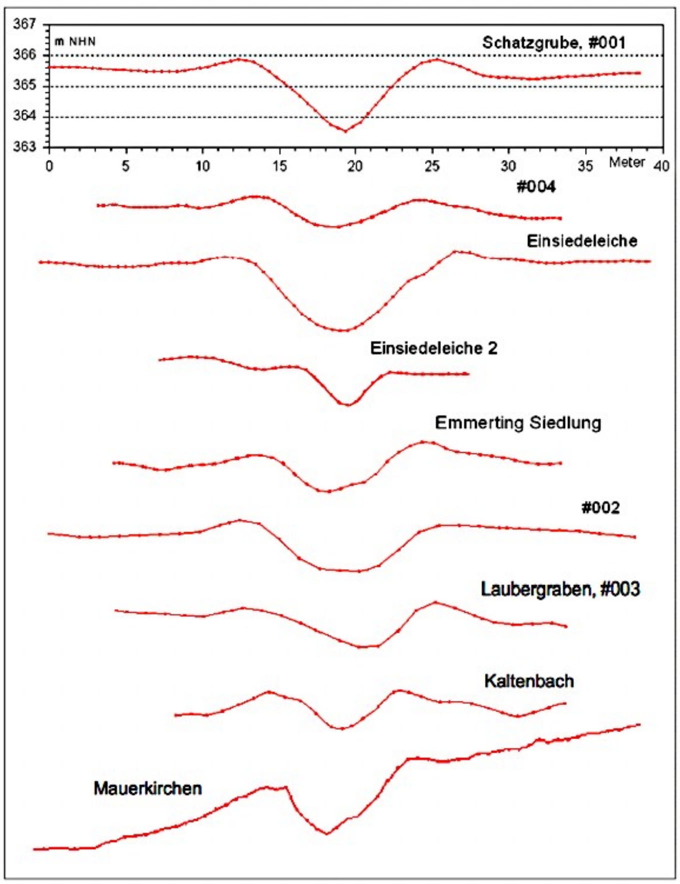


Fig. 2. DGM 1 diametrical cross sections for smaller craters in the Chiemgau meteorite impact strewn field. Except for the Einsiedleiche 2 and Emmerting Siedlung craters the impact nature has been proven (shock metamorphism) or suggested (strong rock deformation, melt rocks, geophysical anomalies). For all cross sections the same scale applies.

We report here in a first part in a summary of our research on the group of small craters of the Chiemgau impact using the example of the early investigated craters of Emmerting (original number #004). Kaltenbach and Mauerkirchen in the north and in the south of the strewn field ellipse (Fig. 3) with the characteristic impact features of melt rocks, glasses and shock effects as well as with geophysical measurements.

In an Appendix we present a compilation of a large number of craters in the immediate and wider surroundings of the craters of Emmerting, Kaltenbach and Mauerkirchen, in which the diverse shapes are expressed in topographical DGM 1 maps together with traversing DGM 1 profiles.

Recently, a group from the Czech Republic (Procházka 2023, Procházka et al. 2024) has been trying to follow our research and more or less claim Chiemgau impact evidence for themselves by making false claims, false statements, and worst distortions of the research history, in the manner of free riders, with some of their own investigations, especially on crater #004, what we can only call dishonest science (Ernstson 2023).

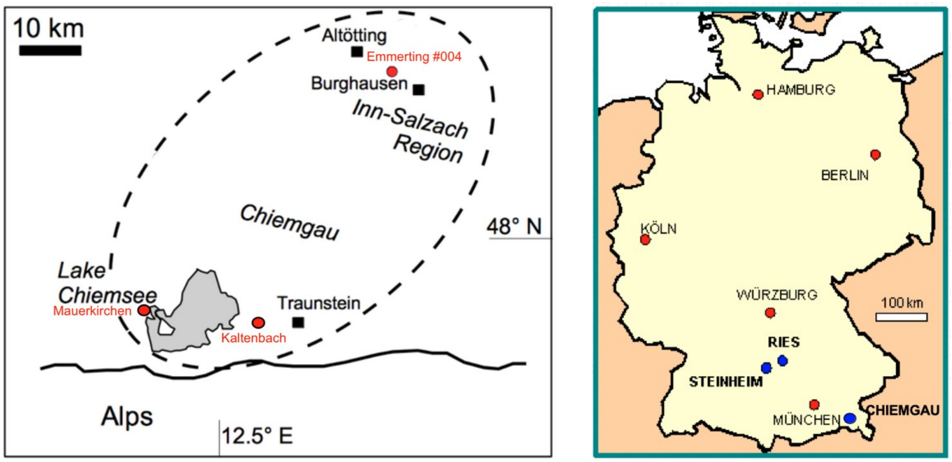


Fig. 3. Location map for impact crater #004 near Emmerting in the northern part and for craters Kaltenbach and Mauerkirchen in the southern part of the Chiemgau crater strewn field (about 100 km southeast of Munich).

Preliminary remark for the following texts.

This article describes a wealth of results for which it appears important that the overview is not lost in their compilation. For this reason, the accumulation of figures is not integrated into a connecting text. Instead, only the corresponding illustrations are arranged in a row, each of which is commented on with more or less lengthy texts as "captions". 2.3 is an exception. Here, a translation of a short version of a German Web text has been adopted.

2 The Emmerting #004 crater

2.1 Morphology and the Digital Terrain Model

Fig. 4. The 11 m-diameter (rim to rim) #004 crater in the Emmerting forest.

Fig. 5. A diametrical trench through the crater. The trench had to be terminated at a shallow depth because the excavator could not make any further progress due to the extremely compacted subsoil and had to give up. The same happened with a borehole through the crater floor, with which only a short core could be obtained (Fig. 13).

Fig. 6. 2013. Dr. Tatyana Shumilova from the Diamond Laboratory, Syktyvkar University, Russia, inspecting the #004 trench. Also see the paper (Shumilova et al. 2018) on the *chiemite* remarkable new carbon impactite, for the first time discovered in the Chiemgau impact strewn field.

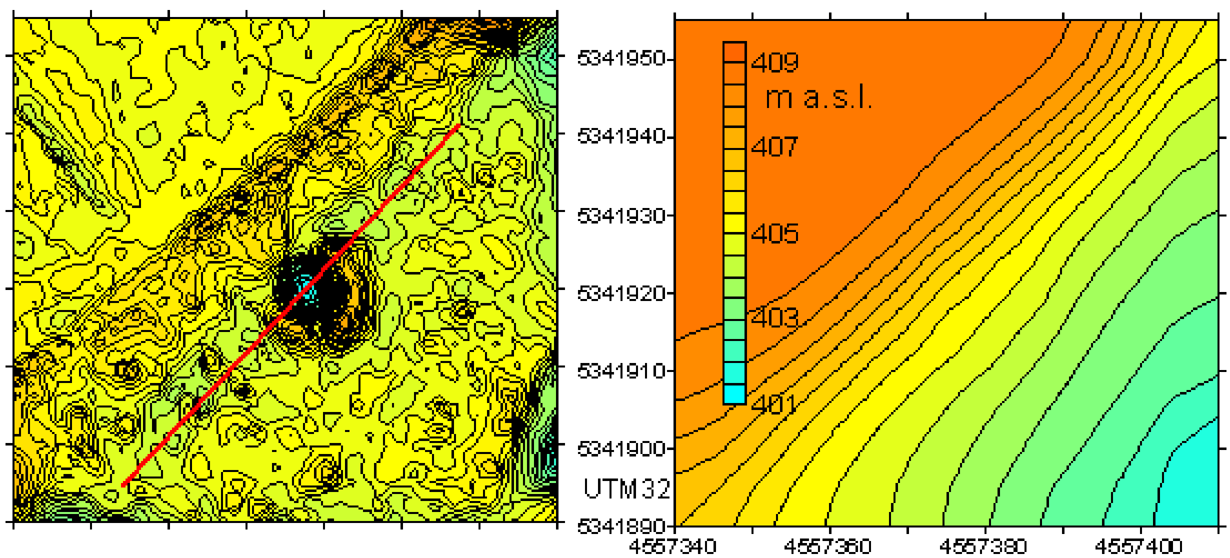


Fig. 7A. The Digital Terrain Model DGM 1 of the #004 crater, a typical model for most of the equally sized craters in the Chiemgau strewn field. For this display and those in following figures, a trend field (to the right) was subtracted using a slight low-pass filtering (moving average) of the data.

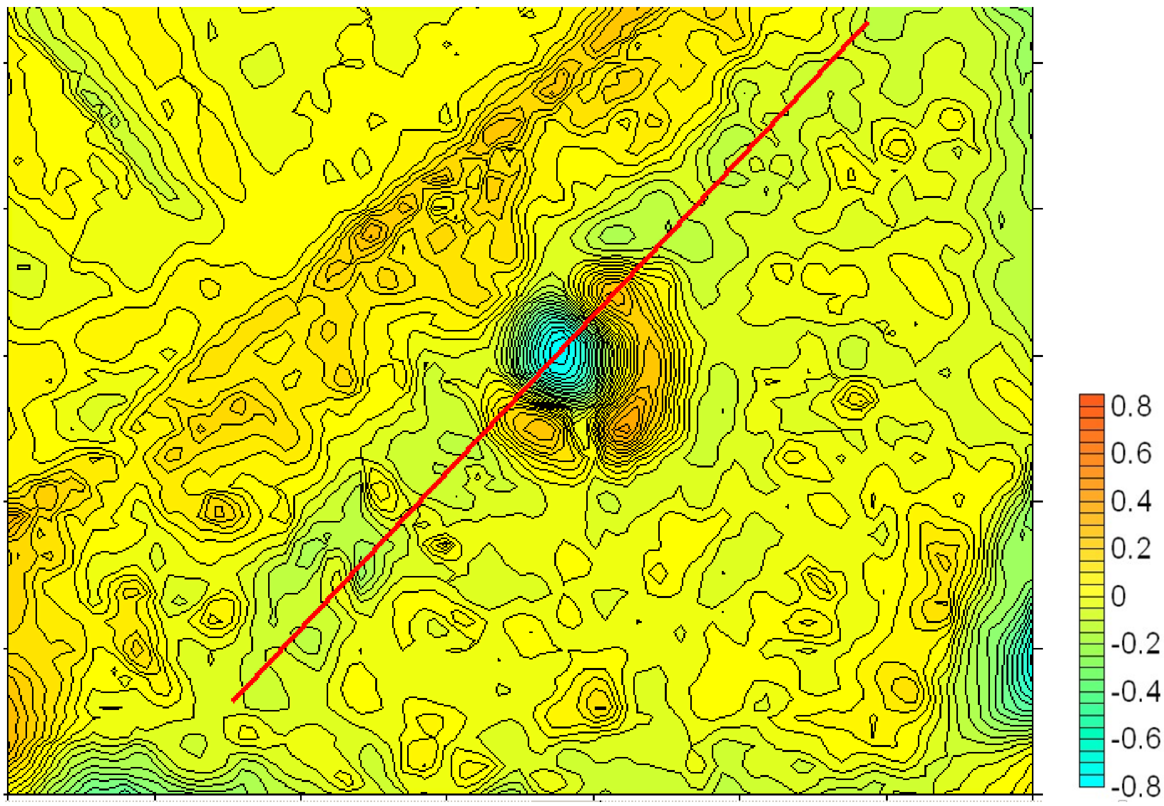


Fig. 7B. The #004 crater topography in better resolution, contour interval 10 cm. Along the red line the DGM 1 profile in Fig. 8 was taken.

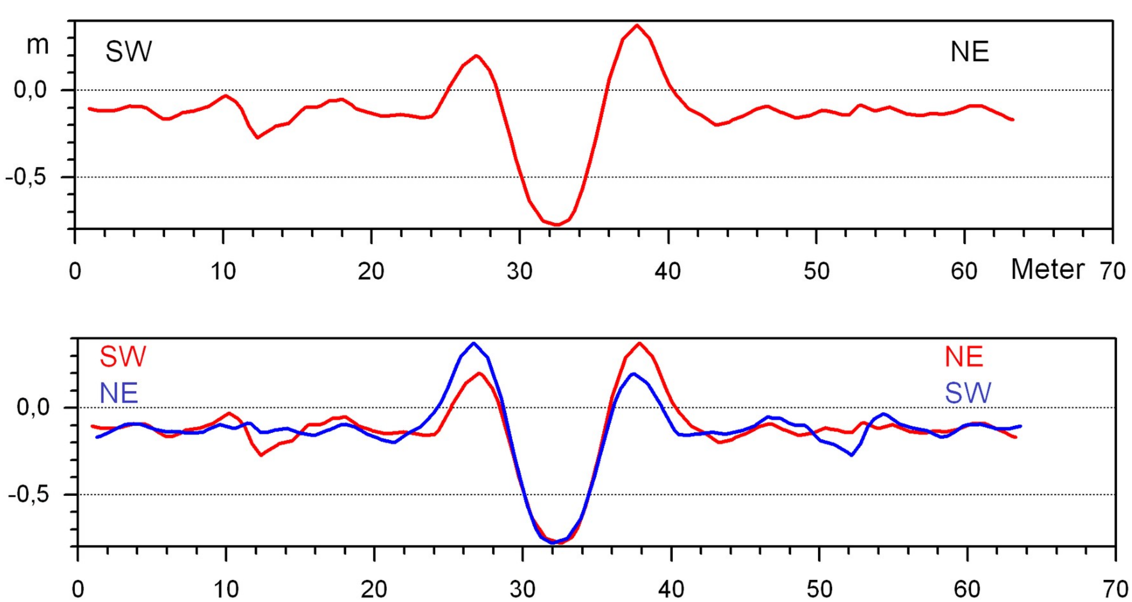


Fig. 8. The DGM 1 profile along the red line in Fig. 7. Note the nearly perfect mirror symmetry with the superimposed reversed profile (blue), exceeding no more than 20 cm over 60 m profile length.

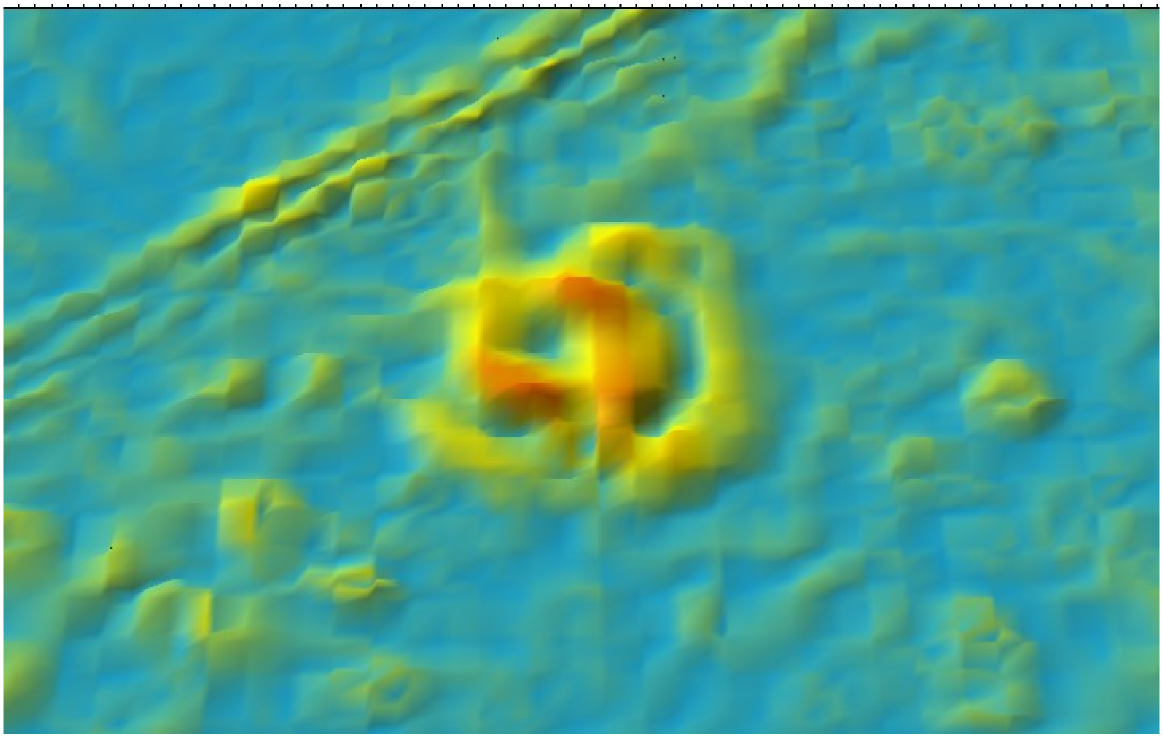


Fig. 9. The #004 crater as DGM 1 pseudo 3D surface. The second outer rim wall, which nobody has ever seen before, demonstrates the enormous potential of the digital terrain models.

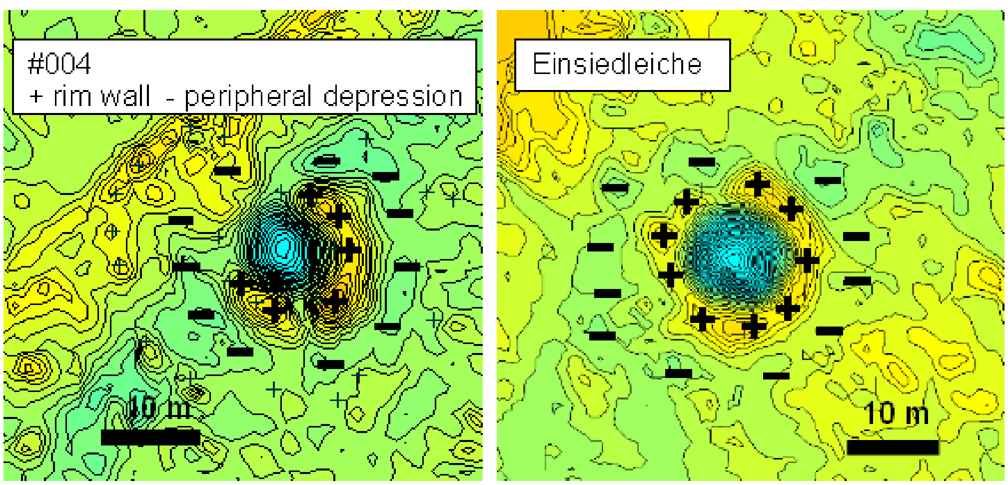


Fig. 10. In addition to Fig. 9: DGM 1 maps of the #004 crater and the xy km distant Einsiedleiche crater, contour interval 5 cm. The peripheral depression (also seen in Fig. 9 between the two rings) has counterparts, which are variably formed in most of the Chiemgau strewn field craters.

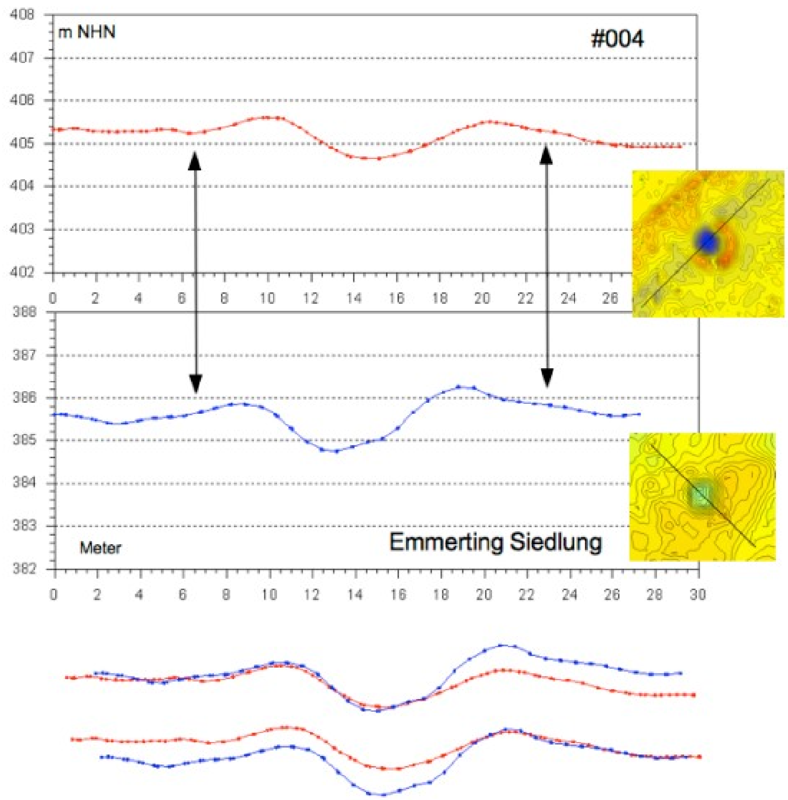


Fig 11. Comparison of diametrical cross sections for the #004 and the nearby Emmerting Siedlung craters. Considering a slight shift of 0.5 m the crater profiles are practically congruent, differing no more than 20 cm. This morphology and that shown in Fig. 8 practically exclude geogenic and anthropogenic formation.

2.2 The field impact evidence

Fig. 12. The #004 crater and the 20 m-diameter halo, where impact temperatures heated the ground up to 1,500 °C.

Fig. 13. Drill core from the floor in the center of the #004 crater. As for the trench (Figs. 5, 6), the short core documents the extreme consolidation of the crater subsoil, which is also visible in the ground penetrating radar measurements down to a depth of several meters and is attributed to extreme consolidation and sintering of the clayey-gravel layers. Digging and drilling Gerhard Benske.

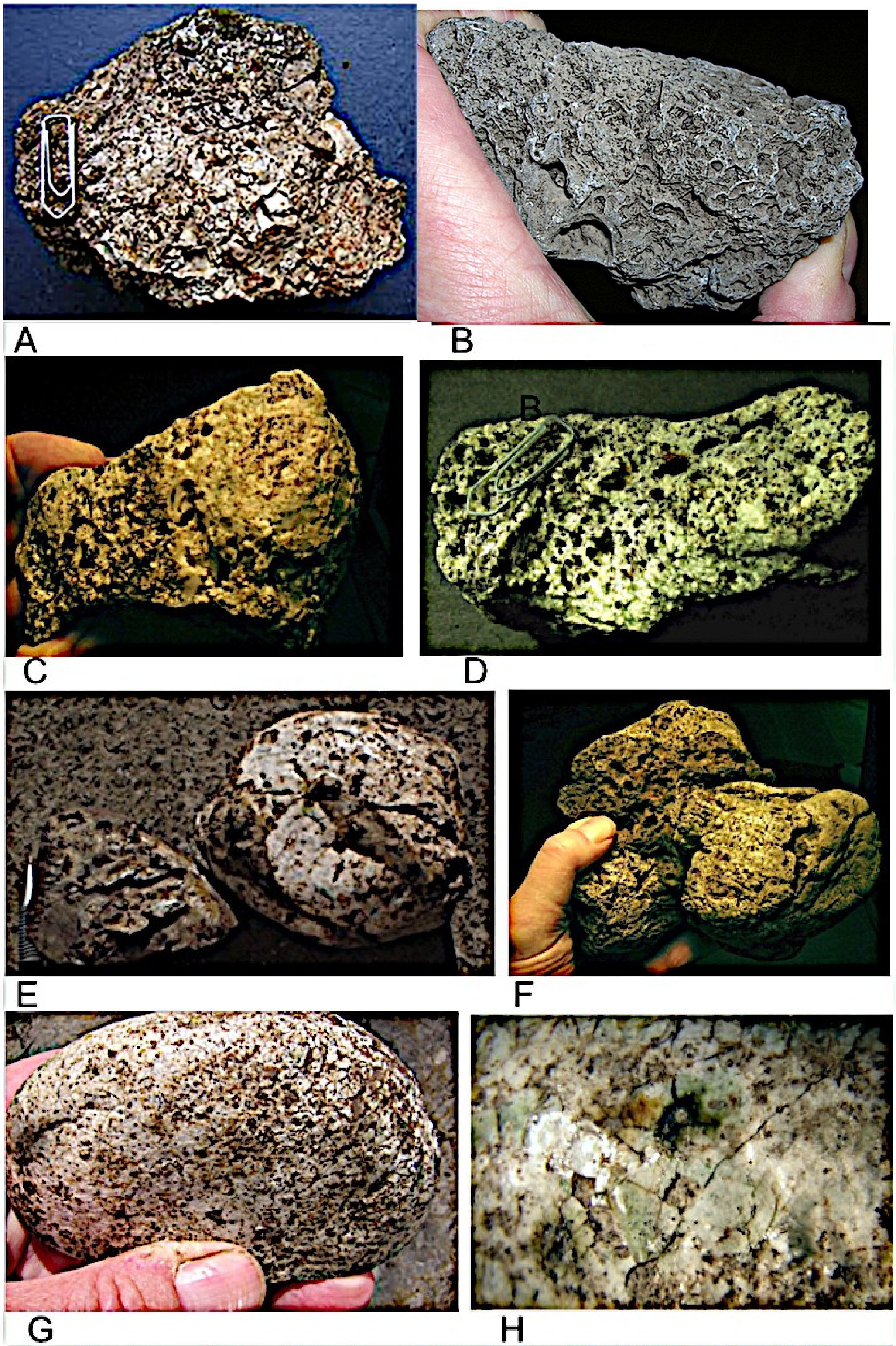


Fig.14. Samples from the #004 Emmerting crater, inside and outside, A: monomictic limestone breccia. B-D: melt rocks, various lithologies. E: cobbles with melt glass skin and open (spallation?) fractures. F: fused together cobbles. G: cobble encased with glass skin (H).

Fig. 15. Extremely porous carbonate clasts from the #004crater are interpreted as relics and crystallization products from a carbonate melt.

2.3 Petrographic and geochemical analyses of mechanically and thermally shocked cobbles

The following section is a strongly abridged version of a translated article by U. Schüssler on the CIRT website (Chiemgau Impact Research Team CIRT, 2006, Schüssler 2006).

Abstract. - 17 cobbles sampled from the #004 Emmerting crater have been studied by thin-section inspection and microprobe analyses. The cobbles from the Molasse sediments represent common rocks from the Alps like quartzites or basic metamorphic rocks (amphibolites, serpentinites). The thin sections clearly show that the cobbles have experienced shock metamorphism at high temperatures and pressures. We observe multiple sets of planar deformation features (PDFs) in quartz and feldspar, diaplectic SiO2 glass and extreme subgrain formation. Heavy in situ tensile fracturing of whole rocks and quartz grains indicates spallation by dynamic shock pulses. Melt glass is in general found in three different occurrences: as a thin crust in many cases completely coating the cobbles, as vesicular, partly recrystallized feldspar glass interspersing quartzite rocks, and as allochthonous melt lumps on the cobbles' surface. The glass coating is assumed to have been formed on entering of excavated and ejected cobbles into the superheated explosion cloud. As the glass is considerably enriched in K and Na practically absent in the studied cobbles, an intermixing from burned-up or vaporized vegetation must be taken into consideration. The field observations and lab analyses exclude normal tectonic processes as well as human activities but clearly establish a meteorite impact event.

2.3.2 Macroscopic and thin section evidence

Sample 004-1

The surface of the sample is covered in places by a thin layer of glass; in one place there is a dark brown, glassy, slag-like melt of foreign material several centimeters in size on the surface. In the section (Fig. 16), the actually light-colored sample is interspersed with numerous small, 1 mm thick and maximum 1 cm long dark fibers. Longitudinal axis of the debris 10 cm.

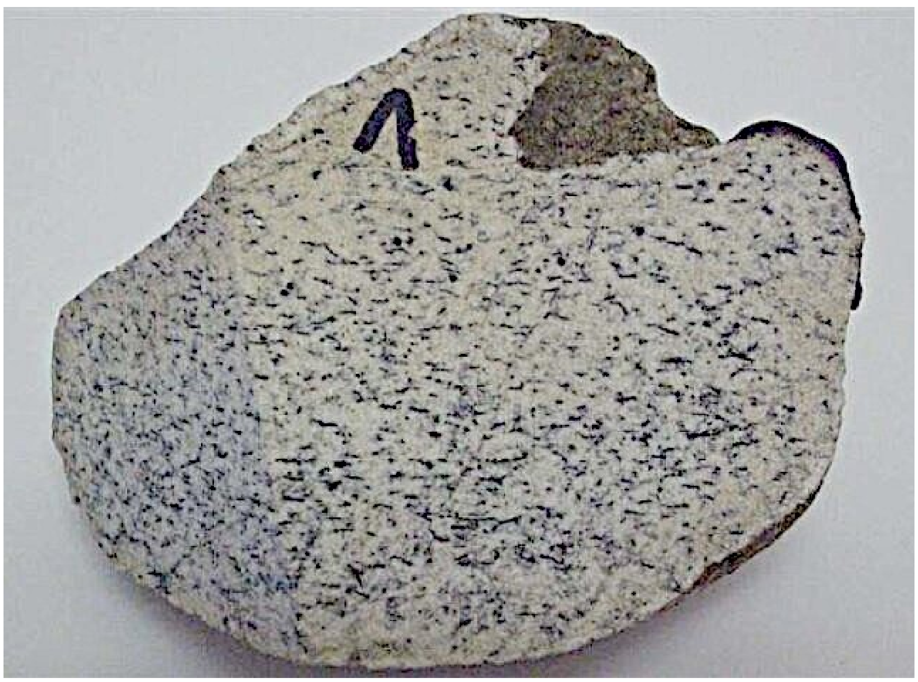


Fig. 16. section of sample 004-1.

The thin section (Fig. 17) shows a rock that originally consisted of quartz and feldspar. While the quartz is almost unchanged, the originally feldspar-rich sections have been transformed into glass over large areas. This effect affects around 30-50 % of the rock. Another striking feature is the large number of small gas bubbles that permeate the entire rock.

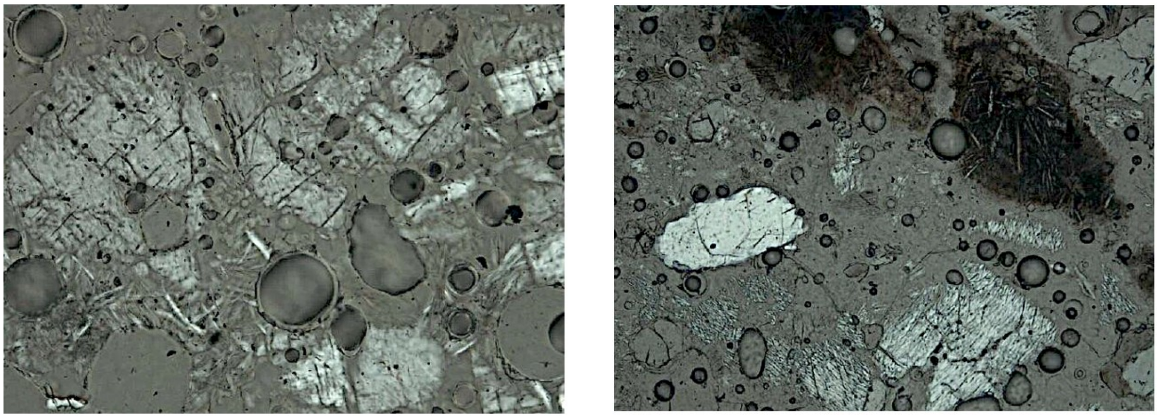


Fig. 17. Thin sections 004-1. Gray feldspars are displaced by the glass (gray-brown). Partly acicular recrystallization, gas bubbles. Bottom edge of image corresponds to approx. 0.5 mm. The brown lump sitting on the surface is intensively welded to the rock along the interface. The slag-like material consists of a glassy microcrystalline matrix in which a large number of thin, light-colored crystal filaments have recrystallized.

Sample 004-3

The entire boulder (Fig. 18; longitudinal axis 10 cm) is covered on the surface by a colorless, in places somewhat greenish, thin layer of glass. According to thin-section findings, it is a quartzite containing feldspar. The quartz crystals are all heavily fractured and extremely undissolved. The thin section shows some remains of the glass coating. Some former quartz crystals are diaplectically vitrified (conoscopically distinguishable from quartz crystals cut perpendicular to the optical axis by the missing axial cross). 0ptically isotropic diaplectic quartz glass is formed without any melting at very high shock pressures (several 100 kbar = several 10 GPa) by destroying the crystal lattice. Flow structures and bubbles are absent, but grain boundaries and fractures may be preserved. According to the current state of science, diaplectic glasses are not formed in nature by any endogenous geological process but solely by shock metamorphism during an impact.

Fig. 18. Quartzite boulder 004-3. Section and surface covered with glass skin.

Sample 004-4 (Fig. 19, 20)

Fig. 19. Sample 004-4: incision and fusion patina on residues of vitreous coating.

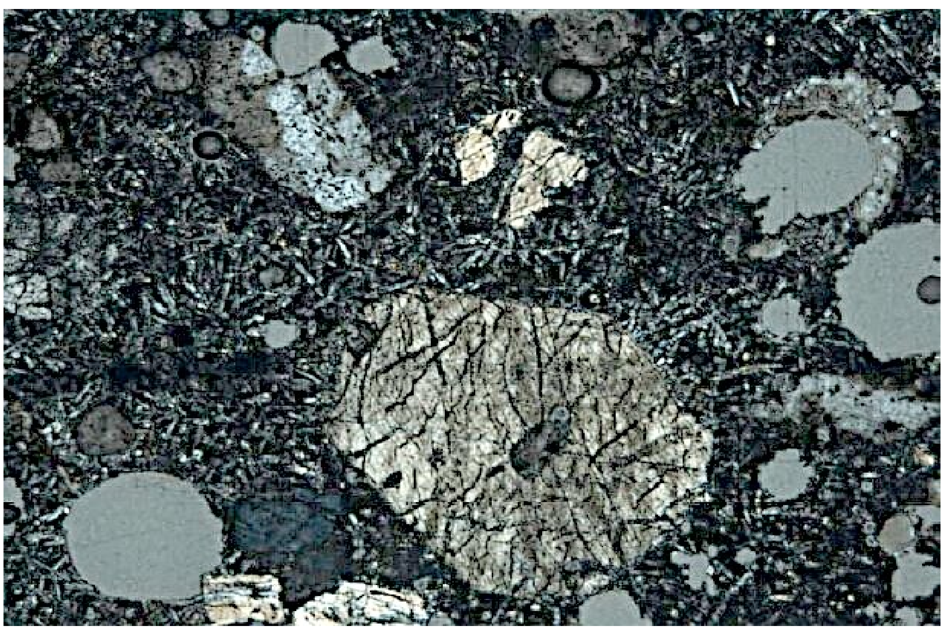


Fig. 20 Thin section of 004-4 showing clinopyroxene (light) and albite (gray) as relict minerals in the fine-grained matrix of the fusion clot, also gray gas bubbles. Longitudinal edge about 2 mm. The thin section shows an almost pure quartzitic composition.

Sample 004-5

Cobble consisting of two different rocks, a lighter, quartzitic one and a darker quartz-feldspar one (Fig. 21). Remains of a vesicular glass crust can be observed on the surface. The entire rock is extremely permeated with gas bubbles (Fig. 22).

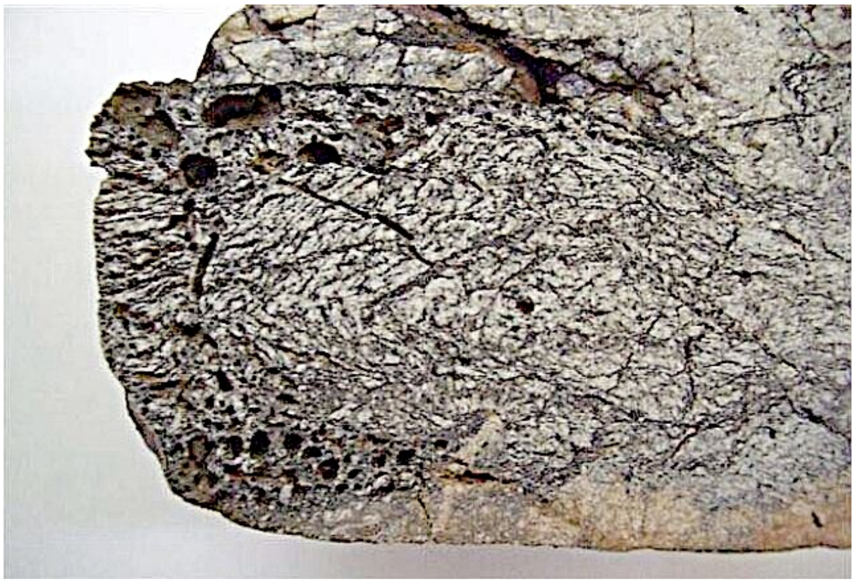


Fig. 21. Sample 004-5 in section. Top left bubbles in the rock, dark glass particles; fritted rim at the bottom, light quartzite at the top, cobble cut-out 5 cm.

Fig. 22: Glass and gas bubbles in the dark boulder section of Fig. 21, longitudinal edge about 5 mm.
Sample 004-6

Dark cobble with a brown, slag-like melted lump (Fig. 23). In cross-section, the melt slug stands out clearly from the actual cobble, but large gas bubbles continue several centimeters into the cobble. Small gas bubbles can also be seen macroscopically throughout the rock, which is almost impossible to identify.

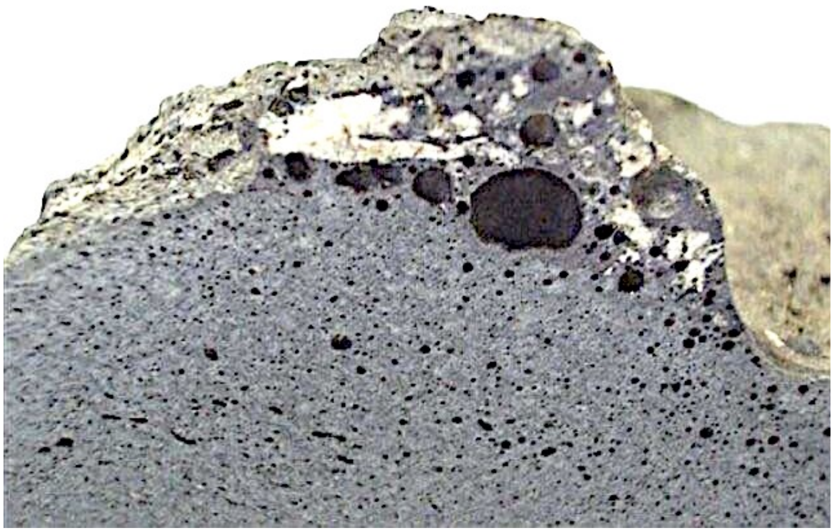


Fig. 23. Section of the sample 004-6.

Sample 004-8

Fig. 24. Section of sample 004-8. longitudinal axis 6 cm. Inhomogeneous, light-dark

"banded" cobble with a bubbly fusion crust on top (to the left). The cobble itself is largely thermally destroyed.

Microscope (Fig. 25. 26): The matrix of the fusion crust is completely without relict minerals, but very vesicular. Especially in the transition area to the boulder, yellow-green-pale-green needle-like recrystallization occurs (pleochroism, colorful interference colors, oblique extinction at low angles indicate amphiboles).

Fig. 25. Transition from quartzitic area at the top left to glassy area with elongated bubbles, which could be interpreted as transitions to spallation cracks. Longitudinal edge ~ 6 mm.

Fig. 26. Vein with partially recrystallized glass, gas bubbles and light quartz, longitudinal

edge ~ 1.3 mm.

Sample 004-10:

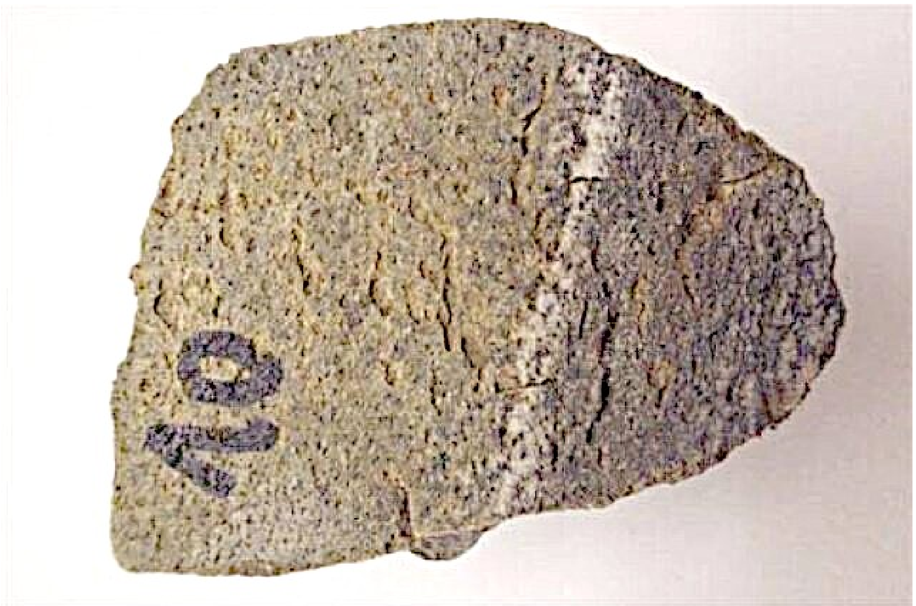


Fig. 27. Section of sample 004-10; longitudinal axis 4.5 cm. Note the many open fissures interpreted as shock spallation cracks.

Small boulder, characterized by (spallation) cracks on the surface and inside the rock (Fig. 27). The rock is also intensively interspersed with bubbles, which can expand in a smooth transition to spallation cracks. The large number of bubbles becomes even clearer in thin section. This is a strongly quartz-bearing rock. The quartz is well preserved, the other mineral components have obviously been melted and have largely recrystallized as a microcrystalline matrix. The quartz grains are often broken into two or three parts, whereby the individual parts have been pulled apart by a few tens of micrometers (spallation). The gaps are filled by recrystallized melt (Fig. 28). - For the process of ***spallation*** during shock loading, see e.g. http://www.chiemgau- impakt.de/2011/08/25/schock-spallation-ein-typischer-impaktprozess-im-chiemgauer- meteoritenkrater-streufeld/.

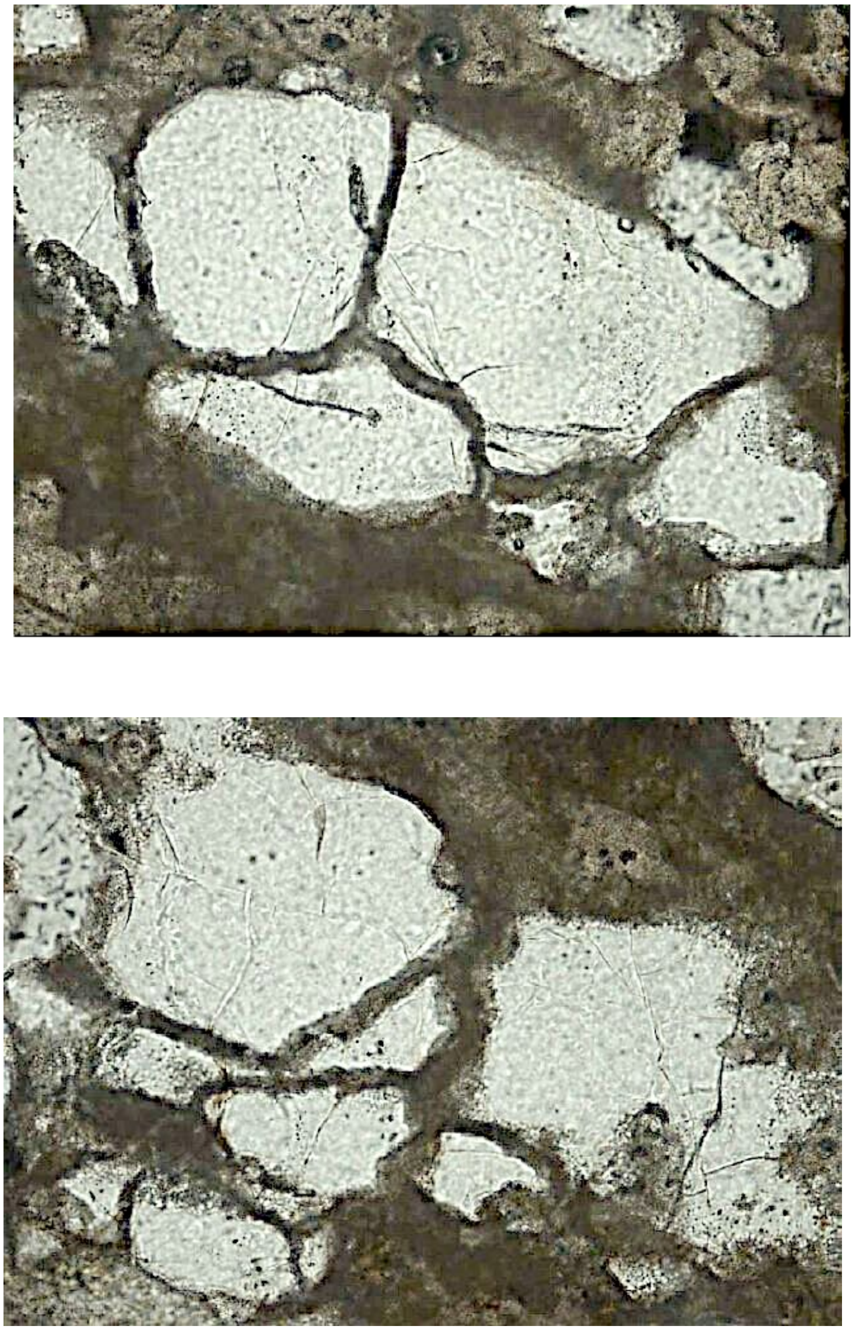


Fig. 28. Quartz grains cracked due to spallation, longitudinal edges of the photos ~ 0.8 mm. The spallation cracks are filled with recrystallized glass.

Sample 004-15

Fig. 29. Section of sample 004-15.

It is not yet entirely clear what happened to this rock. Macroscopically and in cross-section (Fig. 29) it looks like a limestone cobble, and in fact may have been a well-known siliceous limestone cobble from the Limestone Alps. Under the microscope (Fig. 20), the rock is extremely fractured; the polygon-like fragments form a kind of mortar texture. Carbonate can be found on all the cracks, but also partly within the fragments. However, the majority of the fragments consist of a very fine-grained, gray phyllosilicate. This has displaced the carbonate. Remains of microfossils indicate that the carbonate is the primary material. As the mortar texture shows a connection with the impact and the cracks in the texture are filled with carbonate, the whole process is probably impact-related.

Fig. 30 Thin section of sample 004-15. ?Mortar texture, lime with remains of microfossils, partly displaced by fine-grained phyllosilicates (not visible), longitudinal

edge ~ 2 mm.

Sample 004-17

Very fine-grained boulder (Fig. 31) with slight traces of vitrification on the surface. Light gray in cross-section, black speckled. Thin section shows a fine-grained quartzite (± feldspar), all dark spots are small vitrified areas. The rock is similar in principle to sample 004-1, but the vitrification is not as extensive.

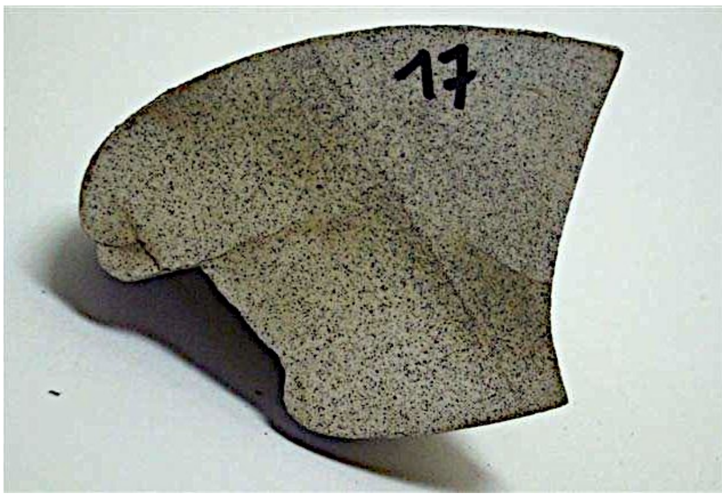


Fig. 31. Section of sample 004-17.

Sample 004-19

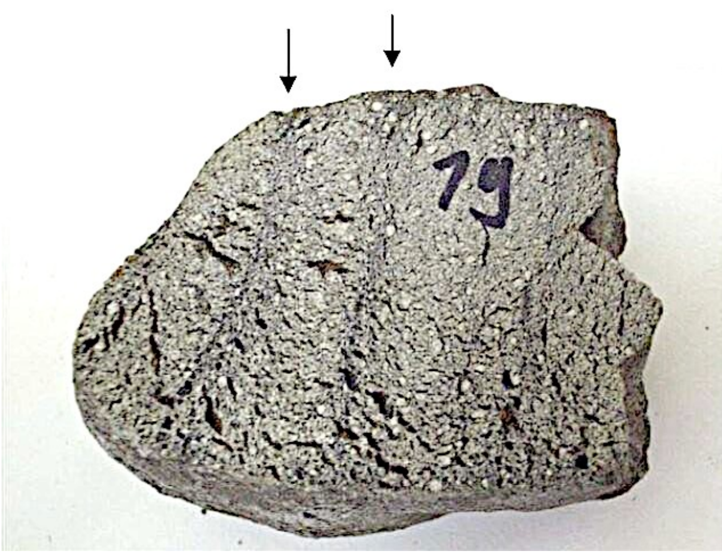


Fig. 32. Section of sample 004-19.

Dark cobble (Fig. 32; longitudinal axis 6 cm) with cracks and bubbles on the surface. The cross-section shows a very bubble-rich rock. The bubbles expand partly to small cracks.
Sample 004-21 (Fig. 33)

Fig. 33: Quartzite boulder, longitudinal axis 12 cm, remains of a glass crust preserved over a large area on the surface (photo width approx. 2 cm).

2.3.3 Microprobe analysis

These samples from crater 004 were analyzed: Sample 004-1: Examination of the vitrified areas in the debris and the brown fused chunk; Samples 004-2 and -3: Examination of the glass crust residues on the cobble; Sample 004-4: Examination of the brown enamel residue.

Glass crust remains on cobbles 004-2 and 004-3 (for the other analyses see the Appendix)

The thickness of the glass layers is 300 to 400 µm. In qualitative tests, only those elements/oxides were identified that were then also measured quantitatively. The main components are SiO_2 , CaO and K_2 O. FeO and $Al2O_3$ are present in highly variable concentrations. The FeO contents are almost always clearly too high to consider vitrification in the context of old glass processing. At one location (004-2-C), the glass consists only of SiO_2 , CaO and K_2 O, apart from trace amounts of the other oxides. These analyses allow an estimation of the melting temperature in the corresponding three-substance system (Fig. 34). The components are normalized to 100 and entered in the triangular diagram. The melting temperature for this glass composition is therefore just under 1000°C, which can be regarded as a minimum for the temperature seen in these scoriae. A test of the composition of the boulders shows that sample 004-2 is a pure quartzite and sample 004-3 is an impure quartzite.

At least for sample 004-2, it can be ruled out that the glass crust was formed by in-situ melting of the rock. K_2O and CaO must have come from other, external sources. The same is probably also true for sample 004-3. This sample does contain some potassium feldspars, but these are vitrified directly in the rock, as in sample 004-1.

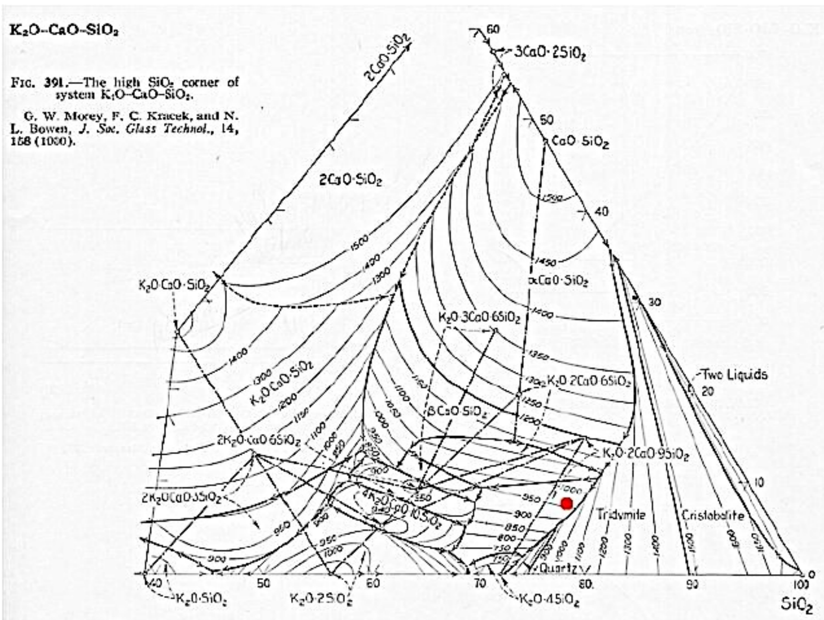


Fig. 34: Analysis 004-2-C in the three-component system SiO_2 - CaO - K_2O and minimum melting temperature (red dot).

3 Shock metamorphism

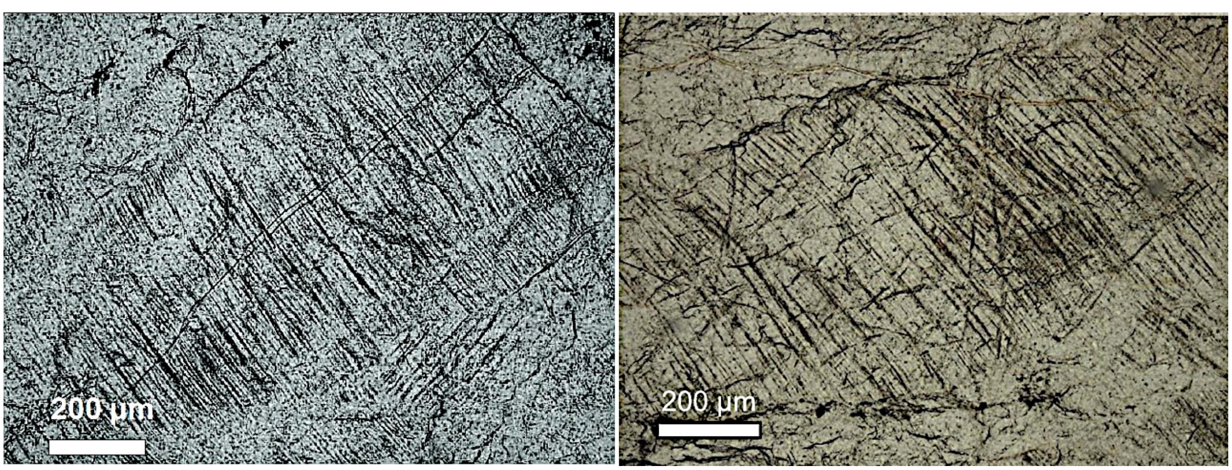


Fig. 35. Planar deformation features (PDFs) in quartz of the quartzite from sample 004-5, The slightly curved PDFs trace the plastically deformed crystal lattice of the quartz.

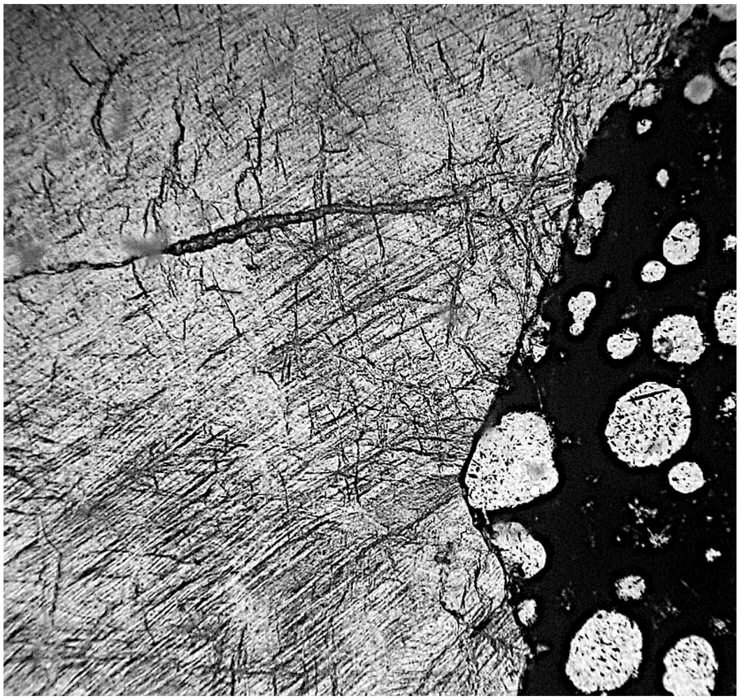


Fig. 36. Quartz with planar deformation features (PDFs) and sets of irregular discontinuous subparallel fractures in contact with dark vesicular glass. The slightly bent PDFs reflect a slightly deformed crystal lattice. Photomicrograph, plane parallel light, field width 480 µm. Gneiss from crater #004.

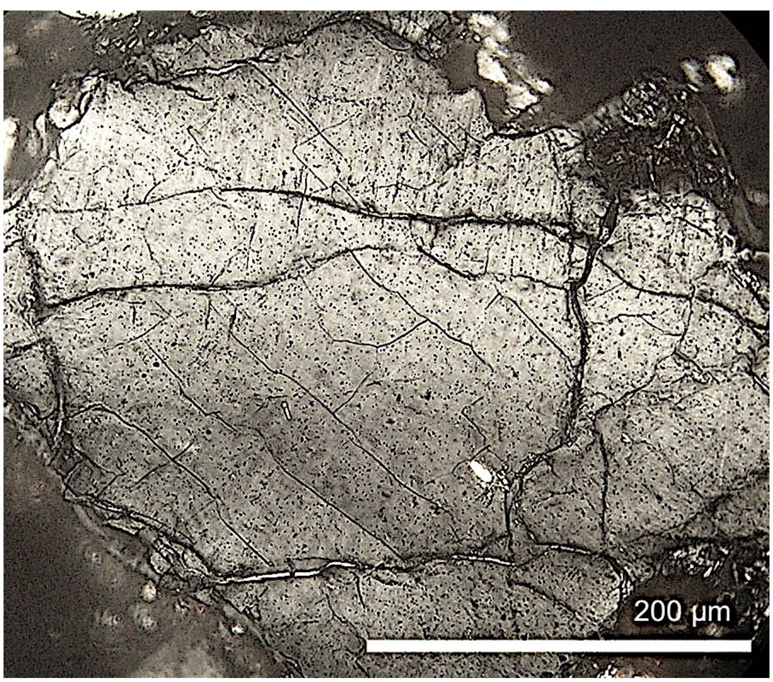


Fig. 37. Multiple sets of planar fractures (PF) and sets of faint PDF; quartz grain in gneiss from crater #004.

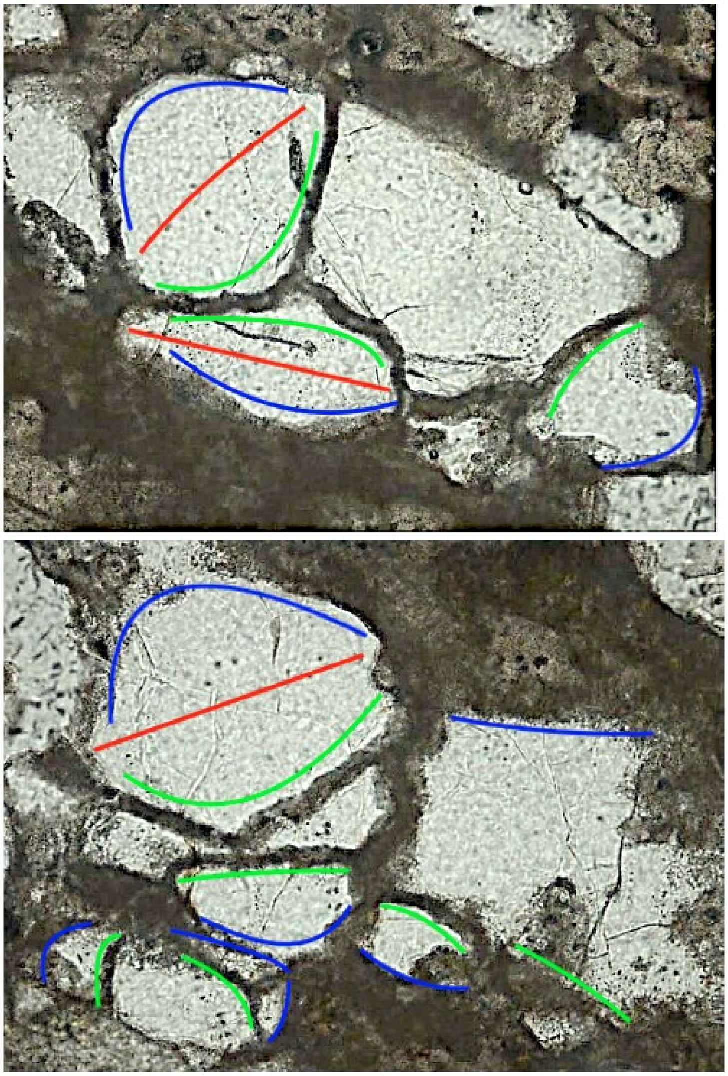


Fig. 38: Quartz grains with open glass-filled fractures cracked due to shock spallation, sample 004-10; field width ~ 0.8 mm. Note the approximate mirror symmetry (red) of fracture (green) and grain boundary (blue) geometries due to the reflection of the compressive shock and tensile pulses at the free grain boundaries. Photomicrographs, crossed polarizers.

4 Geophysics

4.1 Ground penetrating Radar (GPR)

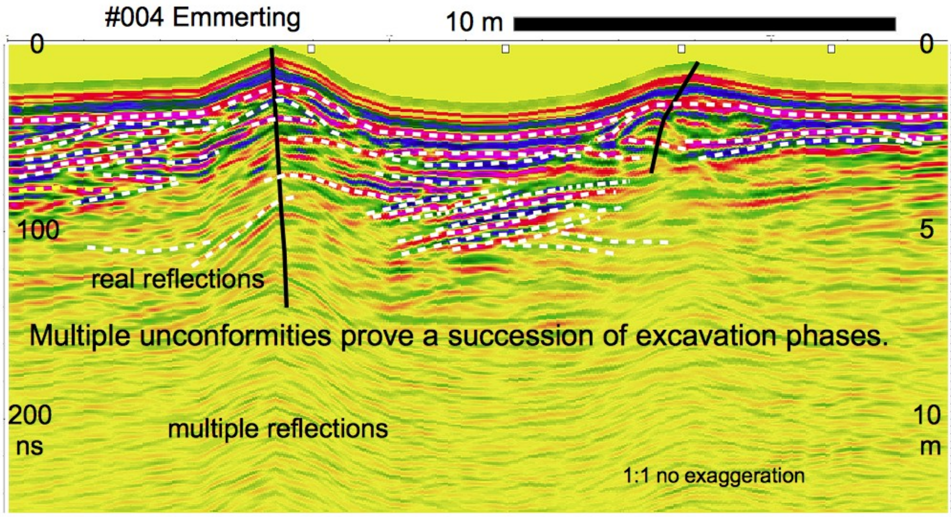


Fig. 39. Radargram across the #004 crater (25 MHz center frequency with modulated 200 MHz; field data from R. Tengler and P. Kalenda); data processing and interpretation J. Poßekel and K. Ernstson. Strong reflections down to a depth of 4-5 m prove extreme compression and/or sintering (drill core Fig. xy) of the clayey-gravelly layers due to extremely high temperatures. Any human activity (ice age, kilns) can be ruled out with absolute certainty - if only because of the strong shock effects. Attempt at an interpretation: Not an ordinary impact of a meteorite (far too high and widespread temperatures) but an explosion crater from an explosion near the earth's surface = ground touching airburst accompanying the comet impact (Moore et al. 2024).

Fig. 40. The Sünching crater established with the DGM 1 (to the right) outside the strewn ellipse for a nice comparison with the #004 crater (Fig. 31). Archeologists know this circular depression very well, which they attribute to a medieval Tower mound. GPR measurements (Transient Technologies, VIY3-300, 300 MHz antenna) tell a completely different story (Fig. 43).

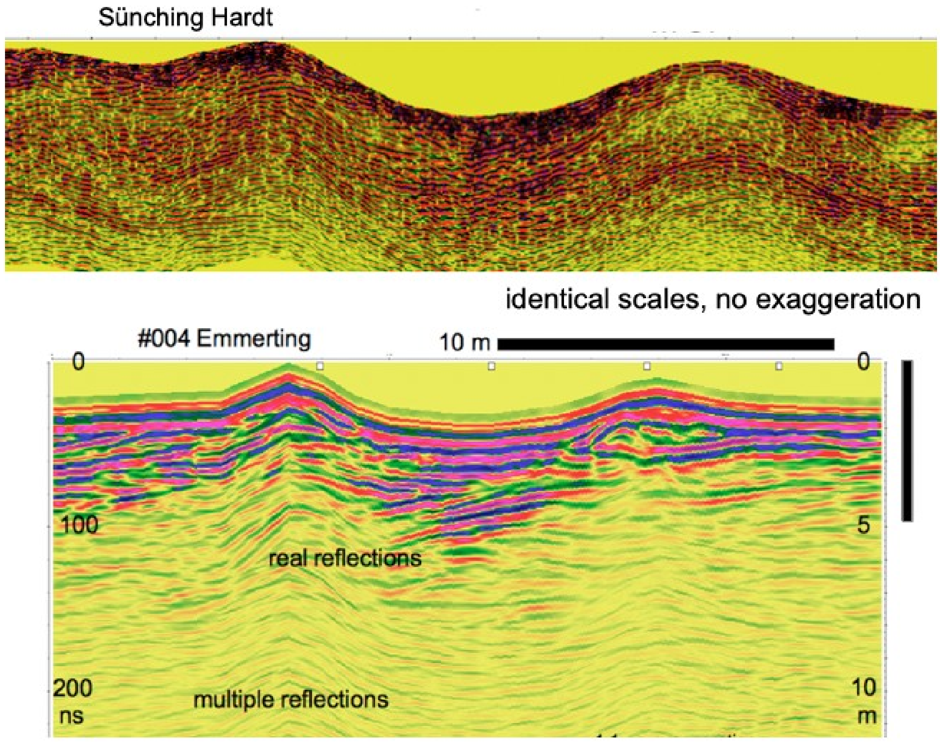


Fig. 41. Comparison of the #004 GPR (Fig. 30) with the Sünching profile, which, different, has been measured with a 300 MHz antenna. In both cases, real reflections are observed down to more than 5 m.

4.2 Geomagnetics

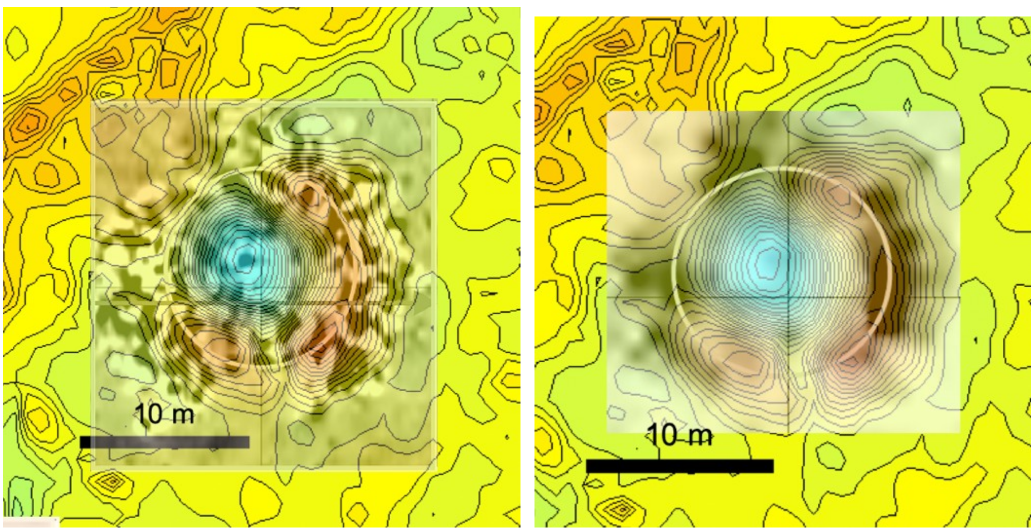


Fig. 42. The results of the early geomagnetic investigations at the #004 Emmerting crater, mapping from Rösler et al. (2006). Left: Checkerboard pattern of magnetic anomalies superimposed on the DGM 1 map. Vertical gradient of the vertical component from -10 nT/m (light) to +10 nT/m (black). Right: Volume-specific magnetic susceptibility of the soil surface, sampling interval 1 m x 1 m; 10^{-4} SI to 10^{-3} SI. The circle indicates the position of the crater rim wall.

3.2 Kaltenbach crater

The Kaltenbach crater had been known for a long time and was originally interpreted archaeologically. It was only with the beginning of impact hypothesis that it came to the attention of researchers and soon revealed the convincing impact inventory.

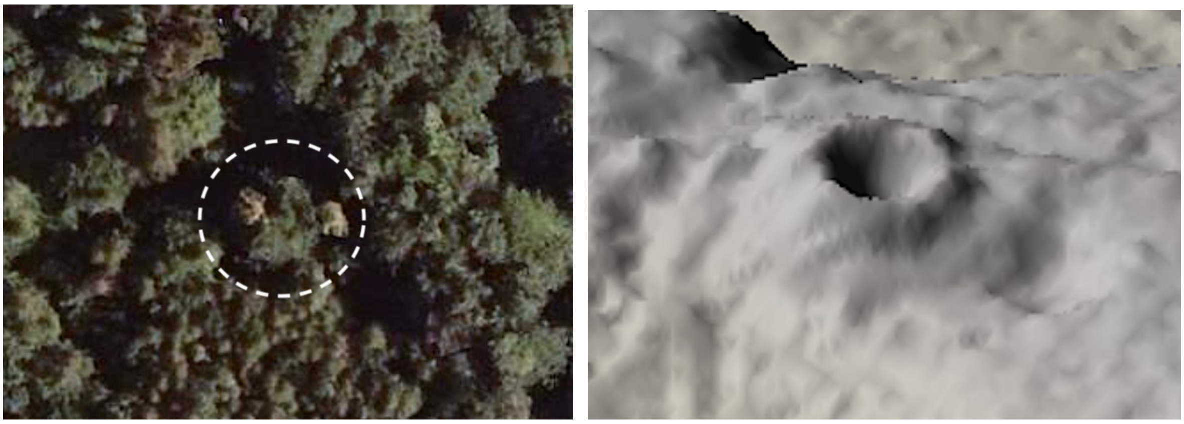


Fig. 43. The Kaltenbach crater in a forest, Google Earth, and the DGM 1, 3D terrain surface (strongly exaggerated). The images convey the tremendous potential of the digital terrain model, which sees the craters even in dense forests and reveals them for detailed morphological analysis.

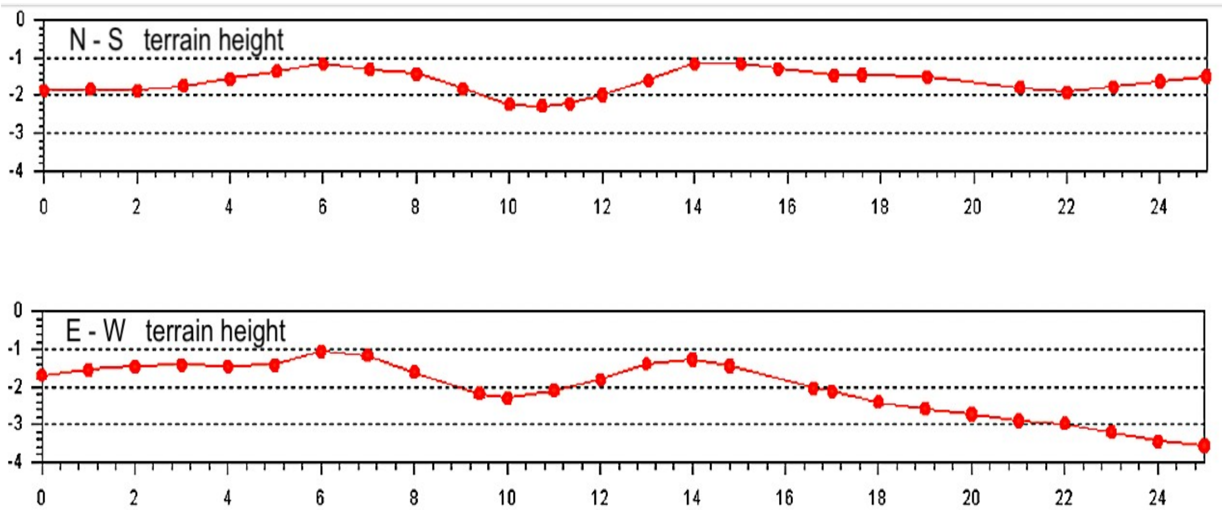


Fig. 44. Diametrical profiles across the Kaltenbach crater from optical leveling; without exaggeration. Also see Fig. 38.

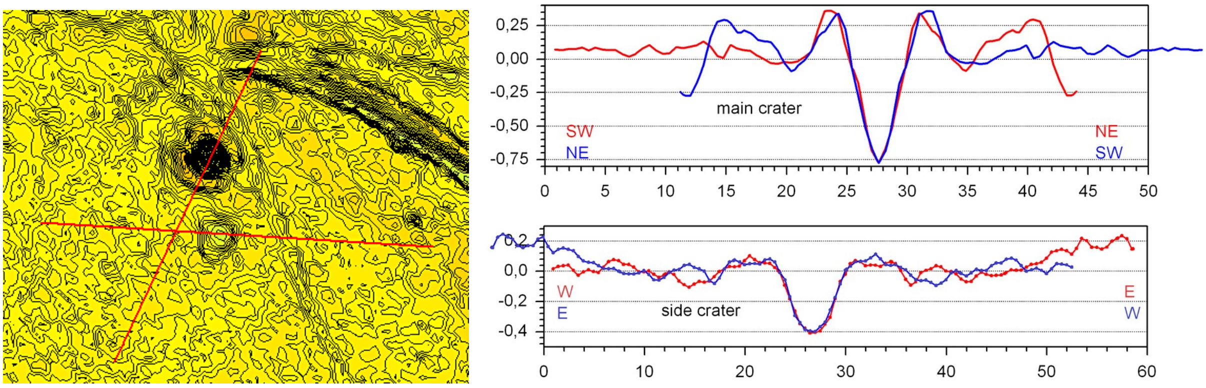


Fig. 45. The Kaltenbach crater and its side crater in the DGM 1 after subtraction of a trend field (soft moving average low-pass filter). The DGM 1 topographic profiles across the craters (red lines and curves) have been mirrored (blue lines) and superimposed to show the nearly perfect symmetry of crater depression and rim wall with centimeter precision. - Before the DGM 1 was used, the presence of a secondary side crater was completely unknown.

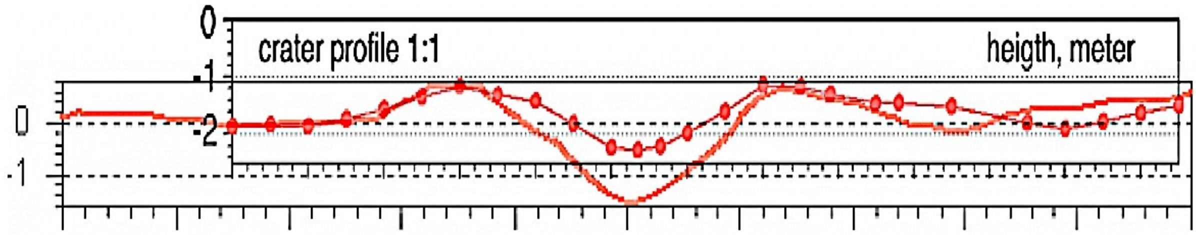


Fig. 46. Diametrical profile across the Kaltenbach cater: Comparison of the optical leveling (dot line) and the DGM 1 profile. The DGM 1 profile was measured before the deep excavation of the crater (Fig. 35) obviously seen in the later DGM 1 topography (line).

Fig. 47. Strongly magnetized limestone boulder uncovered near the center of the Kaltenbach crater.

Fig. 48. Kaltenbach crater: excavated impact melt rocks. Note the greenish millimeter-thin enamel crust similar to samples from the #004 Emmerting crater. Sizes about that of the lower right sample. Photos A. Neumair.

Geophysics - Geomagnetics

Fig 49. Geomagnetic measurements across the Kaltenbach crater with the EBINGER ETsmart Digital Fluxgate Gradiometer.

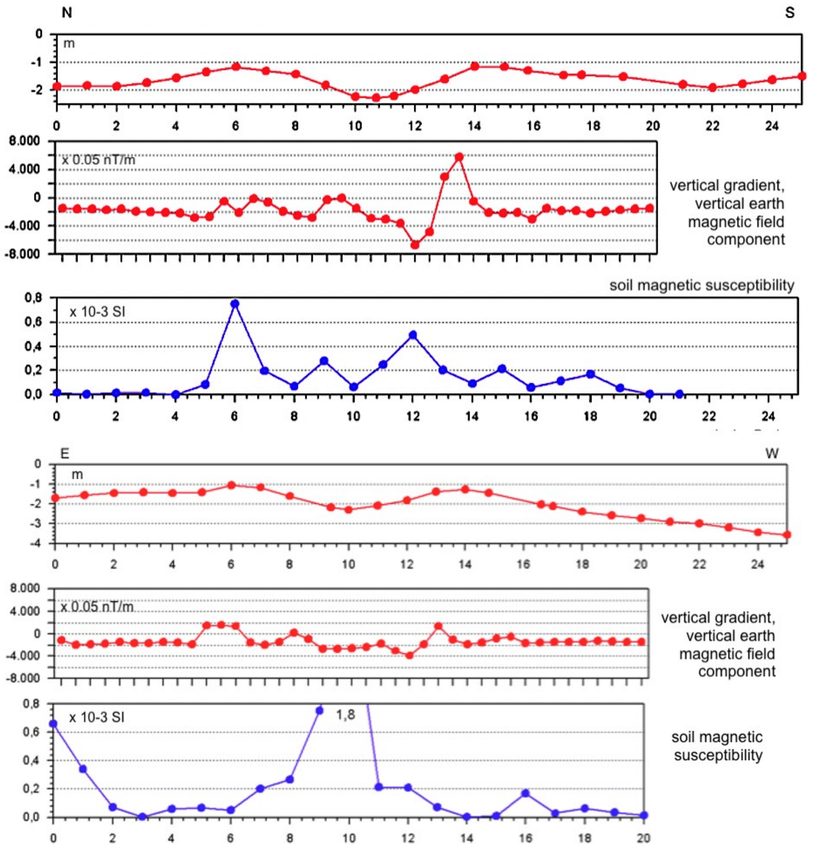


Fig. 50. Geomagnetic measurements across the Kaltenbach crater; topography (Fig. 32), field data and soil magnetic susceptibility.

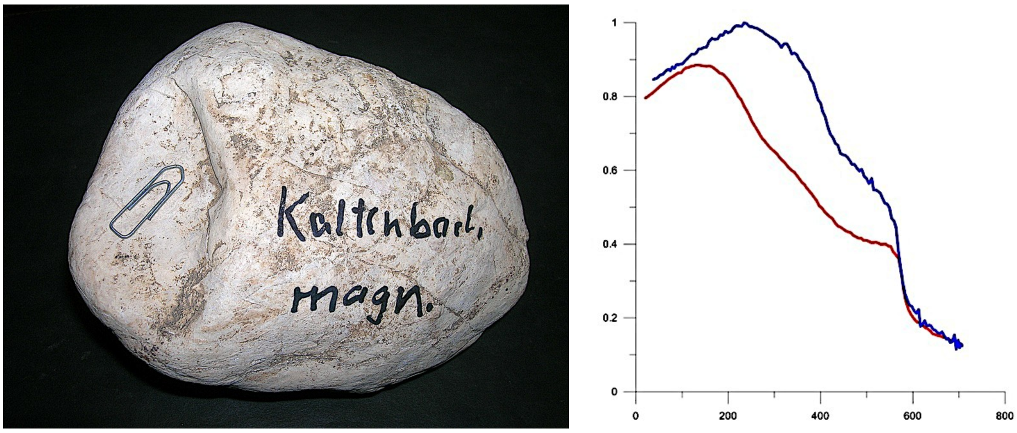


Fig. 51. Rock magnetic investigations of the limestone cobbles from the Kaltenbach crater (at the LIAG institute Göttingen, Dr. T. Wonik) show enormous magnetism with magnetic susceptibilities up to 1,400 * 10^{-5} SI (e.g., this limestone cobble). Measurements of the hysteresis curves (to the right) prove frequency dependence of the susceptibility (> 6%) pointing to superparamagnetic particles of micro and nano size of probably magnetite/titanomagnetite. We suggest that this extremely unusual magnetic behavior must be attributed to the impact and a related shock magnetization. For comparison, we

investigated susceptibilities of various Alpine limestone cobbles from local gravel pits and measured values of the order of 0.00005 x 10^{-5} SI.

3.3 Mauerkirchen crater

Fig. 52. The Mauerkirchen crater during an excavation campaign.

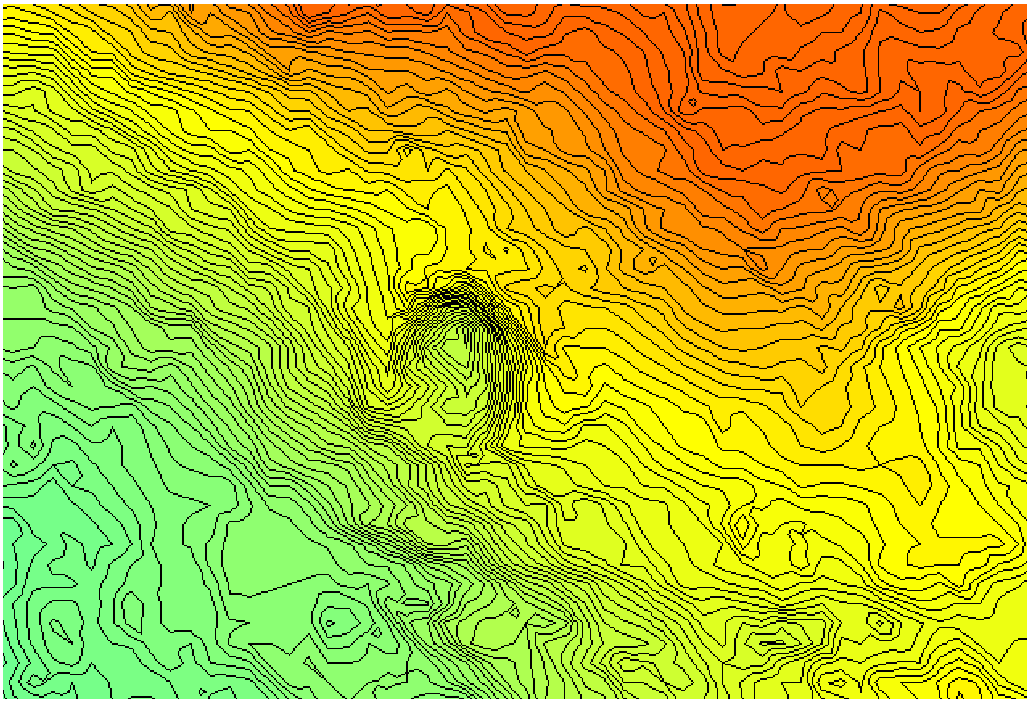


Fig. 53. The Mauerkirchen crater, DGM 1 topographic map; contour interval 5 cm.

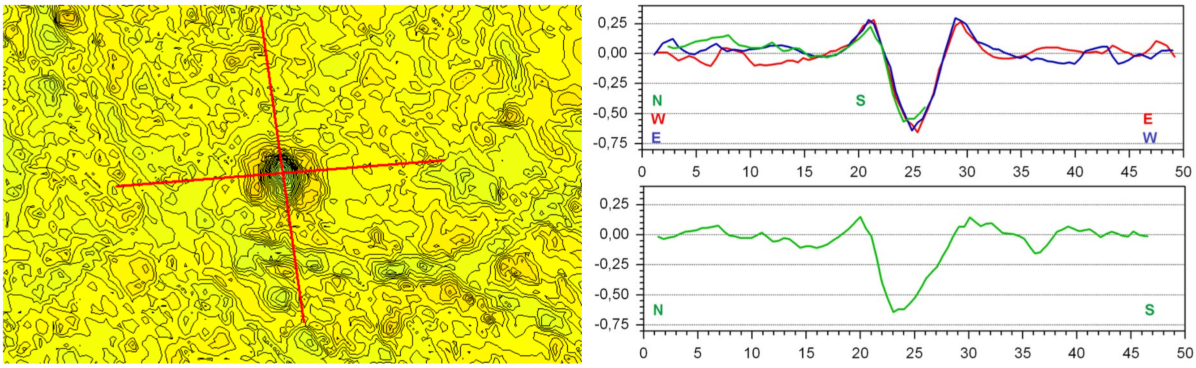


Fig. 54. The DGM 1 topography of the Mauerkirchen crater, morphology-centered by subtraction of a trend field in Fig. 41 (soft moving average low-pass filter). Note the perfect matching of the mirrored W-E profile (red and blue) and the northern section of the N - center profile (green) across crater depression and rim wall. The rim wall opening to the south is addressed in Fig. 55.

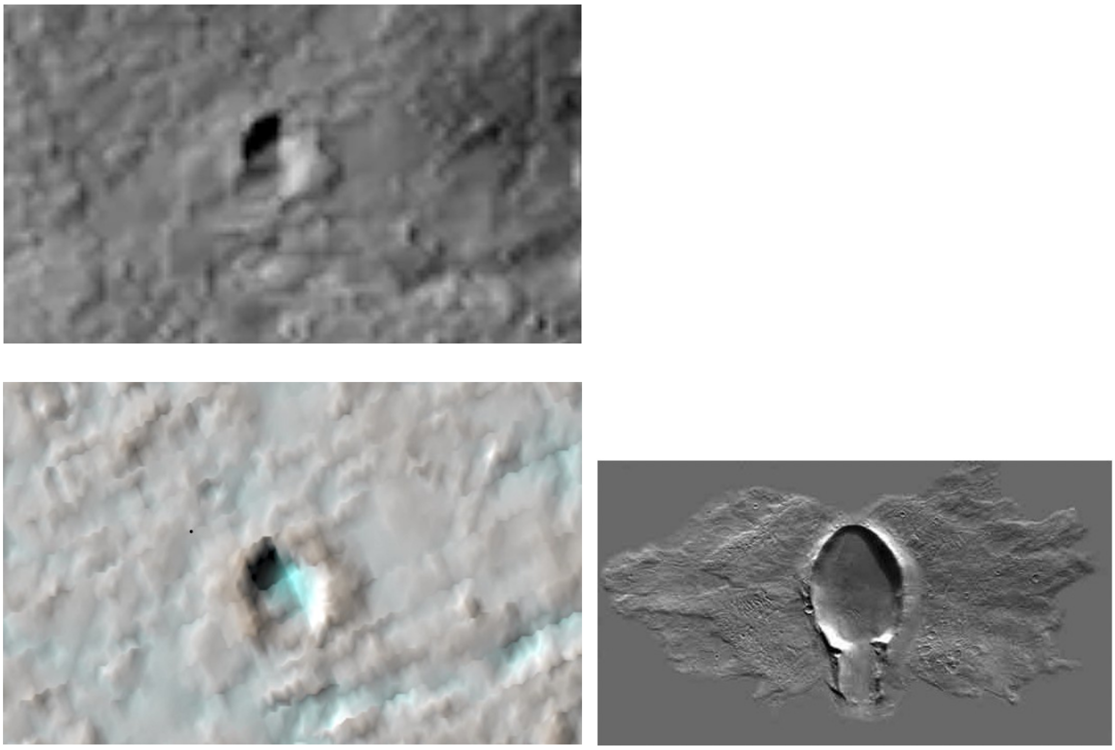
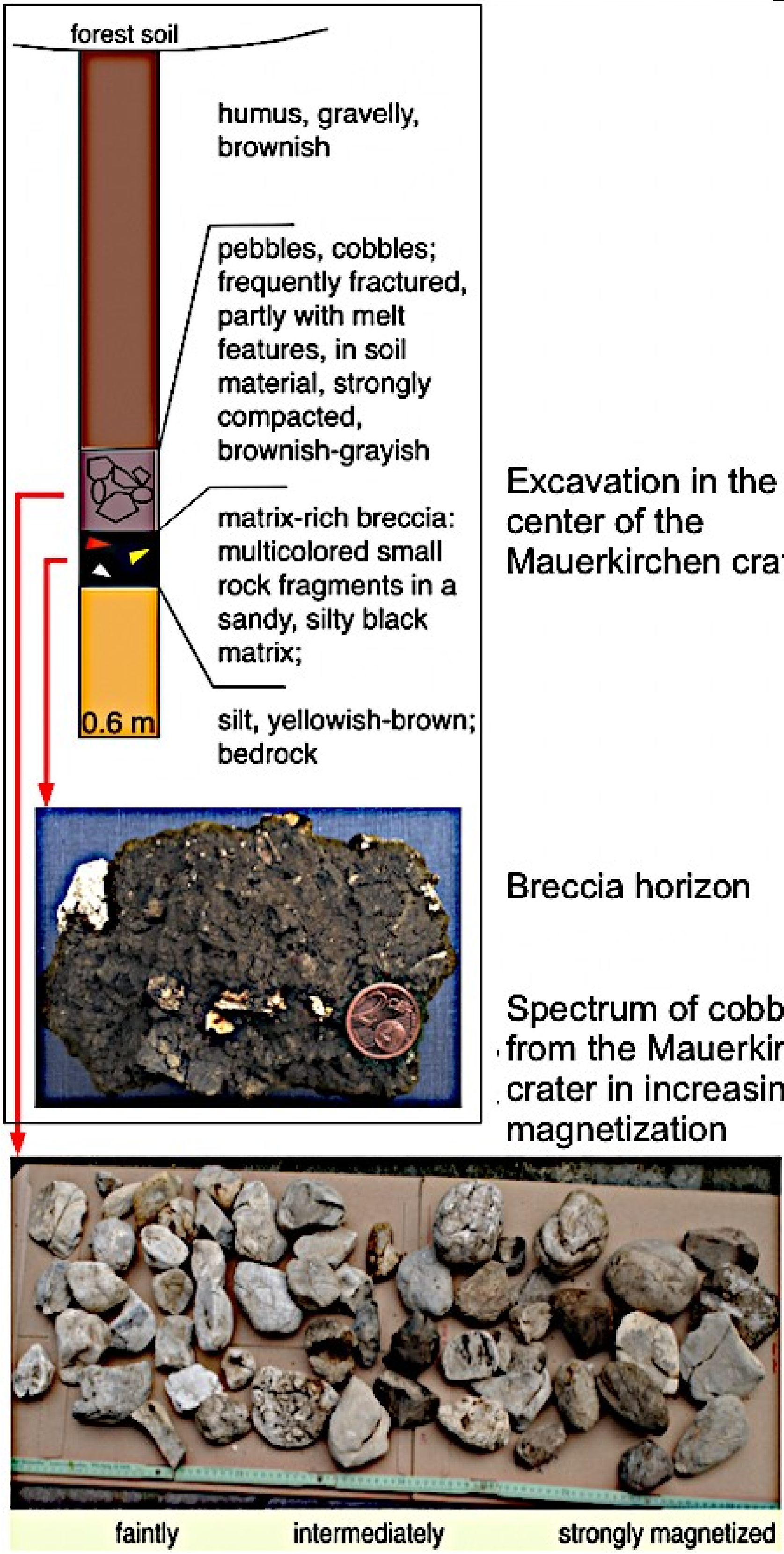


Fig. 55. The DGM 1 shadowed relief of the Mauerkirchen crater morphology (original, upper) and DGM 1 3D surface (centered, lower, slightly rotated counterclockwise). To the right for comparison: elongated unnamed Mars crater with butterfly ejecta, interpreted to have originated from a strongly oblique impact (Credit: NASA / JPL / ASU / mosaic by Emily

Lakdawalla). The same explanation may hold true for the Mauerkirchen crater and an impact from north-northeast.



Excavation in the center of the Mauerkirchen crater

Breccia horizon

Spectrum of cobbles from the Mauerkirchen crater in increasing magnetization

Fig. 56. Excavation in the center of the Mauerkirchen crater. Compared with the #004 Emmerting crater few melt rocks are found. Different from the #004 crater, both the Kaltenbach and Mauerkirchen craters lack an impressive melt rock halo.

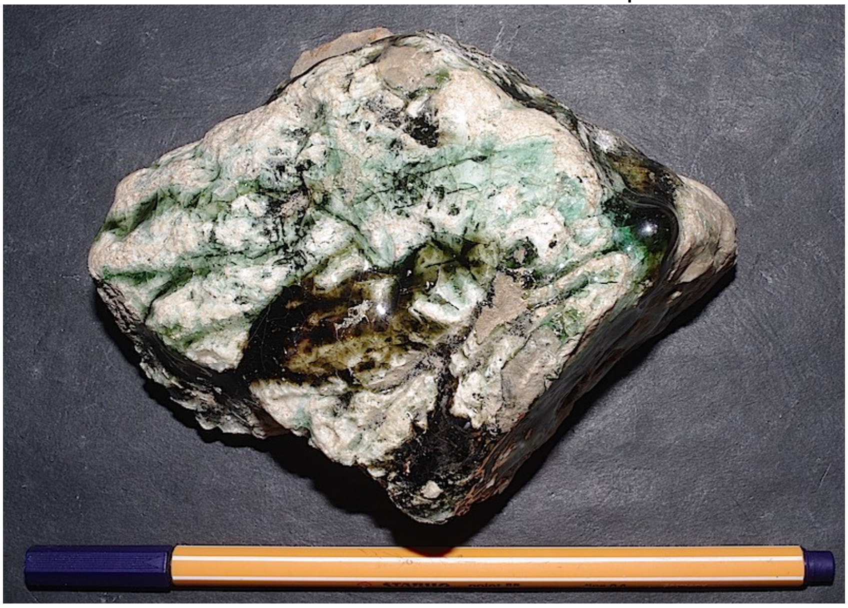


Fig. 57. One of the rare melt rock samples excavated from the Mauerkirchen crater.

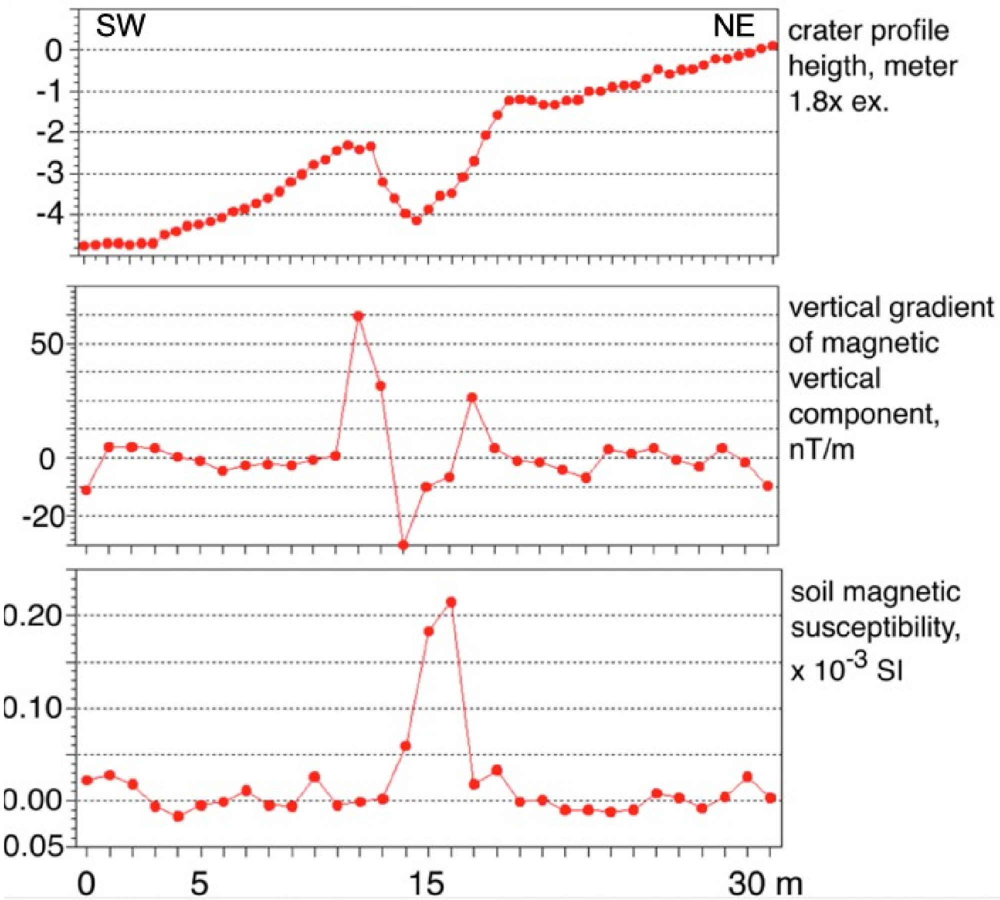


Fig. 58. Geomagnetic measurements across the Mauerkirchen crater; topography, field data and soil magnetic susceptibility. The magnetic signature closely resembles the Kaltenbach crater (Fig. 38).

4 Discussion and Conclusions

A good 20 years ago, a group of local researchers and amateur archeologists caused quite a stir in geological science with their widespread discoveries of the existence of the iron silicides gupeiite and xifengite, practically unknown on Earth, in connection with an accumulation of small, rim-walled craters, with the discussion of a comet impact in south-eastern Bavaria in Holocene times, to which the first scientific investigations contributed with great university interest. When a first publication in the British journal *Astronomy* (2004) caused a worldwide sensation in the media in 2004, this was followed by a counter-campaign from established impact research (Naturkundemuseum Berlin 2006), which blatantly denied the postulated impact as non-existent. The permanently articulated opposition in the following years to this day in the form of press releases, articles denying the impact with falsifying statements, and sometimes insulting reviews of submitted articles on the Chiemgau Impact.

With the exception of very few voices and comments from non-impact "experts", including geologists, the Chiemgau impact is considered established according to the publications listed at the beginning, although it continues to be ignored in the so-called impact community with its Canadian Earth Impact Database, which is not legitimized by anything (Claudin and Ernstson 2023).

In the years following the initial discovery and the documentation of the early findings, further investigations led to the discovery of additional and larger craters (Lake Tüttensee crater, a double crater at the bottom of Lake Chiemsee, the Eglsee crater with the dimensions of the Barringer crater in Arizona, USA), which ultimately made the Chiemgau impact probably the most significant Holocene impact event worldwide.

Several years ago, research into the Chiemgau impact was given a huge boost by the application and analysis of the extremely high-resolution digital terrain model, which can now be acquired online free of charge in the form of the original data sets for the entire crater strewn field and the closer and wider area around the crater strewn ellipse.

With this data and the enormous possibilities of modern graphics programs, impact research has led to a paradigm shift, which is justified in particular by the new findings on the Chiemgau impact and the widespread newly recognized impact fields in Central Europe between the Czech Republic and the Lorraine-French border (Poßekel et al. 2022).

While the Canadian database mentions around 200 names worldwide as established, apparently proven impact structures (which has been repeatedly criticized, e.g., Claudin and Ernstson 2023), a paradigm shift becomes clear with the simplest geological considerations together with the results of the digital terrain models that are now increasingly available in many countries. The key lies in the extreme resolution of the terrain surface, horizontally and vertically, down to the decimeter and centimeter range, whereby the DTM removes buildings and vegetation with sophisticated data processing, so that even in the densest forests the bare ground is recorded and made available to the user in corresponding data sets (x, y, z).

For impact research, it initially has the following consequences:

-- Crater or general impact traces are recognized even in the densest vegetation, such as in dense forests, probably also in jungle regions, or inaccessible swamp areas.
-- Extremely shallow crater structures with surrounding very shallow ring walls are seen.
-- Craters with completely new shapes such as central-peak craters, and terraced and wavy crater rims are described, as they are now published from the Moon and Mars (Rappenglück et al. 2021, Poßekel et al. 2022, Ernstson et al. 2024, Ernstson and Poßekel 2024).
-- Impact structures are recognized, which are observed during severe earthquakes and must therefore be attributed to the quakes triggered by impacts (Ernstson and Poßekel 2024; also see the Appendix).
-- Craters are described that are geologically very young and, due to their extreme flatness, are subject to geological erosion and sedimentation and quickly disappear again. This effect must of course be thought back into the geological past.
-- The newly conceived considerations and hypotheses on airburst impacts in connection with comets and asteroids and a focus on so-called touchdown airburst impacts (West et al.2024) cannot be better supported than by the new observations with the digital terrain model.

The conclusions can be kept brief. The impact evidence recently claimed by some Czech researchers for the Chiemgau impact (Procházka 2023, Procházka et al. 2024) , which has been scientifically investigated and extensively published for a good 20 years, is dishonest and can only be described as poor scientific style.

The absolute ignorance of this phenomenal impact event in impact databases worldwide and even in recent publications (e.g., Brenker and Junge 2023) underlines the backward-looking nature of the traditional so-called impact community, which is completely closed to new developments in its field of research. The *Impact Cratering Committee* set up by the Meteoritical Society in 2023 (https://meteoritical.org/society/leadership/impact-cratering-committee) , which is preparing a new database of terrestrial impact structures, leaves little hope for a real new beginning in international impact research with regard to the published group founder names.

References

Astronomy (2004) Did the Celts see a comet impact in 200 B.C.? https://www.astronomy.com/science/did-the-celts-see-a-comet-impact-in-200-b-c/

Bauer, F., Hiltl, M., Rappenglück, M.A, Ernstson, K. (2020): An eight kilogram chunk and more: evidence for a new class of iron silicide meteorites from the Chiemgau impact strewn field (SE Germany). – Modern Problems of Theoretical, Experimental, and Applied Mineralogy (Yushkin Readings – 7-10 December 2020, Syktyvkar, Russia), Proceedings, 359-360. https://verein.chiemgau-impakt.de/wp-content/uploads/2020/07/Papers-2020-Yushkin-Readings.pdf

Bauer, F., Hiltl, M., Rappenglück, M.A, Ernstson, K. (2019): Trigonal and Cubic FE2SI Polymorphs (Hapkeite) in the Eight Kilograms Find of Natural Iron Silicide from Grabenstätt

(Chiemgau, Southeast Germany). – 50th Lunar and Planetary Science Conference, Poster, Abstract #1520, LPI Contrib. 2132. https://www.hou.usra.edu/meetings/lpsc2019/pdf/1520.pdf, Posterhttps://www.hou.usra.edu/meetings/lpsc2019/eposter/1520.pdf

Bauer, F. Hiltl, M., Rappenglück, M.A., Neumair, A., K. Ernstson, K. (2013): Fe2Si (Hapkeite) from the subsoil in the alpine foreland (Southeast Germany): is it associated with an impact? – 76th Annual Meteoritical Society Meeting, Meteoritics & Planetary Science, Volume 48, Issue s1, Abstract #5056. – Abstract

Brenker, F.E., Junge, A.. (2023) Impact origin of the “Domaine du Meteore”-crater, France. Compelling mineralogical and geophysical evidence for an unrecognized destructive event in the heart of Europe. – 54th LPSC, #1910.

Claudin, F. M. and Ernstson, K. (2023) The Canadian Earth Impact Database, Wikipedia and the Azuara and Rubielos de la Cérida (Spain) Impact Case. - MetSoc Meeting 2023 Los Angeles, DOI: 10.13140/RG.2.2.35749.68329.

Ernstson, K. (2016): Evidence of a meteorite impact-induced tsunami in lake Chiemsee (Southeast Germany) strengthened. – 47th Lunar and Planetary Science Conference, 1263.pdf. Abstract https://www.hou.usra.edu/meetings/lpsc2016/pdf/1263.pdf.

Ernstson, K. and Poßekel, J. (2024) The Chiemgau Meteorite Impact Strewn Field and the Digital Terrain Model: "Earthquake" Liquefaction from Above and from Below. - AGU Fall Meeting 2024, submitted.

Ernstson, K. and Poßekel, J. (2024) Paradigm shift in impact research: the Holocene Chiemgau meteorite impact crater strewn field and the digital terrain model. - Lunar & Planetary Science Conference LPSC 2024.

Ernstson, K, Poßekel, J., and Rappenglück, M.A. (2024) Mars and Moon on earth - Lunar & Planetary Science Conference LPSC 2024.

Ernstson, K., Bauer, F., Hiltl, M. (2023) A Prominent Iron Silicides Strewn Field and Its Relation to the Bronze Age/Iron Age Chiemgau Meteorite Impact Event (Germany). Earth Sciences. Vol. 12, No. 1, pp. 26-40. doi: 10.11648/j.earth.20231201.14 – Open access –

Ernstson, K., Sideris, C., Liritzis, I., Neumair, A. (2012): The Chiemgau meteorite impact signature of the Stöttham archaeological site (southeast Germany). – Mediterranean Archaeology and Archaeometry, 12, 249-259.

Ernstson, K., Mayer, W., Neumair, A., Rappenglück, B., Rappenglück, M.A., Sudhaus, D. and Zeller, K.W. (2010): The Chiemgau crater strewn field: evidence of a Holocene large impact in southeast Bavaria, Germany. – Journal of Siberian Federal University, Engineering & Technology, 1 (2010 3) 72-103.

Ernstson and Poßekel 2017, 2020 a, b, 2024

Ernstson, K., Poßekel, J. (2020) Complex Impact Cratering in a Soft Target: Evidence from Ground Penetrating Radar (GPR) for Three Structures in the Chiemgau Meteorite Impact Strewn Field, SE Germany (1.3 km-Diameter Eglsee, 250 m-Diameter Riederting, 60 m-Diameter Aiching). – Fall Meeting, AGU, online, 1-17 Dec. Abstract EP036-0005. https://agu.confex.com/agu/fm20/meetingapp.cgi/Paper/677731

K. Ernstson, J. Poßekel (2020): Digital terrain model (DTM) topography of small craters in the Holocene Chiemgau (Germany) meteorite impact strewnfield. – 11th Planetary Crater Consortium 2020 (LPI Contrib. 2251), Abstract #2019. https://www.chiemgau-impakt.de/wp-content/uploads/2020/06/PCC-2019.pdf

K. Ernstson, J. Poßekel (2017): Meteorite Impact „Earthquake“ Features (Rock Liquefaction, Surface Wave Deformations, Seismites) from Ground Penetrating Radar (GPR) and Geoelectric Complex Resistivity/Induced Polarization (IP) Measurements, Chiemgau (Alpine Foreland, Southeast Germany). – 2017 Fall Meeting, AGU, New Orleans, 11-15 Dec. Abstract EP53B-1700 https://agu.confex.com/agu/fm17/meetingapp.cgi/Paper/216911, Poster https://www.chiemgau-impakt.de/wp-content/uploads/2017/08/Poster-2017-AGU.pdf

K. Ernstson, J. Poßekel, M. A. Rappenglück (2020): Near-ground airburst cratering: petrographic and ground penetrating radar (GPR) evidence for a possibly enlarged Chiemgau Impact event (Bavaria, SE-Germany). – 50th Lunar and Planetary Science Conference, Poster, Abstract #1231. https://www.hou.usra.edu/meetings/lpsc2020/pdf/1231.pdf, Poster https://www.hou.usra.edu/meetings/lpsc2020/eposter/1231.pdf

Ernstson, K., Hilt, M., Neumair, A.: Microtektite-Like Glasses from the Northern Calcareous Alps (Southeast Germany): Evidence of a Proximal Impact Ejecta . – 45th Lunar and Planetary Science Conference, held 17-21 March, 2014 at The Woodlands, Texas. LPI Contribution No. 1777, p.1200. – Abstract

Ernstson, K., Müller, W., Neumair, A. (2013): The proposed Nalbach (Saarland, Germany) impact site: is it a companion to the Chiemgau (Southeast Bavaria, Germany) impact strewn field? – 76th Annual Meteoritical Society Meeting, Meteoritics & Planetary Science, Volume 48, Issue s1, Abstract #5058. – Abstract

Ernstson, K. & Neumair, A. (2011), Geoelectric Complex Resistivity Measurements of Soil Liquefaction Features in Quaternary Sediments of the Alpine Foreland, Germany, Abstract NS23A-1555 presented at 2011 Fall Meeting, AGU, San Francisco, Calif., 5-9 Dec. Abstract

K. Ernstson, T. G. Shumilova (2020): Chiemite — a high PT carbon impactite from shock coalification/carbonization of impact target vegetation. – Modern Problems of Theoretical, Experimental, and Applied Mineralogy (Yushkin Readings – 7-10 December 2020, Syktyvkar, Russia), Proceedings, 363-365. https://verein.chiemgau-impakt.de/wp-content/uploads/2020/07/Papers-2020-Yushkin-Readings.pdf

K. Ernstson, T. G. Shumilova, S. I. Isaenko, A. Neumair, M. A. Rappenglück (2013): From biomass to glassy carbon and carbynes: evidence of possible meteorite impact shock coalification and carbonization. – Modern problems of theoretical, experimental and applied mineralogy (Yushkin Memorial Seminar–2013): Proceedings of mineralogical seminar with international participation. Syktyvkar: IG Komi SC UB RAS, 2013. 546 p. . – Abstract

Hiltl, M., Bauer, F., Ernstson, K., Mayer, W., Neumair, A., & Rappenglück, M.A. (2011). SEM and TEM analyses of minerals xifengite, gupeiite, Fe2Si (hapkeite?), titanium Carbide (TiC) and cubic moissanite (SiC) from the subsoil in the Alpine Foreland: Are they cosmochemical? 42nd Lunar and Planetary Science Conference, Abstract #1391.

Hoffmann, V., Rösler, W., Patzelt, A., & Raeymaekers, B. (2005). Characterisation of a small crater-like structure in SE Bavaria, Germany. 68th Annual Meteoritical Society Meeting, Gatlinburg, Abstract #5158. Access: https://www.lpi.usra.edu/meetings/metsoc2005/pdf/download/alpha_g-i.pdf

Hoffmann, V., Tori, M., Funaki, M. (2006). Peculiar magnetic signature of Fe-Silicide phases and dia- mond/fullerene containing carbon spherules. Travaux Géophysiques XXVII - Abstracts of the 10th „Castle Meeting“ – New Trends in Geomagnetism, Paleo, Rock and Environmental Magnetism, 52–53.

Impact Cratering Committee (2023). - Meteoritical Society https://meteoritical.org/society/leadership/impact-cratering-committee

S. Isaenko, T. Shumilova, K. Ernstson, S. Shevchuk, A. Neumair, and M. Rappenglück: Carbynes and DLC in naturally occurring carbon matter from the Alpine Foreland, South-East Germany: Evidence of a probable new impactite. – European Mineralogical Conference, Vol. 1, EMC2012-217, 2012., European Mineralogical Conference 2012. Abstract

Liritzis, N. Zacharias, G.S. Polymeris, G. Kitis, K. Ernstson, D. Sudhaus, A. Neumair, W. Mayer, M.A. Rappenglück, B. Rappenglück (2010): THE CHIEMGAU METEORITE IMPACT AND TSUNAMI EVENT (SOUTHEAST GERMANY): FIRST OSL DATING. – Mediterranean Archaeology and Archaeometry, Vol. 10, No. 4, pp. 17- 33.

Naturkundemuseum Berlin (2006) Press Release and Comment by CIRT (Chiemgau Impact Research Team). - https://www.chiemgau-impakt.de/pdfs/erwiderung.pdf (in German).

Neumair, A., Ernstson, K. (2013): Peculiar Holocene soil layers: evidence of possible distal ejecta deposits in the Chiemgau region, Southeast Germany – 76th Annual Meteoritical Society Meeting, Meteoritics & Planetary Science, Volume 48, Issue s1, Abstract #5057. – Abstract.

J. Poßekel, K. Ernstson (2020): Not just a rimmed bowl: Ground penetrating radar (GPR) imagery of small caters in the Holocene Chiemgau (Germany) meteorite impact strewn field. – 11th Planetary Crater Consortium 2020 (LPI Contrib. 2251), Abstract #2014. https://www.chiemgau-impakt.de/wp-content/uploads/2020/06/PCC-2040.pdf

J. Poßekel, K. Ernstson (2019): Anatomy of Young Meteorite Craters in a Soft Target (Chiemgau Impact Strewn Field, SE Germany) from Ground Penetrating Radar (GPR)

Measurements. – 50th Lunar and Planetary Science Conference, Abstract #1204, LPI Contrib. 2132. https://www.hou.usra.edu/meetings/lpsc2019/pdf/1204.pdf, Poster https://www.hou.usra.edu/meetings/lpsc2019/eposter/1204.pdf

Poßekel, J., Molnár. M., and Ernstson, K. (2022) The Proposed Meteorite Impact Event in the Czech Republic: Evidence Strengthened by Investigations with the Digital Terrain Model. - Lunar & Planetary Science Conference LPSC 2022, DOI: 10.13140/RG.2.2.17849.65123.

Procházka, V. (2023) Melt behavior in two impact craters at Emmerting, Germany: Deformation, expansion, injections, and the role of underpressure and mutual collisions of pebbles. - 54th Lunar and Planetary Science Conference.

Procházka. V, Herrmann, H., Kalenda, P., Martinec, P., Mizera, J., Trojek, T., Thinová, L., Kletetschka, G., Adámek, J., and Souček, K. Comparison of Melting-Affected Rocks from Presumed Small Impact Craters and Old Limekilns in Bavaria, Germany. - Preprints.org (www.preprints.org) NOT PEER-REVIEWED Posted: 22 March 2024 doi:10.20944/preprints202403.1373.v1.

Prochazka, V., & Trojek, T. (2017). XRF- and EMP- investigation of glass coatings and melted domains of pebbles from craters in Chiemgau, Germany. 48th Lunar and Planetary Science Conference, Abstract #2401. Access: https://www.hou.usra.edu/meetings/lpsc2017/pdf/2401.pdf

Rappenglück, B., Hiltl, M., Ernstson, K. (2021) The Chiemgau Impact: evidence of a Latest Bronze Age/Early Iron Age meteorite impact in the archaeological record, and resulting critical considerations of catastrophism. In: Beyond Paradigms in Cultural Astronomy, BAR international series: Vol. 3033, C. González-García, R. M. Frank, L. D. Sims, M. A. Rappenglück, G. Zotti, J. A. Belmonte, andI. Šprajc (ed.), Oxford, Great Britain, BAR, pp. 57–64.

Rappenglück, B., Hiltl, M., Rappenglück, M. A., Ernstson, K. (2020b) The Chiemgau Impact — a meteorite impact in the Bronze¬/Iron Age and its extraordinary appearance in the archaeological record. In: Himmelswelten und Kosmovisionen — Imaginationen, Modelle, Weltanschauungen: Proceedings der Tagung der Gesellschaft für Archäoastronomie in Gilching, 29-31 März 2019, G. Wolfschmidt (ed.), Hamburg, tredion, pp. 330–349.

B. Rappenglück, M. Hiltl, K. Ernstson (2020a): Exceptional evidence of a meteorite impact at the archaeological site of Stöttham (Chiemgau, SE-Germany). In: Draxler, Sonja, Lippisch, Max E. (eds.) Harmony and Symmetrie. Celestial regularities shaping human cultures. – Proceedings of the 26th Annual Meeting of the European Society of Astronomy in Culture, August 27 – September 2018, Graz, Oxford: BAR publishing.

B. Rappenglück, M. Hiltl, K. Ernstson (2020): Artifact-in-impactite: a new kind of impact rock. Evidence from the Chiemgau meteorite impact in southeast Germany. – Modern Problems of Theoretical, Experimental, and Applied Mineralogy (Yushkin Readings – 7-10 December 2020, Syktyvkar, Russia), Proceedings, 365-367.

https://verein.chiemgau-impakt.de/wp-content/uploads/2020/07/Papers-2020-Yushkin-Readings.pdf
Rappenglück, B., Hiltl, M., Poßekel, J., Rappenglück, M. A., Ernstson, K. (2023) People experienced the prehistoric Chiemgau meteorite impact – geoarchaeological evidence from southeastern Germany: a review. Mediterranean Archaeology and Archaeometry. Vol. 23, No. 1, pp. 209-234. doi: 10.5281/zenodo.7775799 – Open Access –

B. Rappenglück, M. Hiltl, K. Ernstson (2020): Artifact-in-impactite: a new kind of impact rock. Evidence from the Chiemgau meteorite impact in southeast Germany. – Modern Problems of Theoretical, Experimental, and Applied Mineralogy (Yushkin Readings – 7-10 December 2020, Syktyvkar, Russia), Proceedings, 365-367. https://verein.chiemgau-impakt.de/wp-content/uploads/2020/07/Papers-2020-Yushkin-Readings.pdf

B. Rappenglück, M. Hiltl, K. Ernstson (2020c): The Chiemgau Impact: evidence of a Latest Bronze Age/Early Iron Age meteorite impact in the archaeological record, and resulting critical considerations of catastrophism. – 25th Annual Meeting of the European Association of Archaeologists, Bern, 4-7 September 2019, Oxford: BAR publishing. (Reviewed and accepted, forthcoming).

B. Rappenglück, M. Hiltl, K. Ernstson (2019): Metallic Artifact Remnants in a Shock-Metamorphosed Impact Breccia: an Extended View of the Archeological Excavation at Stöttham (Chiemgau, SE-Germany) – 50th Lunar and Planetary Science Conference, Poster, Abstract #1334, LPI Contrib. 2132. https://www.hou.usra.edu/meetings/lpsc2019/pdf/1334.pdf,-Poster. -https://www.hou.usra.edu/meetings/lpsc2019/eposter/1334.pdf

Barbara Rappenglück, Kord Ernstson, Ioannis Liritzis, Werner Mayer, Andreas Neumair, Michael Rappenglück and Dirk Sudhaus (2012): A prehistoric meteorite impact in Southeast Bavaria (Germany): tracing its cultural implications. – 34th International Geological Congress, 5-10 August 2012 – Brisbane, Australien. Abstract

Barbara Rappenglück, Michael A. Rappenglück, Kord Ernstson, Werner Mayer, Andreas Neumair, Dirk Sudhaus & Ioannis Liritzis (2010): The fall of Phaethon: a Greco-Roman geomyth preserves the memory of a meteorite impact in Bavaria (south-east Germany). – Antiquity, 84, 428-439.

Rappenglück, B., Ernstson, K., Mayer, W., Neumair, A. Rappenglück, M.A., Sudhaus, D., and Zeller, K.W.: The Chiemgau impact: An extraordinary case study for the question of Holocene meteorite impacts and their cultural implications. – In: Belmonte, J. A. (ed.), Proceedings of the International Conference on Archaeoastronomy, SEAC 16th 2008 "Cosmology across Cultures. Impact of the Study of the Universe in Human Thinking", Granada September 8-12, 2008, A.S.P. Conf. Ser., 2009.

Rappenglück, B. and Rappenglück, M.A. (2006): Does the myth of Phaethon reflect an impact? – Revising the fall of Phaethon and considering a possible relation to the Chiemgau Impact. – Mediterranean Archaeology and Archaeometry, Proceedings of the International

Conference on Archaeoastronomy, SEAC 14th 2006, „Ancient watching of cosmic space and observation of astronomical phenomena“, Vol. 6, No. 3 (2006), 101-109.

Rappenglück, M. A., Poßekel, J., and Ernstson, K. (2021) Mars and Moon on earth: formation of small terraced impact craters and ground penetrating radar investigations. - 12th Planetary Crater Consortium Meeting 2021.

Michael A. Rappenglück, Frank Bauer, Kord Ernstson, Michael Hiltl: Meteorite impact on a micrometer scale: iron silicide, carbide and CAI minerals from the Chiemgau impact event (Germany). – Problems and perspectives of modern mineralogy (Yushkin Memorial Seminar–2014) Proceedings of mineralogical seminar with international participation Syktyvkar, Komi Republic, Russia 19–22 May 2014.. – Abstract

M. Rappenglück, B. Rappenglück, K. Ernstson (2017): Kosmische Kollision in der Frühgeschichte. Der Chiemgau-Impakt: Die Erforschung eines bayerischen Meteoritenkrater-Streufelds. – Zeitschrift für Anomalistik, Band 17, 235 -260. English translation: https://pdfs.semanticscholar.org/0b62/4ca79c834edc46c86e1fa575c70f726608c8.pdf?_ga=2.133770253.2003692324.1598954865-1676338455.1598954865

Rappenglück, M.A., Bauer, F. Hiltl, M., Neumair, A., K. Ernstson, K. (2013): Calcium-Aluminium-rich Inclusions (CAIs) in iron silicide matter (Xifengite, Gupeiite, Hapkeite): evidence of a cosmic origin – 76th Annual Meteoritical Society Meeting, Meteoritics & Planetary Science, Volume 48, Issue s1, Abstract #5055. – Abstract

Rösler, W., Patzelt, A., Hoffmann, V., and Raeymaekers, B. (2006): Characterisation of a small craterlike structure in SE Bavaria, Germany. - European Space Agency First International Conference on Impact Cratering in the Solar System. ESTEC, Noordwijk , The Netherlands, 812 May.

Rösler, W., Hoffmann, V., Raeymaekers, B., Schryvers, D., & Popp, J. (2005). Carbon spherules with dia- monds in soils. Paneth Kolloquium, Abstract PC2005 #026. Access: http://www.paneth.eu/ PanethKolloquium/Archive_files/PanethKolloquium_2005.pdf 2006

Schryvers, D., & Raeymaekers, B. (2005). EM characterisation of a potential meteorite sample. Proceedings of EMC, Antwerp, vol. II, 859–860.Schüssler, U., Rappenglück, M. A., Ernstson, K., Mayer, W., Rappenglück, B. (2005). Das Impakt-Krater-Streufeld im Chiemgau. European Journal of Mineralogy, 17(1), 124.

U. Schüssler, Michael A. Rappenglück, K. Ernstson, W. Mayer & B. Rappenglück (2005): Das Impakt-Kraterstreufeld im Chiemgau. – Eur. J. Mineral. 17, Beih. 1: 124.

T. G. Shumilova, S. I. Isaenko, V. V. Ulyashev, B. A. Makeev, M. A. Rappenglück, A. A. Veligzhanin, K. Ernstson (2018): Enigmatic Glass-Like Carbon from the Alpine Foreland, Southeast Germany: A Natural Carbonization Process. – Acta Geologica Sinica (English Edition), Vol. 92, Issue 6, 2179-2200. https://onlinelibrary.wiley.com/doi/10.1111/1755-6724.13722

Shumilova, T. G., Isaenko S. I., Makeev B. A., Ernstson K., Neumair A., Rappenglück M. A.: Enigmatic Poorly Structured Carbon Substances from the Alpine Foreland, Southeast Germany: Evidence of a Cosmic Relation. 43nd Lunar and Planetary Science Conference (2012), 1430.pdf. Abstract.

Yang, Z. Q., Verbeeck, J., Schryvers, D., Tarcea, N., Popp, J., & Rösler, W. (2008). TEM and Raman charac- terisation of diamond micro- and nanostructures in carbon spherules from upper soils. Diamond & Related Materials, 17, 937–943.

APPENDIX

Digital Terrain Models DGM 1, topographic maps and profiles, in the surroundings of the #004 Emmerting, Kaltenbach and Mauerkirchen craters.

The compilation shows the enormous variability of shapes in the small craters in a selection out of far more structures in the three areas. Short descriptions of each are added. In the cases where an overlay of red and blue profile lines is shown, the often almost perfect symmetry of the structures is conveyed down to the centimeter range (as can already be seen in the main text section), which reasonably excludes anthropogenic and known geological processes of formation.

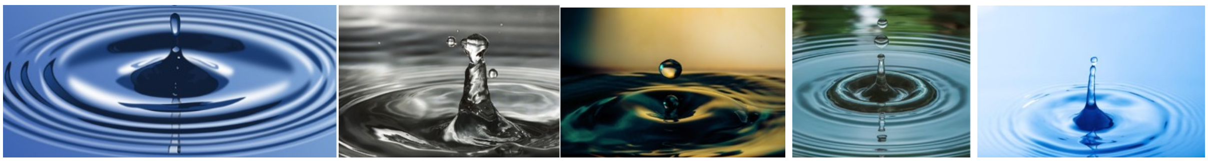
It is important to remember that all maps and derived profiles are the result of data processing. The original topographic maps are subjected to an elimination of a terrain trend with the calculation of a simple low-pass filter (areal moving average). The difference between the original field and the trend field creates a kind of zero-centering of the surface, on which smaller structures of interest with their detailed morphologies can be analyzed much better.

When calculating the difference with a trend field, it should be noted that there is no single, unambiguous solution. Geophysicists are familiar with this when they use various possible methods to derive a so-called regional field from the measured field, for example gravimetry, and subtract this from the original field in order to obtain the so-called residual field as an object of interest for further processing. It is obvious that the original field is a superposition of the regional field with the residual field and, as mentioned, a clear separation is not possible, but this can be influenced by the construction and choice of the regional field. Exactly this process can be transferred to the evaluation of the digital terrain model, depending on whether relatively small or larger impact objects are of interest.

Coordinates are not given for good reasons, to make it more difficult for rock hunters to plunder and destroy important and interesting structures, which has happened in the past when excavations were observed in published craters covered with extensive tarpaulins.

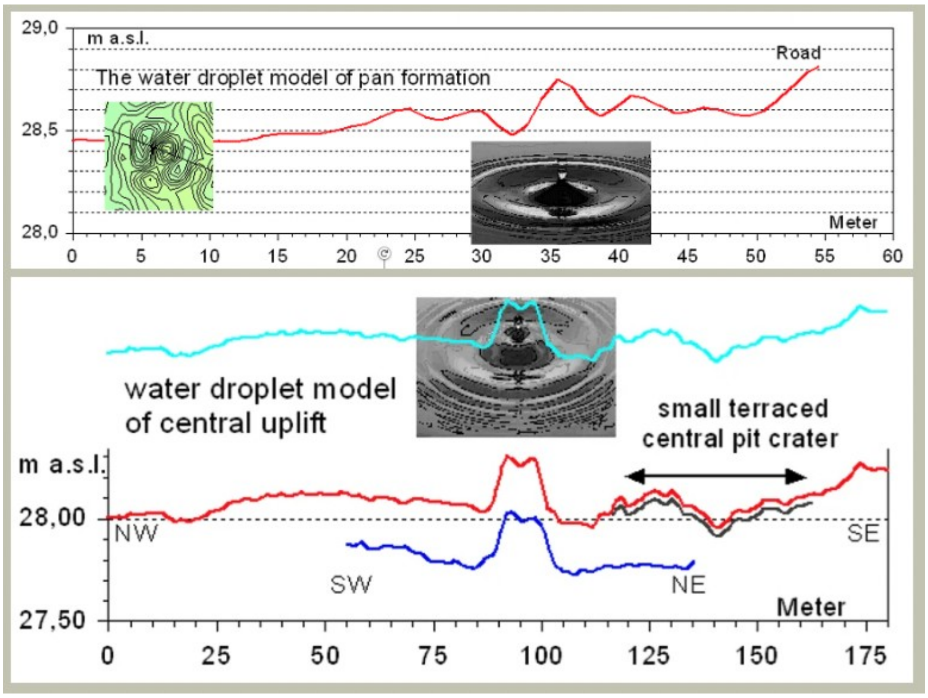
General considerations

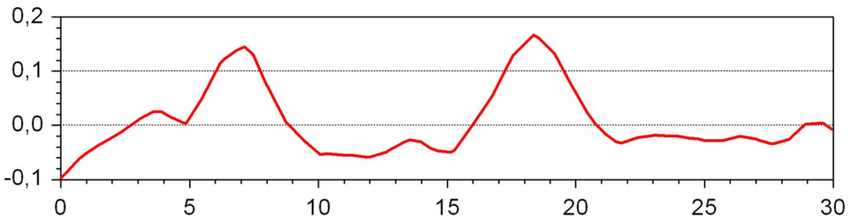
It is interesting to note that many of the impact craters discussed here bear a striking resemblance to the impact of water droplets on a water surface, which can also be observed for other liquids (e.g. oil). The comparison, of course, concerns snapshots of water with the formation of a transient crater with undulating rings and with the momentary formation of a central uplift that collapses. Different stages of these water droplet snapshots can be recognized almost congruently during impacts into the subsurface, where the corresponding snapshots remain like frozen.

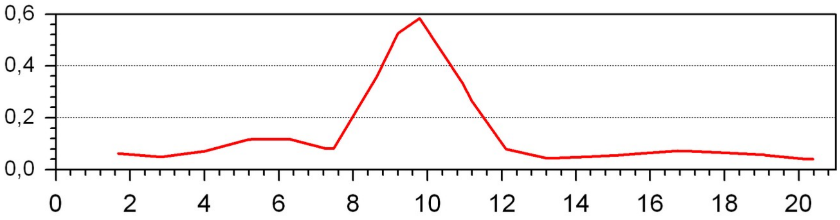


Water droplets. Free source: https://pixabay.com/de/images/search/wassertropfen/, and source: Drop Stock photos by Vecteezy

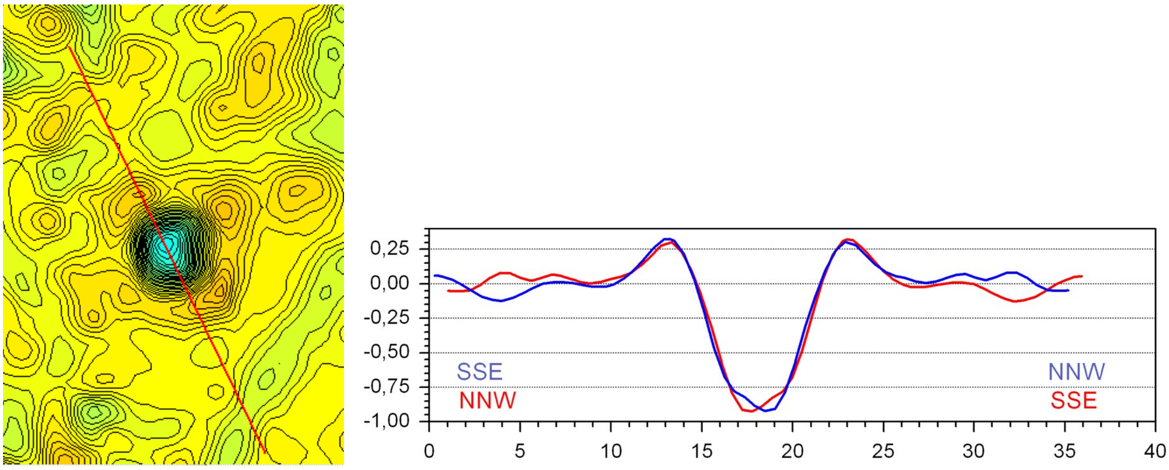
It remains open for discussion which phase of the snapshots depends on which parameters, and here projectile mass and impact velocity, but above all the subsurface properties such as material, strength and water content must be mentioned. All of this together probably determines perhaps the most important aspect of the water drop model, and that is the rock or soil liquefaction known from severe earthquakes, which is already discussed elsewhere (Ernstson and Poßekel 2024). Here, the comparison of the water droplet model with soil liquefaction during impact becomes particularly clear (see images below).



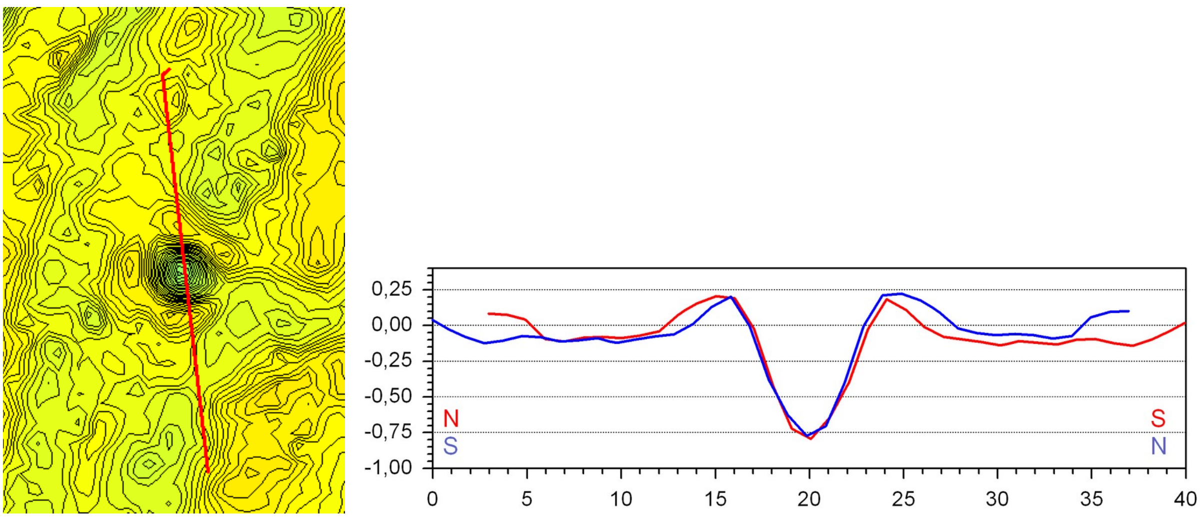




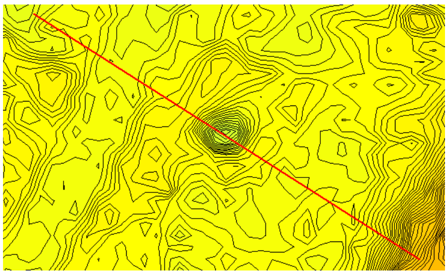
Emmerting field

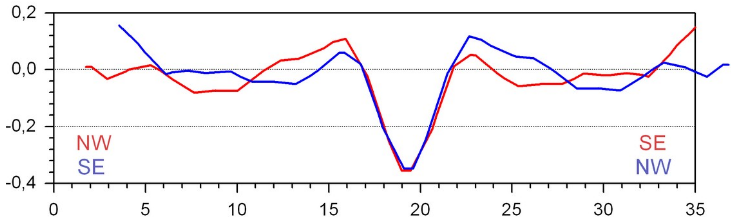


Emmerting Siedlung; wavy outer rim; mirrored profiles differ by centimeters only.

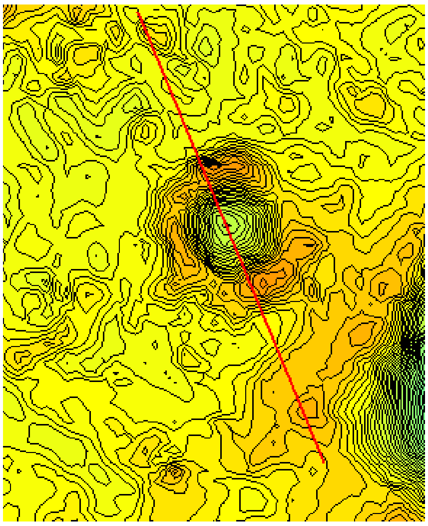


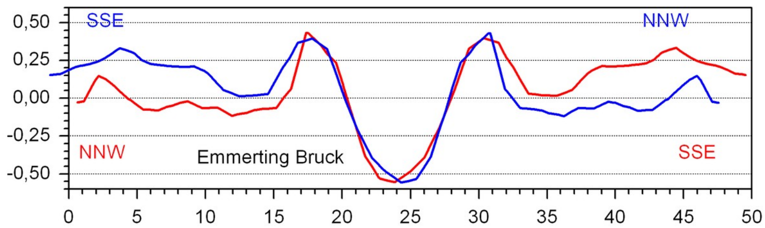
Emmerting #005 crater. Similar to Emmerting Siedlung crater.



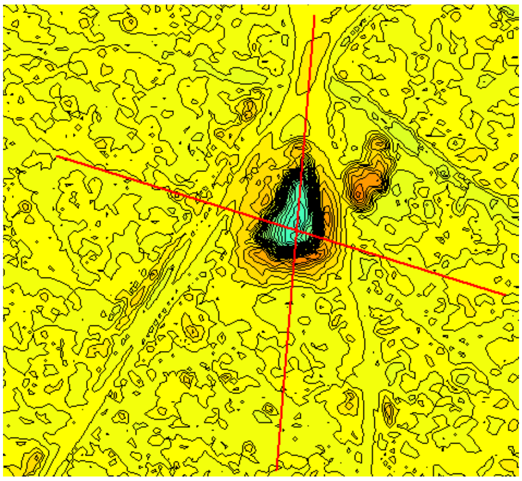


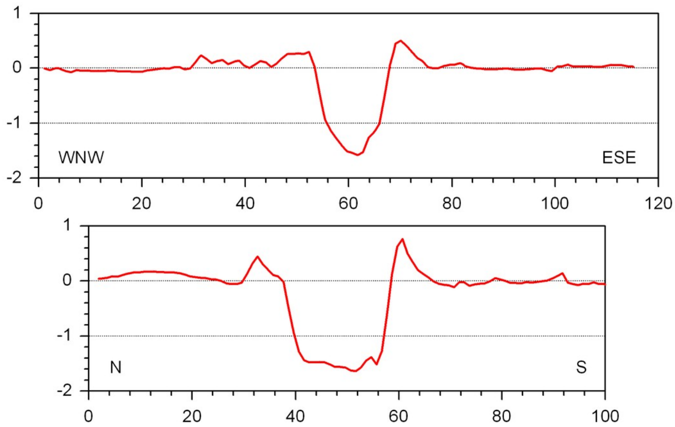
Emmerting, north of #005.



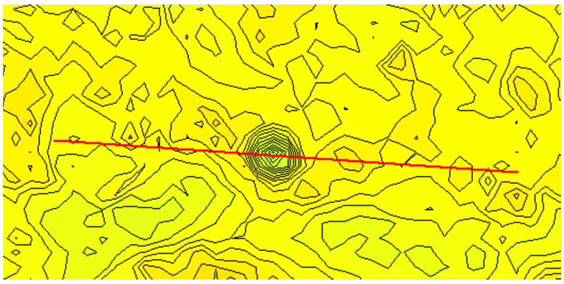


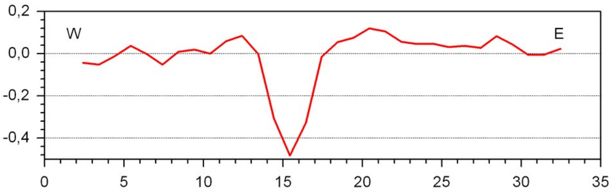
Emmerting Bruck. Wavy pan crater.



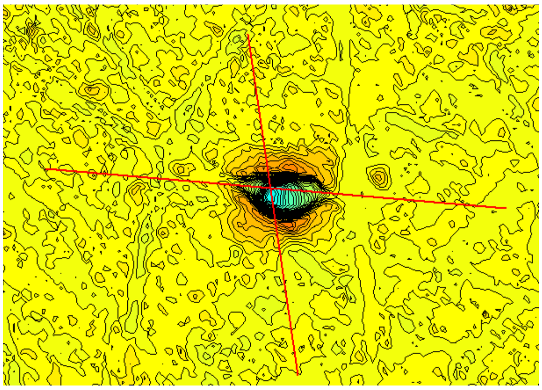


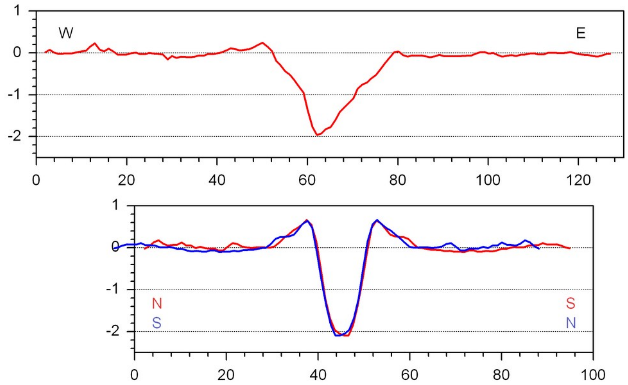
Emmerting, tile north, multiple impact, pear-shaped, a form that is frequently observed and may point to a multiple broken projectile or a strongly oblique impact.



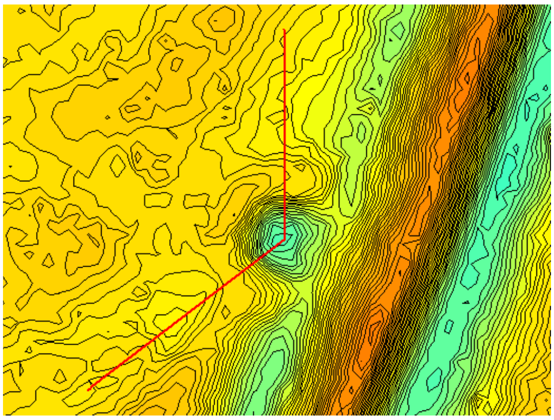


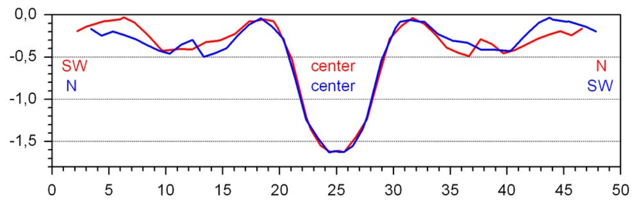
Emmerting, tile north, wavy outer rim.



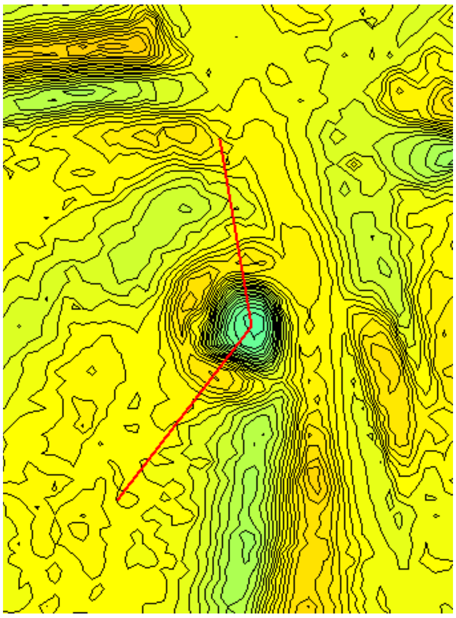


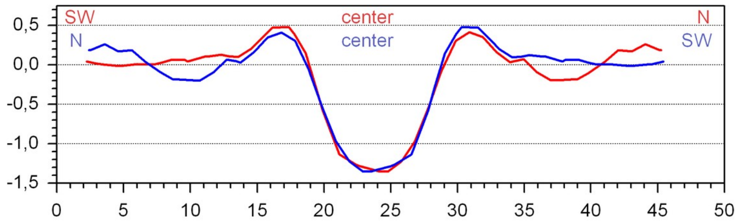
Emmerting, tile north, multiple impact of a broken projectile.



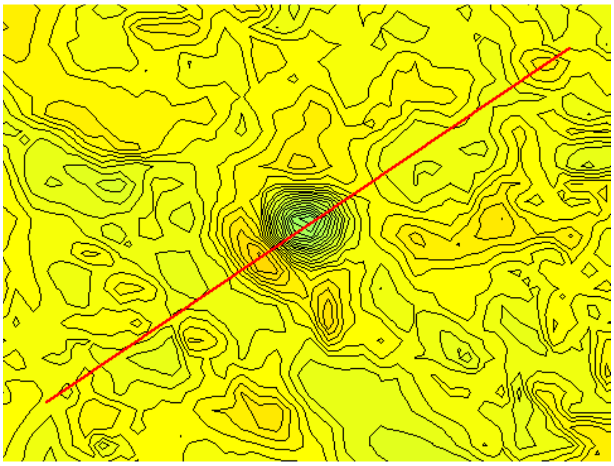


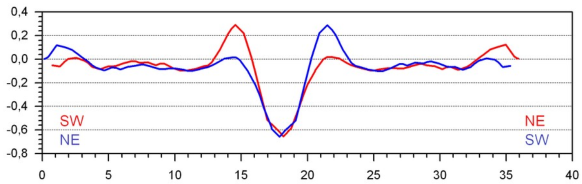
Laubergraben 3; droplet pan crater.



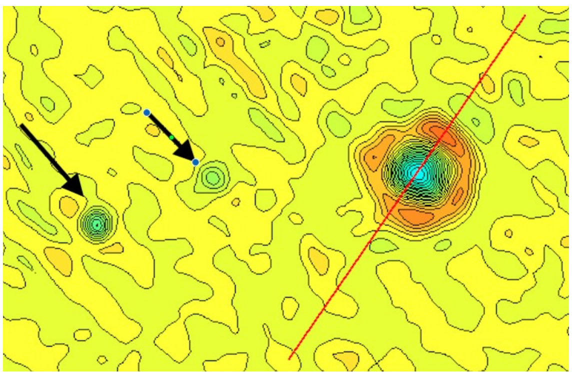


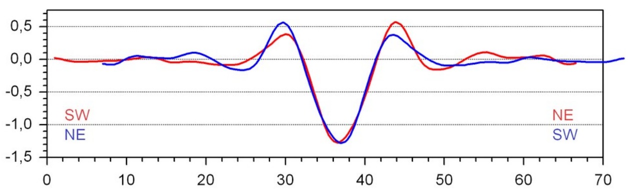
Laubergraben 2; similar to Laubergraben 3.





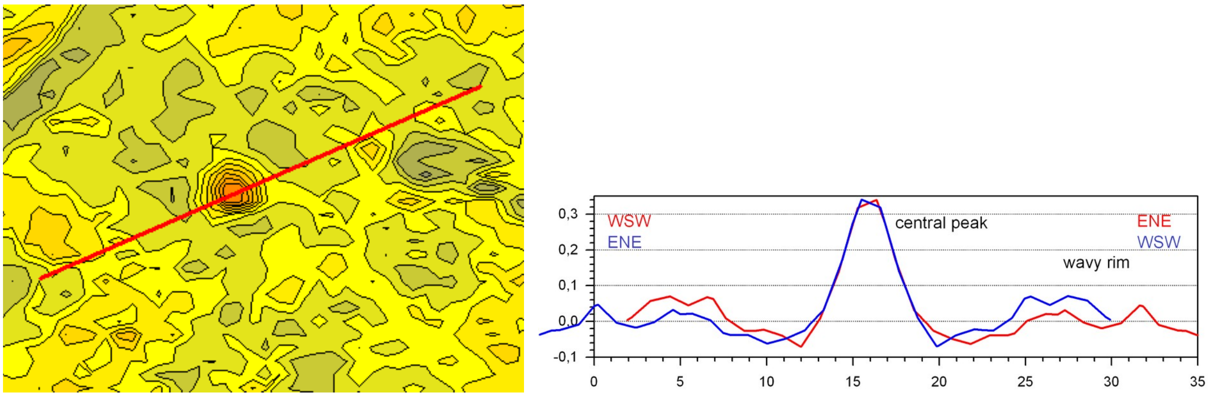
Unteremmerting Nachtgeräumt 2; slightly wavy larger pan crater.



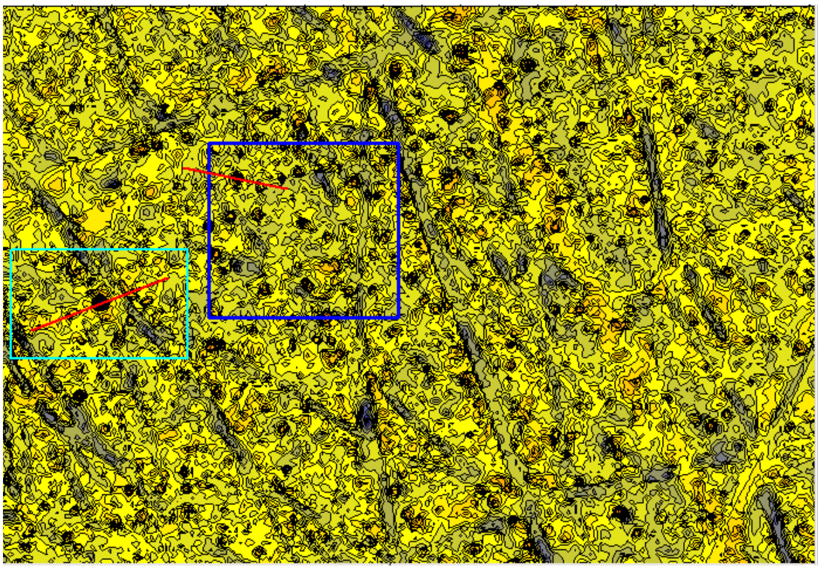


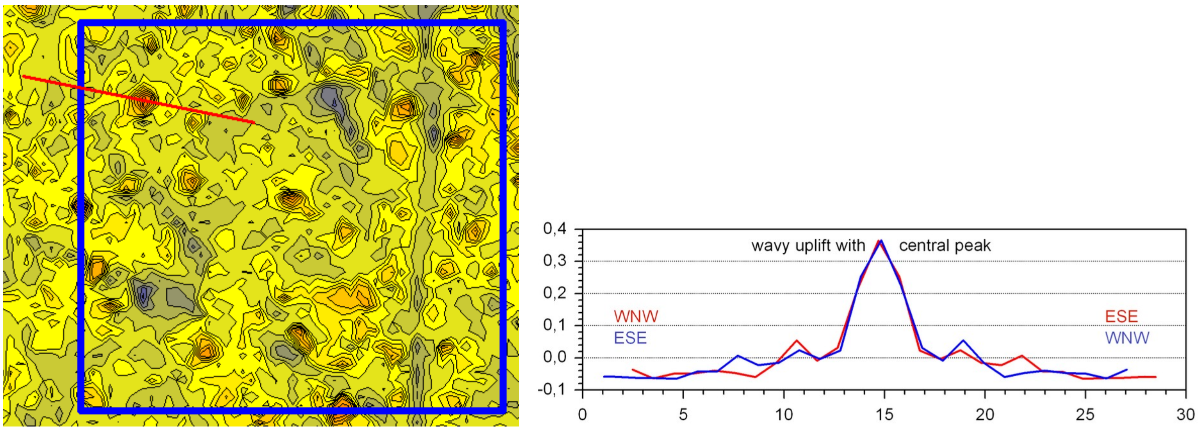
Einsiedleiche and two side craters. slightly wavy pan crater.

Emmerting water droplet craters

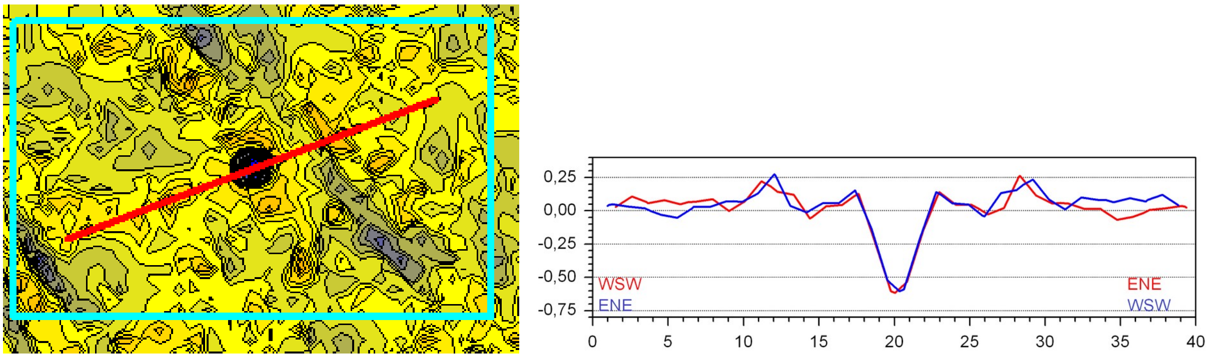


Emmerting west, water droplet 1; distinct peak in a pronounced wavy pan crater.


A densely pockmarked forest area near Emmerting with dominating boil structures.

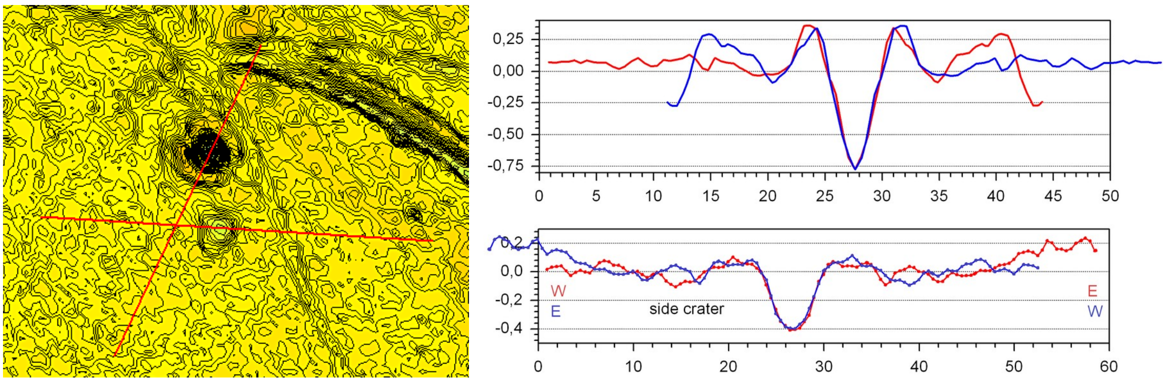


A typical 20 m-diameter wavy uplift with a distinct central peak.

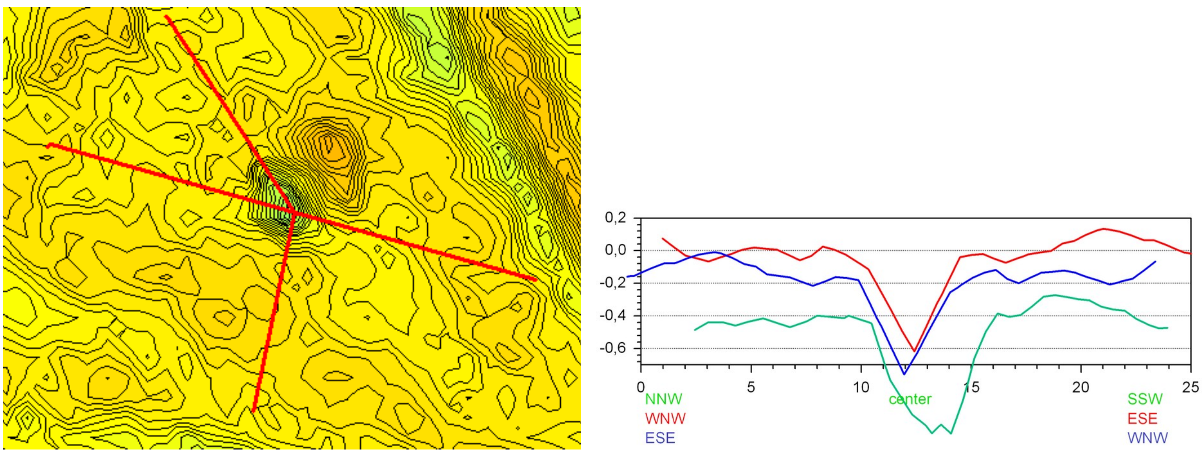


Nearly mirror image of the boil: a wavy rim crater.

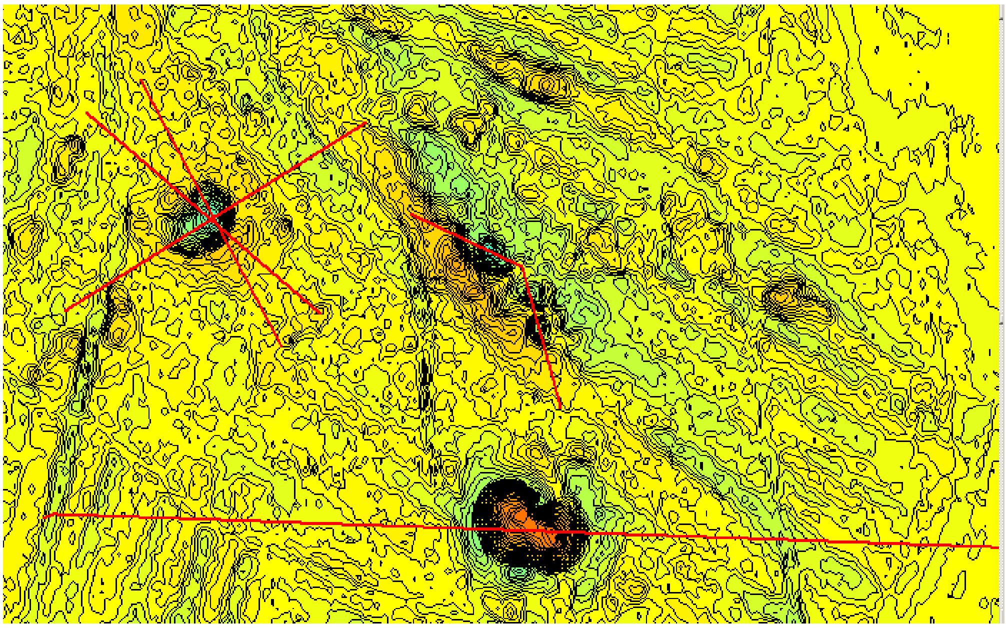
Kaltenbach crater field



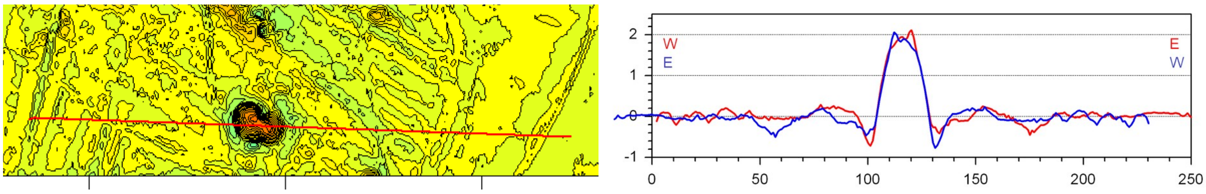
The early investigated Kaltenbach crater, main crater and side crater. The side crater was only recently detected in the DGM 1 topography.



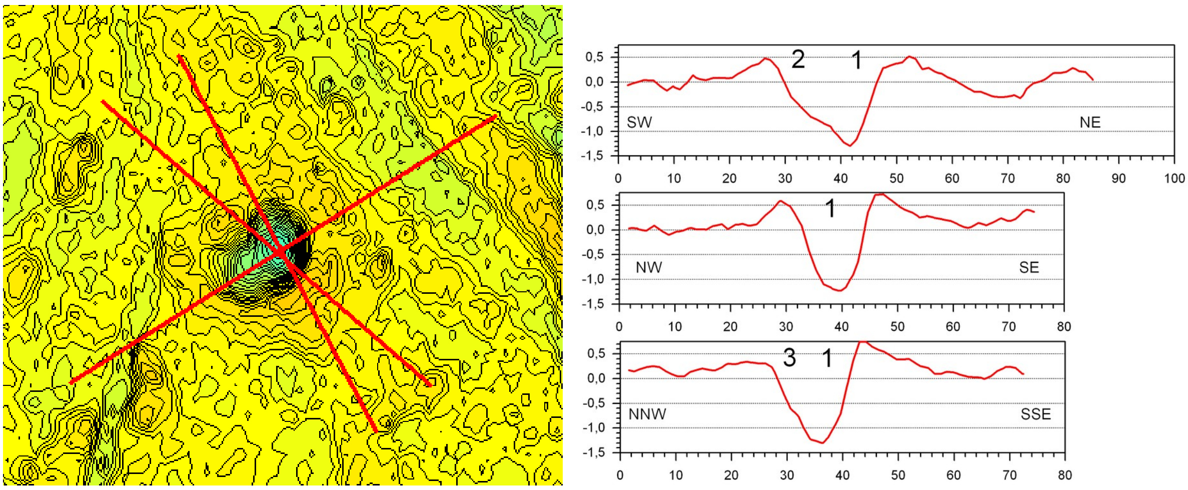
Kaltenbach, doublet pear-shaped crater, northeast of main crater.



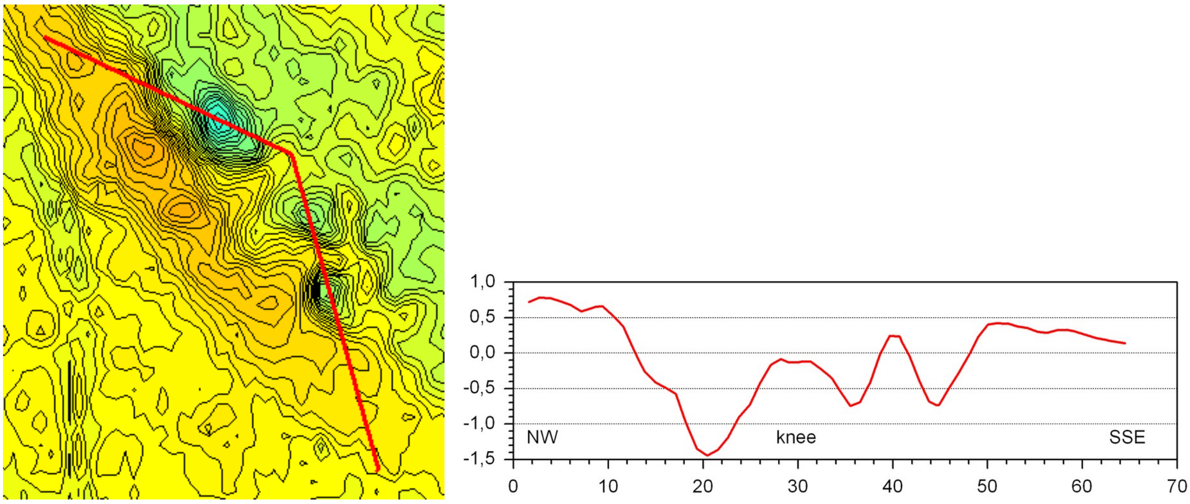
Kaltenbach Marwang, crater and boil.



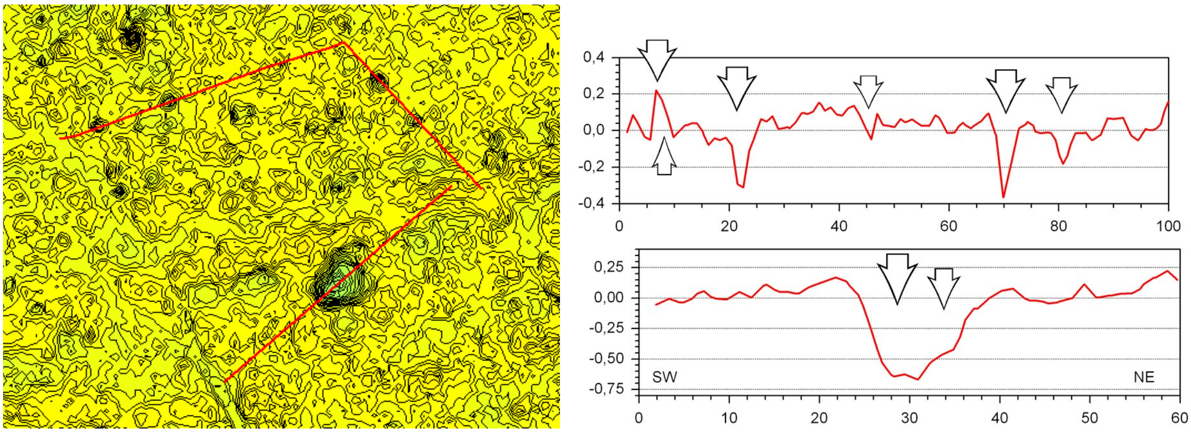
Kaltenbach Marwang, 200 m-diameter water droplet wavy structure with prominent central peak. This larger boil will be addressed in Part 2 of the Chiemgau impact structures discussion.



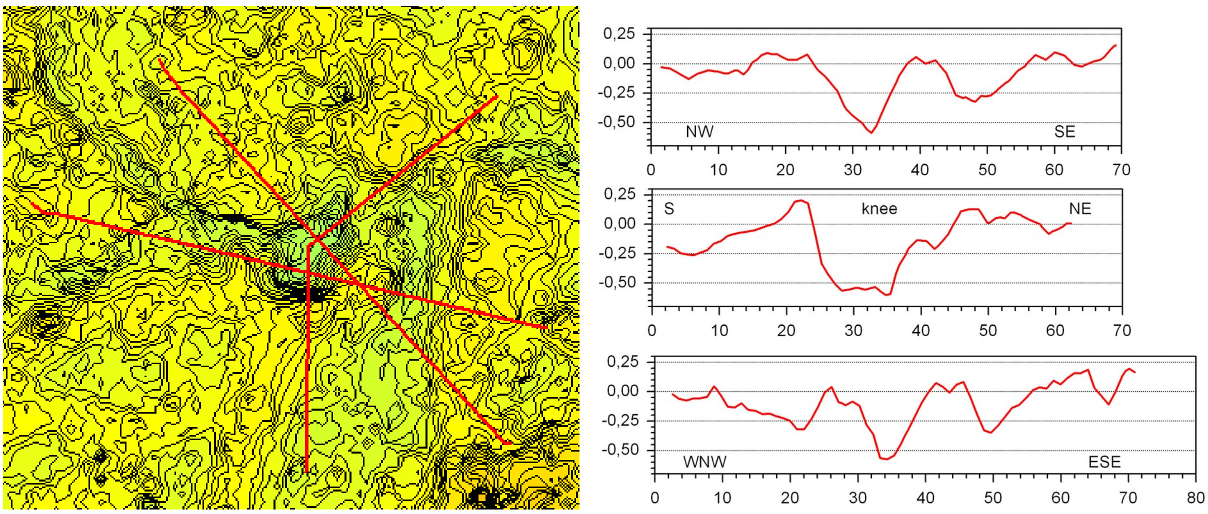
Kaltenbach Marwang, triplet crater with distinct rim wall.



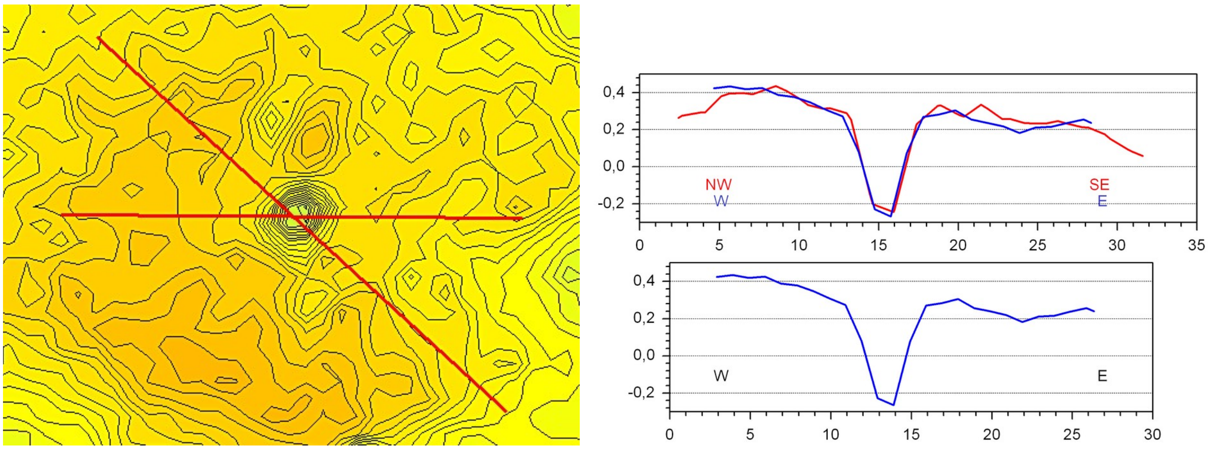
Kaltenbach Marwang, multiple craters with a continuous rim wall to the southwest.



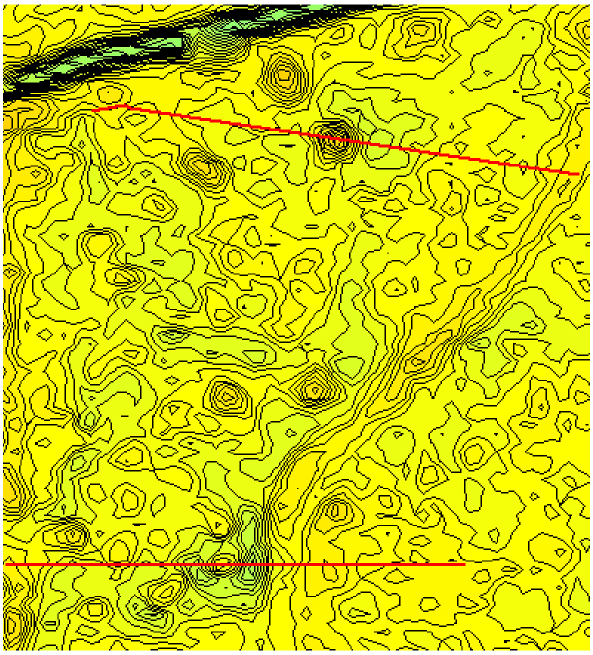
Kaltenbach Marwang, selection of a crater cluster

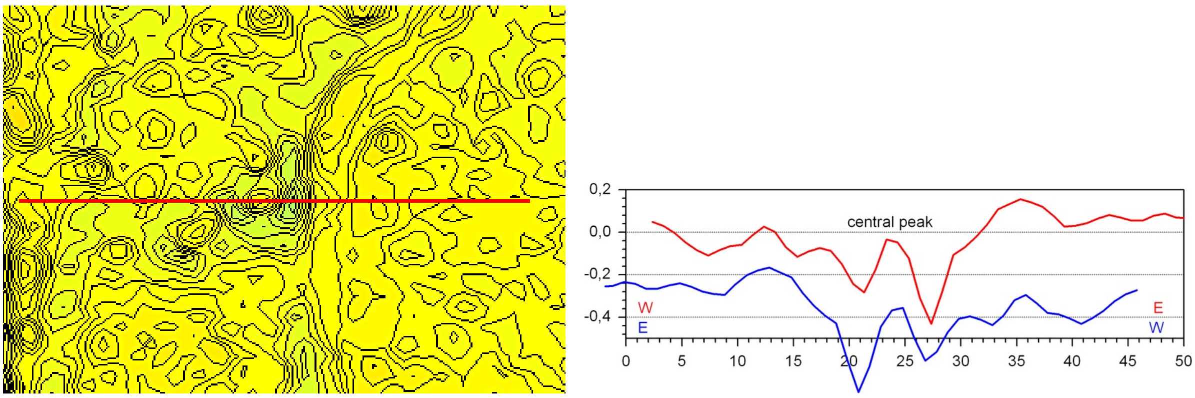


Kaltenbach Marwang, multiple-impact crater with a complex shape.

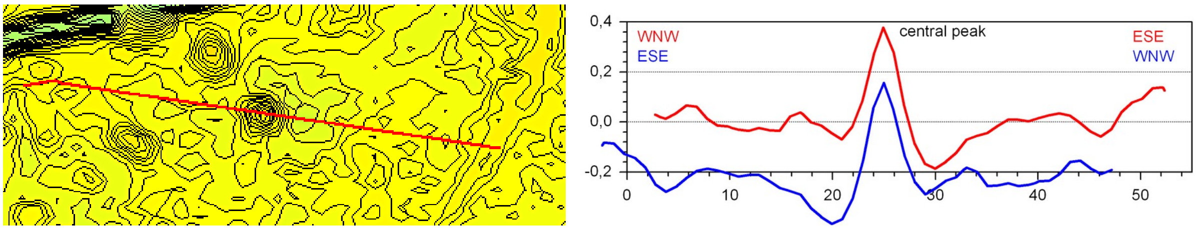


Kaltenbach, western tile, NE quadrant, terraced crater.

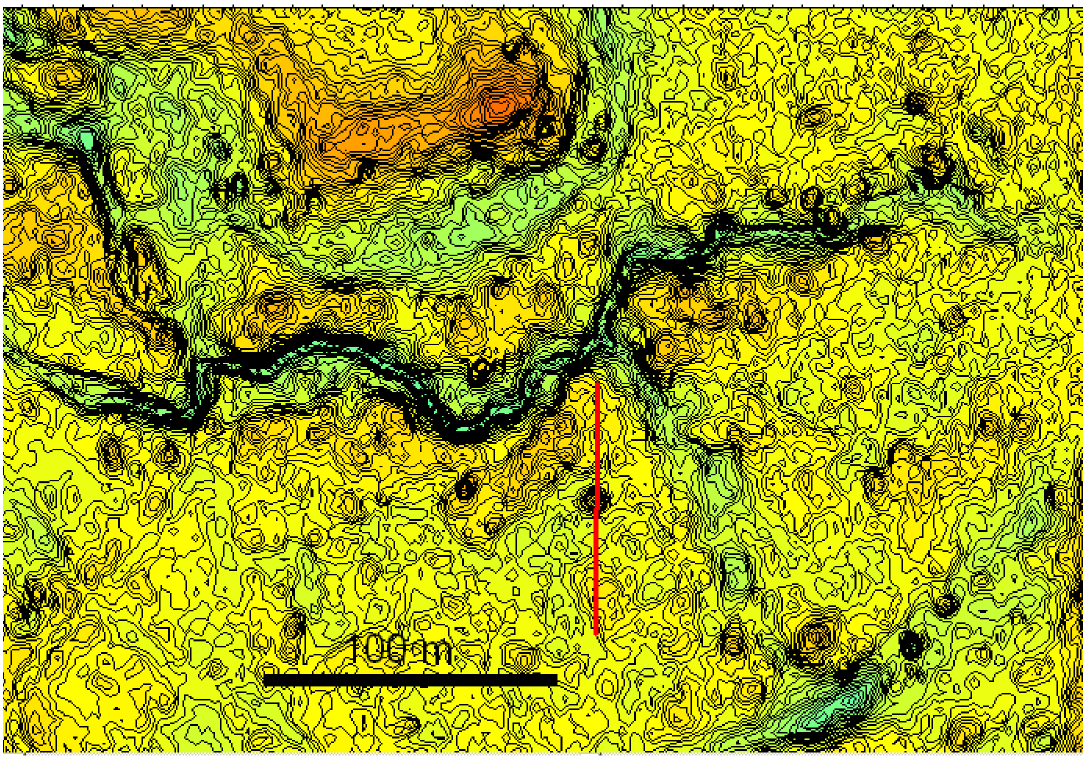

Kaltenbach west, NE Quadrant, cluster of central-peak craters, see the following images.



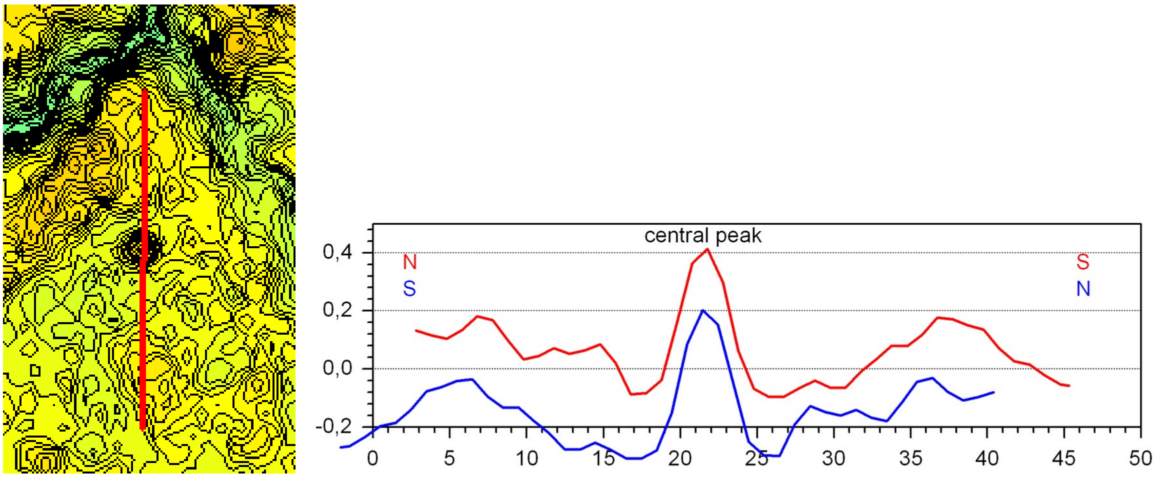
Kaltenbach western tile, NE quadrant, wavy central-peak crater.



Kaltenbach, western tile, NE quadrant, terraced-wavy, central-peak crater.

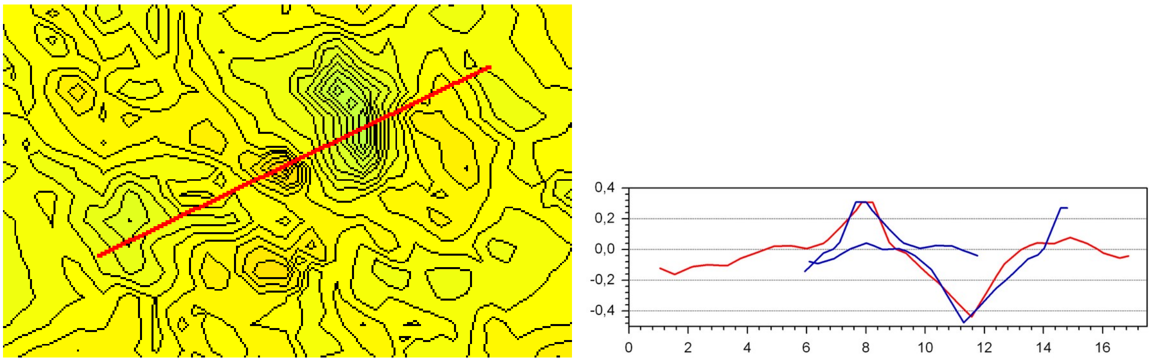


Kaltenbach western tile, NE quadrant, cluster of central-peak craters, one selected (below)-

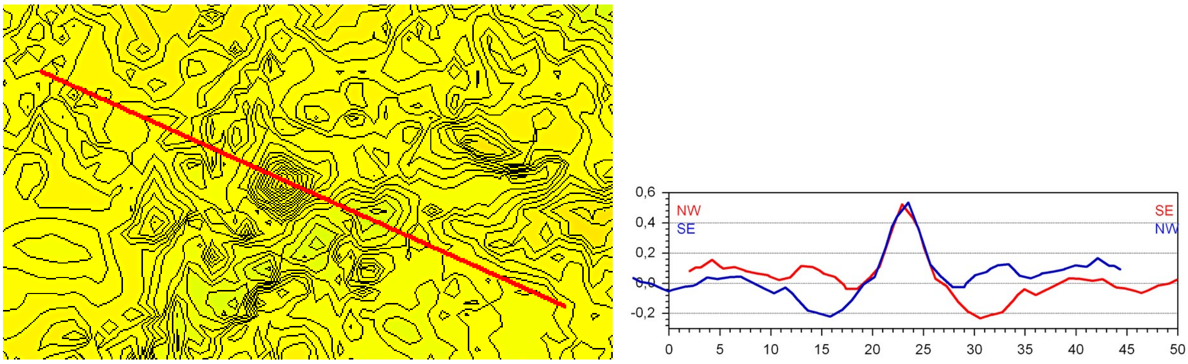


Kaltenbach western tile, NE quadrant, terraced-wavy, central-peak crater.

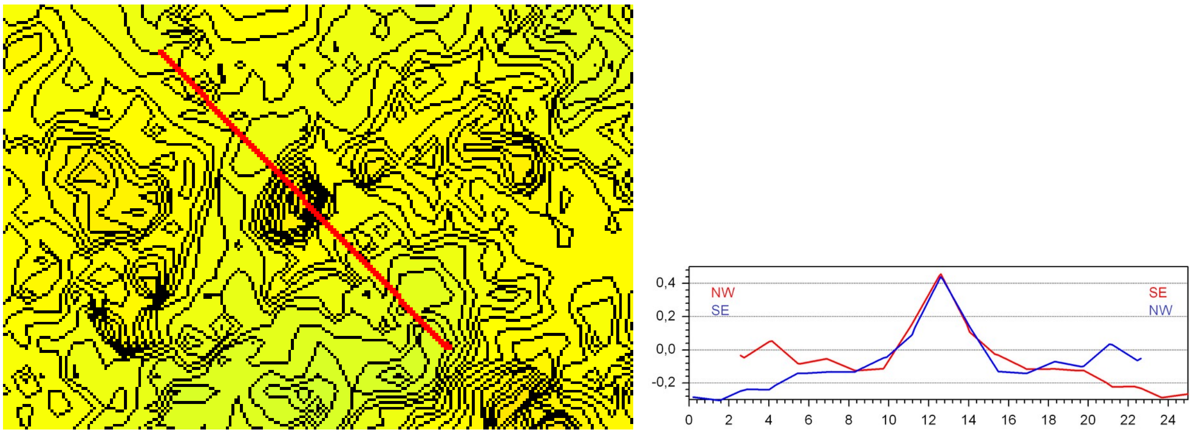
Mauerkirchen crater field



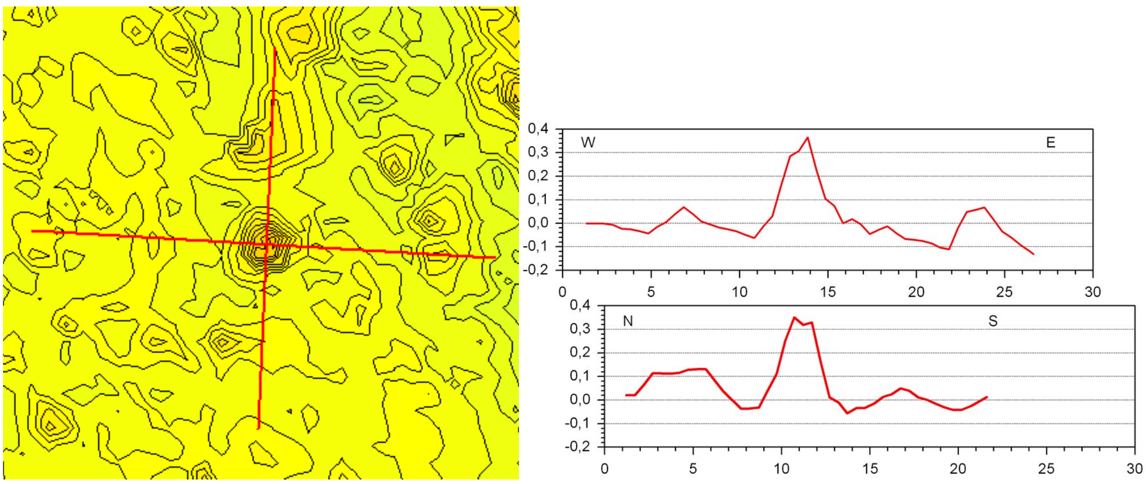
Mauerkirchen, small boil and crater structures.

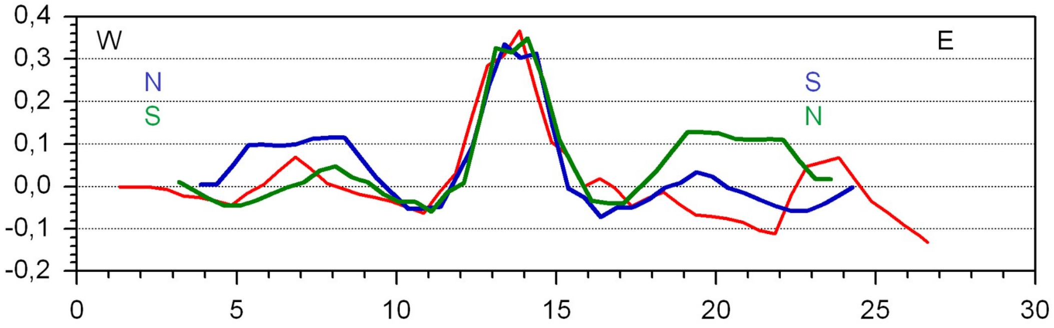


Mauerkirchen, wavy central-peak pan crater.

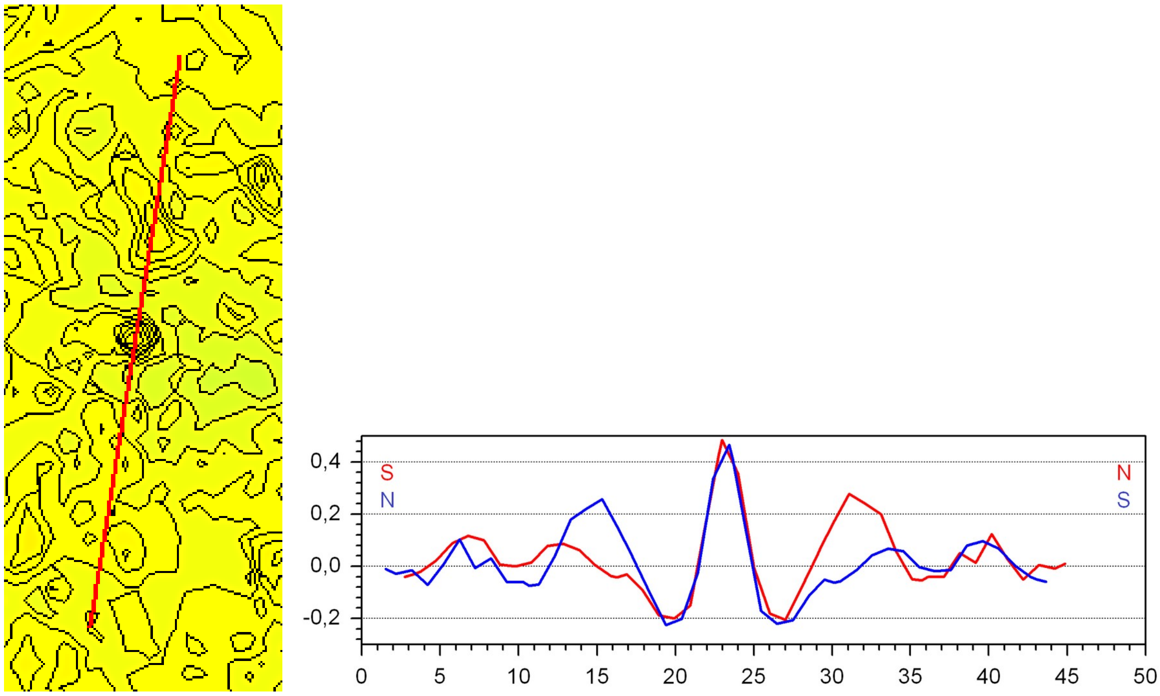


Mauerkirchen, flat pan central-peak crater.

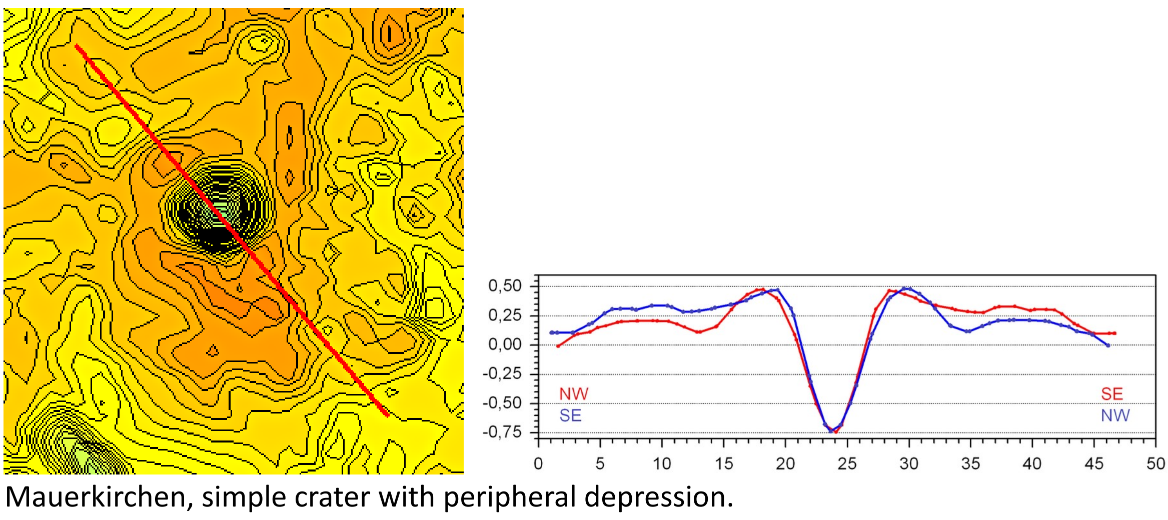




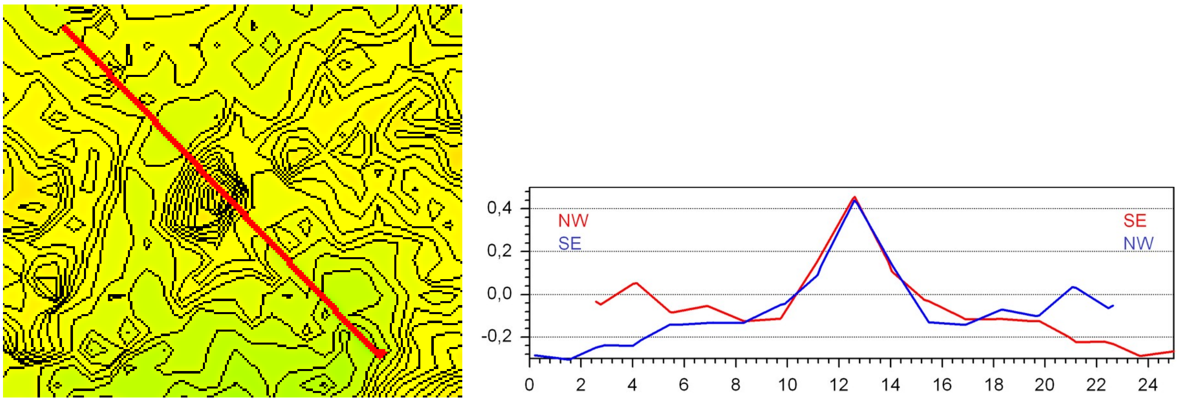
Mauerkirchen, distinct water droplet central-peak crater.



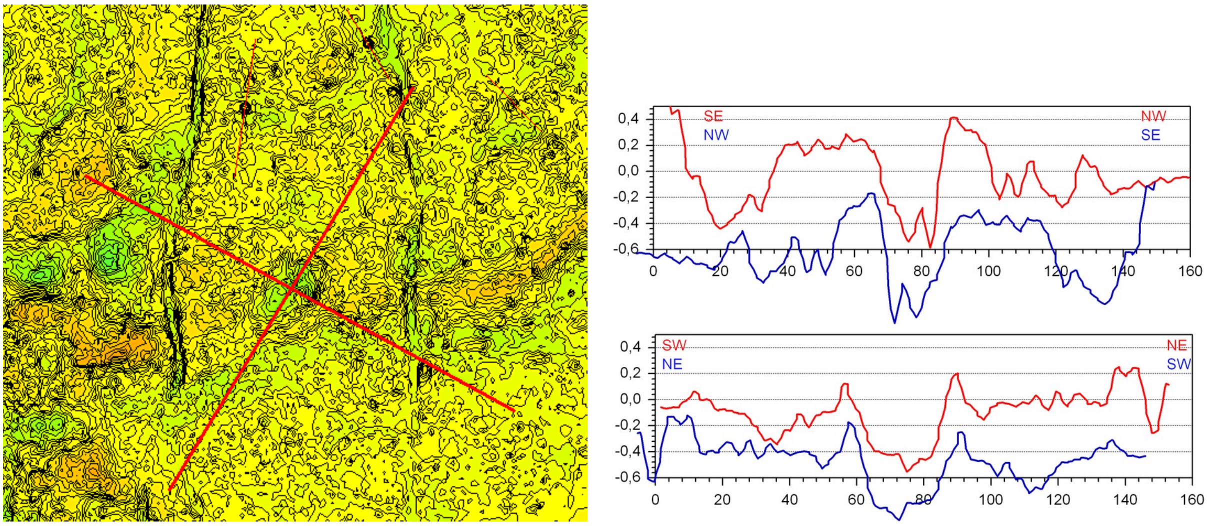
Mauerkirchen, distinct water droplet crater.



Mauerkirchen, simple crater with peripheral depression.



Mauerkirchen, simple boil in a wavy pan.



Mauerkirchen, elliptical crater from impact of a broken projectile or from a strongly oblique impact.