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THE CHIEMGAU METEORITE IMPACT SIGNATURE OF THE STÖTTHAM ARCHAEOLOGICAL SITE (SOUTHEAST GERMANY)

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ABSTRACT

Archaeological excavation at Chieming-Stöttham in the Chiemgau region of Southeast Germany revealed a diamictic (breccia) layer sandwiched between a Neolithic and a Roman occupation layer. This exotic layer bears evidence of its deposition in a catastrophic event that is attributed to the Chiemgau meteorite impact. In the extended crater strewn field produced by the impact, geological excavations have uncovered comparable horizons with an anomalous geological inventory intermixed with archaeological material. Evidences of extreme destruction, temperatures and pressures including impact shock effects suggest that the current views on its being an undisturbed colluvial depositional sequence as postulated by archaeologists and pedologists/geomorphologists is untenable.

KEYWORDS: Bavaria, Chiemgau, Meteorite Impact, Bronze Age

1. INTRODUCTION

Natural catastrophes documented in the archaeological record have always played an important role of scientific interest and, at the same time, of much speculation. Floods (tsunamis), volcanic eruptions and earthquakes have influenced cultural changes, and a special case of natural disasters during Bronze Age civilisations was presented by Peiser et al. (1998). With regard to the Bronze Age events, for the first time meteorite impact hazards have got increased consideration (e.g., Ball et al., 2007) so far without any real documentation in the archaeological stratigraphical record. This is different for the large Chiemgau meteorite impact event (Rappenglück and Ernstson; 2008, Ernstson and Rappenglück, 2008; Ernstson et al. 2010, 2011; Rappenglück et al. 2010, 2011; Hiltl et al. 2011; Liritzis et al. 2010; Shumilova et al. 2012; Isaenko et al. 2012) that happened some 4000-2500 B.P. and affected a probably densely populated region, although the magnitude of the cultural implications is still being discussed (Rappenglück et al., 2006, 2009, 2012). Despite a clear evidence of an impact event opposition has formed by regional administrative bodies from geology (Bayerisches Landesamt für Umwelt, LfU; Doppler et al., 2011) and archaeology (Bayerisches Landesamt für Denkmalpflege , BLfD; Völkel et al., 2012). We examine here the case of the Stöttham archaeological site that was commented upon by Völkel et al. (2012).

2. THE CHIEMGAU IMPACT

The Chiemgau strewn field (Ernstson et al., 2010) was dated to the Bronze Age/Celtic era based on archaeological finds (Ernstson et al. 2010). It comprises over 80 mostly rimmed craters scattered in a region of about 60 km x 30 km in the very South-East part of Germany (Lat Long Fig. 1). The diameters of individual craters range between a few metres and a few hundred metres, and these include the Lake Tüttensee crater the hitherto established largest crater of the strewn field exhibiting a rim-to-rim diameter of about 600 m and an extensive ejecta blanket. Geologically, the craters occur in moraine and fluvioglacial sediments of Pleistocence age. The craters and surrounding areas are featuring heavy deformations of cobbles and boulders, abundant fused rock material (impact melt rocks and various glasses), evidence of shock-metamorphism, and geophysical anomalies (Ernstson et al., 2010). The impact as the cause is substantiated by the abundance of metallic, glass and carbon spherules, accretionary lapilli, and finds of strange matter in the form of iron silicides like gupeiite, xifengite and probably hapkeite, and various carbides like, e.g., moissanite SiC (Hiltl et al., 2011). Impact-induced wide-spread earthquake-like shaking of the ground led to rock liquefaction processes the ramifications of which persist and irritate people until today (Ernstson et al., 2011). It is suggested that the impactor was a 1,000 m diameter sized low-density disintegrated, loosely bound asteroid or a disintegrated comet. This is to account for the extensive strewn field (Ernstson et al., 2010).

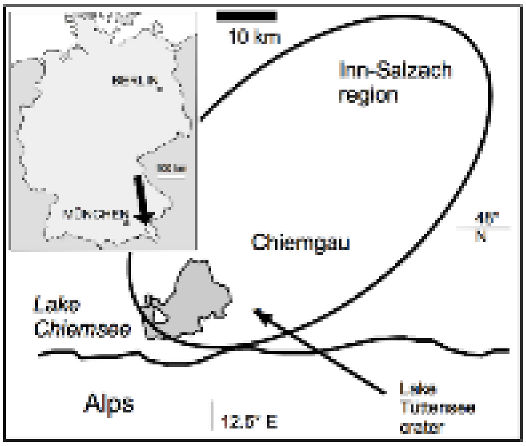

Fig. 1. Location map for the Chiemgau region and the outline of the elliptically shaped strewn field of the Chiemgau impact event.

3. THE STÖTTHAM ARCHAEOLOGICAL SITE AND EXCAVATION

Earlier studies on the Chiemgau impact

indicated that the disaster must radically have affected the local population. Geological and archaeological excavations (Ernstson, 2006 a, b) uncovered remnants of stone and pottery artefacts (e.g., Ernstson, T., 2007) together with fractured bones and teeth of domestic animals, and tufts of possibly human hair embedded in typical impact ejecta deposits.

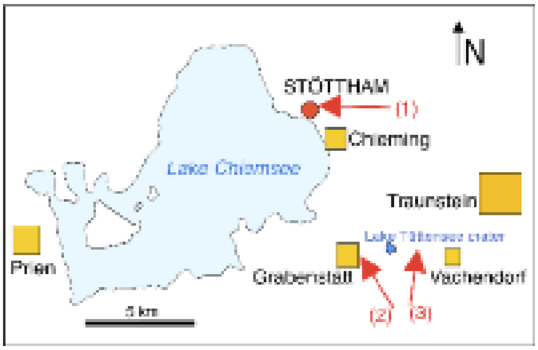

Fig. 2. Location map for the Stöttham archaeological excavation (1) and the Grabenstätt (2) and Mühlbach (3) geologic excavations.

In the year 2007, on occasion of a routine archaeological excavation by an archaeological company in the course of house construction in the town of Chieming-Stöttham (Fig. 2) the Chiemgau Impact Research Team (CIRT) coincidentally attended the excavation and discovered a very conspicuous intercalated layer (Fig. 3). Rapidly, the anomalous character of this deposit that did not at all match the archaeological context (Fig. 4) was realized, and a thorough geoscientific investigation and documentation by scientists linked with the CIRT began.

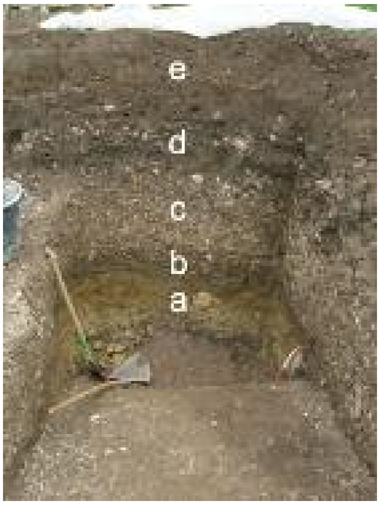

Fig. 3. Part of the Stöttham excavation with the sandwiched impact layer. The geologic/ archaeological stratigraphy. a: moraine, b: lower colluvium/lower occupation layer, c: diamictite/catastrophic layer, d: upper colluvium/upper occupation layer with Roman paving, e: soil. Image taken from Neumair et. al. (2010).

Fig. 4. Detail of the diamictic texture of the impact layer.

Geologically, the conspicuous layer inferred to be an impact-related diamictic intercalation with intermixed artefacts of the Bronze Age, most probably of the Urnfield culture (ca. 1300-800 BC), as well as of the Hallstatt culture (ca. 800-500 BC) (Fig.5). This was in a stratigraphical sequence that so far was seen to lie between Neolithic culture below and a Roman paving above (Fig. 3). This presented a unique situation of a layer formed by a catastrophic impact, that was sandwiched between dated archaeological horizons. Typical archaeological objects, fractured bones and teeth uncovered from the various horizons are shown in Fig. 6.

In 2008, at the behest of the Bavarian State Office for Monument Preservation (Bayerisches Landesamt für Denkmalpflege, BLfD), the archaeological excavation at Stöttham was accompanied by an investigation

Fig. 5. Intermixed in the impact layer: a Hallstatt shard. Millimetre scale.

Fig. 6. Archaeological objects (bronze burins, quartzite hammerstone) and fragments of bones, a tooth and pottery from the Stöttham exposure.

performed by *Wissenschaftszentrum Weihenstephan für Ernährung, Landnutzung und Umwelt der Technischen Universität München [Science Center of Nutrition, Land Use and Environment, Technical University of Munich, at Weihenstephan]* led by J. Völkel. Völkel et al. (2012) describe the Stöttham exposure from the pure standpoint of a geomorphologist/pedologist seeing the deposit as a continuous, nearly undisturbed post-glacial colluvial infill into a channel. This was a contrast to the prevailing understanding and ignored the existing evidence of an impact.

4. EVIDENCE FOR THE METEORITE IMPACT DEPOSITION OF THE STÖTTHAM CATASTROPHIC LAYER

The investigations of geology, petrography and impact research on the anomalous catastrophic layer indicated it to comprise rounded, subrounded, heavily shattered and extremely corroded cobbles (Fig. 7) in a clayey-silty, slightly sandy matrix intermixed with splintered wood, charcoal, fractured bones and teeth, and archaeological objects, among them a number of shards. The contrast of this peculiar geologic horizon to the colluvial layers below and above is remarkable (see Figs. 3, 4). High-temperature signature that was reached consequent to impact is given by partly melted silica limestone cobbles, a typical rock from the Alps (Fig. 8), and a sandstone clast with sporadically interspersed glass (Fig. 9). A formation of the melt from impact shock release is possible. Particles of a dirty brown glass (possibly molten soil) contribute to the diamictitic layer. Some minerals, e.g. amphiboles, show a loss of water and indication of possible shock melting. Bronze mica from heat decomposition, beginning at about 500°C, is frequently observed. Evidence of heat disintegration of limestone pebbles by decarbonisation and/or partial melting is abundant. These pebbles show shells of white calcareous powder or, under slight compression, completely disintegrate into white powder, which gives a typical white-spotted appearance to the diamictite as seen in Figs. 3, 4. Substantive chemical or physical corrosion of carbonate pebbles, frequently leading to distinct skeleton sculptures, is also abundant (Fig. 7). Silicate pebbles may likewise show significant corrosion. Elutriation of the diamictite matrix revealed carbonaceous, glassy and metallic spherules (Fig. 10) that, because an industrial origin can be excluded, are evidence of an extraterrestrial impact event (Szöőr et al., 2001; Dressler and Reimold, 2002; Firestone, 2009).

Fig. 7. Typical cobbles uncovered from the diamictic impact layer. Left: strong corrosion of carbonate and silicate rocks by heat and/or post-impact nitric-acid precipitation. Right: extremely disintegrated gneiss cobble with bronze mica from strong heating and a heavily fractured sandstone with well preserved coherence proving high confining pressure upon embedding in the diamictite.

Fig. 8. From the Stöttham impact layer: sawed surface of a silica limestone exposed to strong heating. Only a core has retained its original texture. In the outer zone the carbonate has disappeared by decarbonisation and/or melting.

Fig. 9. Stöttham diamictite: photomicrograph of a sandstone sample containing glass from probable shock melt – black under crossed polarisers of the microscope. Field width 1.6 mm.

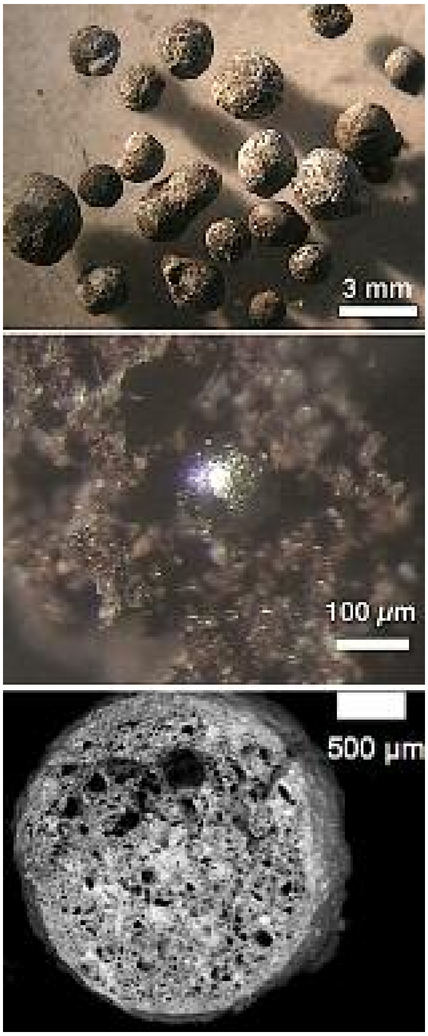

Fig. 10. Spherules from the Stöttham impact layer (top down): strongly magnetic carbonaceous spherules, a metallic spherule embedded in slaggy glass, and SEM image of a vesicular glass spherule.

Microscopic evidence - shock metamorphism

Under the polarising microscope, shock metamorphism in rocks from the Stöttham catastrophic layer was seen. In nature, this is exclusively ascribed to hypervelocity meteorite impact (e.g., Grieve et al. 1996, French 1998) leading to extreme pressures and temperatures. In sandstones, we observed rock melt (Fig. 9) and multiple sets of planar deformation features (PDFs) in quartz (Stöffler and Langenhorst, 1994) (Fig. 11). In a quartzite cobble diaplectic quartz crystals were seen requiring shock pressure of at least 10 GPa (e.g., Engelhardt et al., 1969) (Fig. 12). PDFs and diaplectic quartz are a clear manifestation of strong crystal lattice distortion by shock pressure, that on release can raise the temperature to melt rock material.

Fig. 11. Shock effect: multiple sets of planar deformation features (PDFs) in quartz from two sandstone cobbles. Left: four sets (indicated by lines) of decorated PDFs of moderate signature. Photomicrograph, crossed polarisers. Right: The seemingly curved PDFs are in fact two sets crossing under acute angle. An additional slight bending is attributed to a plastic deformation of the quartz lattice as seen from the undulatory extinction. Polarisers slightly rotated from the crossed position. Scale bar 200 µm.

Fig. 12. Peculiar fracture patter in quartz from a characterising cobble in the Stöttham impact layer with sets of planar fractures and isotropic spots (dark to black) characterizing the grain as a diaplectic quartz. Diaplectic means that the impact shock destroyed the crystal lattice to produce co-called diaplectic glass. In contrast to melt glass, the formation of diaplectic glass typically lets the fracture structures intact. Photomicrograph, crossed polarisers; field width 1.1 mm.

5. THE STÖTTHAM ARCHAEOLOGICAL EXPOSURE IN THE CONTEXT OF OTHER CHIEMGAU IMPACT DEPOSITS

Although the Stöttham archaeological site proves to be unique with regard to the clear stratigraphy of an impact layer intercalated between two dated cultural periods, it must be seen in the much larger context of the far-reaching Chiemgau impact event. From more than 60 geological excavations that focussed on the environs of the Lake Tüttensee crater, it became evident that the Stöttham catastrophic layer with the intriguing impact features has many counterparts in a much larger area. Details of these excavations have been reported elsewhere (e.g., Ernstson et al., 2010, Rappenglück et al., 2010), and here we focus on a few attributes that can be compared with the Stöttham findings. The impact layer that has been encountered at a depth between 1-2 metre around Lake Tüttensee can be tracked up to the town of Grabenstätt and roughly 1 km in the opposite direction. There the Grabenstätt and Mühlbach geologic excavations are located, which is about 10 km to the south of Stöttham (Fig. 2). The impact layer at both exposures shows the same diamictic composition of heavily fractured and unfractured, in part extremely corroded cobbles and boulders in a predomi-

Fig. 13. The Grabenstätt excavation (depth about 1.5 m) of the impact layer. Inserted a close-up of the diamictite largely conforming to the Stöttham layer.

nantly loamy and clayey matrix (Fig. 13), and some stratification as a probable result of reworking.

Fig. 14. Multicoloured breccia from the Mühlbach impact layer.

Intermixed are abundant splinters of wood, charcoal, fractured bones and teeth altogether making a real multicoloured breccia (Fig. 14).

Like in Stöttham, evidence of extreme temperatures and pressures including shock-metamorphic effects is observed. Figs. 15-17 provide typical example of changes in the rock and mineral changes due to shock analogous to Stöttham. As seen in Fig. 15, a silica limestone ("Kieselkalk") cobble completely lost its original texture to become the aspect of a vesicular melt rock. The very high temperature experienced by the cobble is indicated by the formation of the mineral pseudowollastonite (Fig. 16), a high-temperature modification of the common wollastonite $CaSiO_3$, that is artificially produced and is rare in a natural environment. To our knowledge, pseudowollastonite has never before been described for an impact rock. Multiple sets of planar fractures (PFs) and the small spots of diaplectic glass in the quartz grain from Fig. 16 remind of the quartzite cobble from Stöttham (Fig. 12). Also PFs are considered a typical shock effect although in rare cases they may originate from very strong tectonic overprint. Here,

Fig. 15. A silica limestone cobble from the Mühlbach excavation that has undergone very strong heating.

Fig 16. Fibrous calcite and pseudowollastonite surrounding a cavity; photomicrograph, crossed polarisers; from the strongly heated silica limestone in Fig. 15. Field width 550 μm.

Fig. 17. Sets of planar fractures (PFs) and beginning isotropisation (diaplectic quartz) as indication of shock overprint of a quartzite cobble from the Grabenstätt location. Field width 1.1 mm.

tectonics can be excluded because the PFs occur in the outer zone of the affected cobble only. Analogous to the Stöttham quartzite cobble, small spots of diaplectic glass are additional confirmation of a shock event.

As has already been noted earlier (Ernstson et al., 2010) the abundance of shock deformation in the Lake Tüttensee rocks is striking and has been ascribed to a process of probable shock focus in the hard cobbles and boulders embedded in a soft matrix. Characteristic examples of these deformations in various minerals are shown in Fig. 18.

Fig. 18. Typical shock effects as identified in rocks from the Lake Tüttensee impact layer. Top down: Planar deformation features (PDFs) in two quartz grains; two crossing sets of kink bands in mica; multiple sets of plastically deformed microtwins in calcite.

Fig. 19. A Stone Age/Bronze Age drilled quartzite boulder recovered from the Mühlbach impact layer. Image from Ernstson, T. (2007)

Unlike Stöttham, the layers below and above the catastrophic horizon around Lake Tüttensee do not give any clear age, but do have intermixed artefacts (Stone Age and Bronze Age shards and stone tools, Fig. 19) to set a lower limit to the deposition of the diamictic layer i.e. the impact event. In particular, the bulk of the ceramics from Bronze Age, most probably Urnfield culture, found in both the Stöttham und Lake Tüttensee catastrophic layers, suggest a close archaeological linkage.

6 CONCLUSIONS

The Stöttham archaeological site and excavation enable two conclusions. The first is the perception that evidently for the first time the occurrence of a large meteorite impact event has been documented within a dateable archaeological stratigraphy and that advanced impact research together with physical dating (Liritzis et al., 2010) has strikingly entered the field of archaeometry. The close similarity to exposures in a much larger area demonstrates that the Stöttham case has a far reaching relevance for the archaeological time span (Bronze Age/Celtic era) and the affected region under consideration. At the same time we observe a strict refusal of this coherence exemplified by the study of Völkel et al. (2012) that was initiated by the BLfD. Unfortunately, the BLfD did not consider to protect the Stöttham unique exposure now destroyed.

It appears that the combined geologic and archaeological stratigraphy provides a clear indication of the Stöttham layer to be of impact origin contrasting with the viewpoint of geomorphology and soil science

(Völkel et al., 2012). We specifically want to point out that Völkel et al. have investigated exclusively the Stöttham outcrop measuring 300 m^2 at best, while any integration into an extended context is lacking. Thus their extrapolation to a larger spatial scale becomes untenable, and point data from this individual location without a contextual framework may be misleading. The unambiguous presence of a diamictite in addition to the existence of extreme destruction, extreme temperatures and extreme pressures implying clear shock effects undoubtedly suggest that the Stöttham diamictite is an impact-related layer that formed due to a meteorite impact during the Bronze Age/Celtic era.

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