METALLIC ARTIFACT REMNANTS IN A SHOCK-METAMORPHOSED IMPACT BRECCIA: AN EXTENDED VIEW OF THE ARCHEOLOGICAL EXCAVATION AT STÖTTHAM (CHIEMGAU, SE-GERMANY)

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Introduction: In 2010 a routine archeological excavation at the town of Chieming-Stöttham in the Chiemgau region in Southeast Germany (Fig. 1) revealed an exotic layer sandwiched between Neolithic and a Roman occupation layer (Fig. 2). The exotic diamictic (breccia) layer showed all evidence of a deposition in a catastrophic event that was rapidly attributed to the Chiemgau meteorite impact [1, 2, and references therein] (Fig. 1) that happened in the Bronze Age/Iron Age.

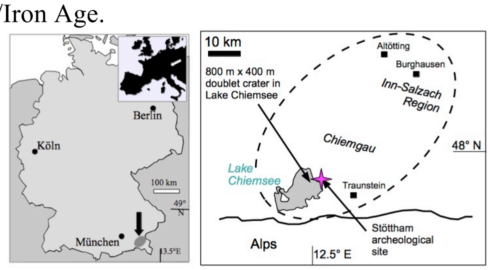


Fig. 1. Location map for the Stöttham archeological excavation site within the roughly elliptically encircled Chiemgau meteorite impact strewn field.

The ample occurrence of extreme destruction, extreme temperatures and highest pressures including impact shock effects (Fig. 4) proved incompatible with an undisturbed colluvial depositional sequence as postulated by archeologists and pedologists/geo-morphologists [3]. Following their argumentation the Bavarian Office for Geology (LfU) and the Bavarian Monuments Preservation Office (BLfD) declared the unparalleled Stöttham exposure as a normal colluvium which continously developed since the end of the last Ice Age and let it fill up and overbuild. A recent inspection of the depot of archieved samples from the excavation revealed a key to an unexpected scenario, and we report highlighting results of both archeological and meteorite impact relevance.

The Chiemgau impact event: In a roughly elliptically shaped strewn field (Fig. 1) around 100 mostly rimmed craters with diameters between a few meters and a few 100 meters occur. Exceptional and relevant in the context of this paper is a rimmed doublet crater at the bottom of Lake Chiemsee [1], which was in detail mapped by echosounder measurements. Apart from the craters and their distinct morphology as revealed from precise Digital Terrain Model (DTM) analyses, the impact strewn field shows all and abundant evidence of impact signature as is required within the impact research community (impact melt rocks, impact glasses, shock metamorphism like PDF and diaplectic glass - quartz and feldspar, shatter cones, meteoritic matter [1, 2, 4-8]).

The Stöttham exposure - early research: Because of the short distance and the considerable size, the Lake Chiemsee doublet crater was reasonably considered the source for the Stöttham catastrophe layer (Fig. 2), which is interpreted as impact ejecta sustained by a big, now established Lake Chiemsee tsunami [9]. A short overview of the archeological and impact-related inventory is shown in Figs, 3, 4 and in more detail described in [10].

Fig. 2. The impact diamictic layer in the archeological excavation.

Fig. 3. Artifacts and fragments of bones, a tooth and pottery from the impact layer.

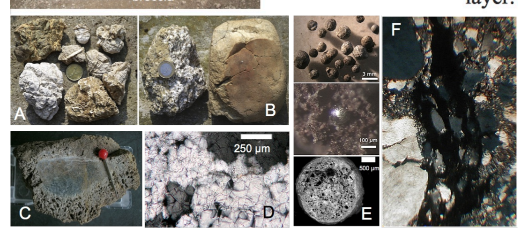


Fig 4. Impact inventory from the diamictic catastrophe layer: Corrosion by heat and/or nitric acid precipitation (A); disintegrated and fractured cobbles (B); partly melted silica limestone (C); shock in quartz: multiple PFs and spots of diaplectic glass (D); carbonaceous, metallic and glassy spherules (E); shock melt in sandstone; black under crossed polarizers (F).

New investigations - shocked polymictic impact breccias with remnants of metallic artifacts: The new investigations focused on samples, which had archeologically been termed "slags" but which, on cutting them, proved to be polymictic melt rock breccias of prevailing amphibolitic, quartzite, silica limestone, and sandstones components (Fig. 5). The melt rock character and breccias-within-breccias with up to three breccia generations fit well with the impact scenario of the first Stöttham study. Iron and copper fragments were particularly noticeable as components of the breccias, which, in view of the initiation of the archeological excavation, were to be regarded as remains of artifacts.

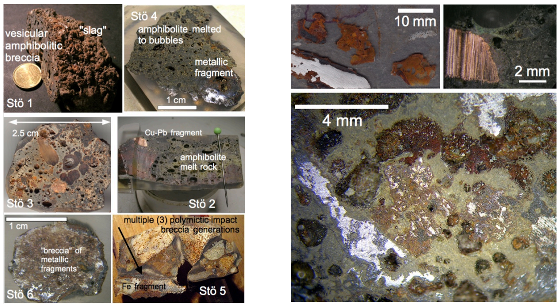
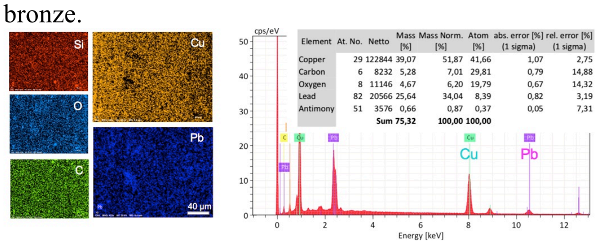


Fig. 5. Left: Polymictic impact breccias (archeologically termed "slag") from the Stöttham excavation. Right: Remnants of metallic artifacts in the impact breccia: iron, lead bronze, tin bronze.

A preparation of a total of six "slag" samples for SEM-EDS analyses revealed as a surprise that the particles originally regarded as copper (Fig. 5) were apparently an alloy with a high lead content (Fig. 6, Fig. 7), which gave them the character of a lead bronze.



Element	At. No.	Netto	Mass [%]	Mass Norm. [%]	Atom [%]	abs. error [%] (1 sigma)	rel. error [%] (1 sigma)
Copper	29	122844	39,07	51,87	41,66	1,07	2,75
Carbon	6	8232	5,28	7,01	29,81	0,79	14,88
Oxygen	8	11146	4,67	6,20	19,79	0,67	14,32
Lead	82	20566	25,64	34,04	8,39	0,82	3,19
Antimony	51	3576	0,66	0,87	0,37	0,05	7,31
		Sum	**75,32**	**100,00**	**100,00**		

Fig. 6. SEM-EDS of copper-lead bronze (Fig. 5, upper right). Cu and Pb are intimately mixed.

But also the finest fragments of a (normal) tin bronze were detected (Fig. 5). Another unusual feature was the EDS analysis of a larger iron fragment (Fig. 5), which practically consists of the purest iron (with a few carbon percentages).

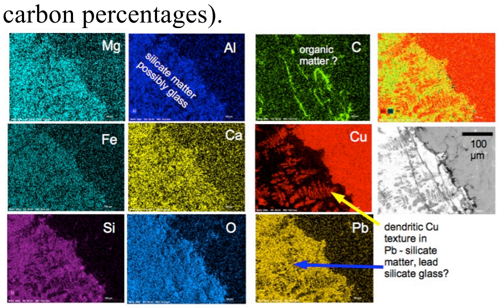


Fig. 7. SEM-EDS: Complex copper - lead mobilization within the breccia matrix.

The formation of the breccia with the embedding of the metal particles must have been a very complex process, which must have led to the partial separation of the metal components and their mobilization within the silicate rock components and possibly enabled the formation of a kind of lead glass (Fig. 7).

Shock metamorphism: All specimens examined with thin sections and the polarization microscope show more or less pronounced shock metamorphism (Fig. 8). These include melt glass, often as a breccia matrix for various mineral fragments, ballen structures in combination with diaplectic silica glass, multiple sets of PDF in quartz, and mosaicism and PDF in hornblende.

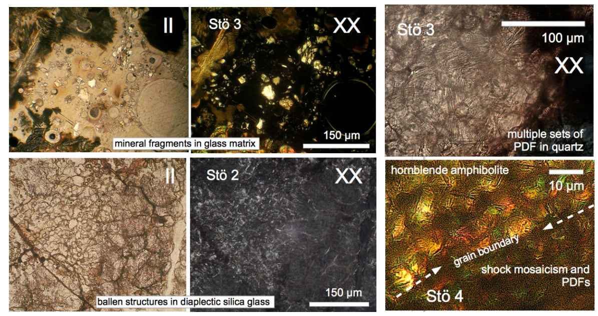


Fig. 8. Photomicrographs of shock metamorphism in impact breccias under discussion. With regard to cogenetic melt components and shock effects the breccias according to common nomenclature may be termed a suevite. II: parallel light, XX: crossed polarizers.

Discussion and conclusions: The new investigations demonstrate once more impressively that the Stöttham archeological site had been involved in a meteorite impact invent, the Chiemgau impact. The original finding of a meteorite impact layer between two archeological horizons was to be classified as unique worldwide. From the point of view of both archeology and impact research, the new analyses have put the crown on it by revealing human objects and impact shock intimately intertwined in the same samples - a worldwide novelty. An upcoming more exact dating of the Chiemgau impact, based on the metallic components, will be a significant side effect of these unusual samples and their investigation.

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