The osseous industry of the LGM site Kammern-Grubgraben (Lower Austria), excavations 1985–1994, and its position within the European Late Upper Palaeolithic

Die organische Industrie der LGM-Fundstelle Kammern-Grubgraben (Niederösterreich), Grabungen 1985–1994, und ihre Position innerhalb des Späten Jungpaläolithikums in Europa

Sebastian J. Pfeifer[1]*, Kerstin Pasda[2], Marc Händel[3], Andreas Maier[4] & Thomas Einwögerer[3]

[1] Friedrich Schiller University Jena, Seminar of Prehistoric Archaeology, Löbdergraben 24a, 07743 Jena, Germany; ORCID: 0000-0002-1102-4265, email: sebastian.pfeifer@uni-jena.de; sebastian.pfeifer@gmx.net

[2] Friedrich-Alexander-Universität Erlangen-Nürnberg, Institut für Ur- und Frühgeschichte, Kochstr. 4/18, 91054 Erlangen, Germany; ORCID: 0000-0003-3016-3815

[3] Austrian Academy of Sciences, Austrian Archaeological Institute, Hollandstrasse 11-13, 1020 Vienna, Austria; ORCID: 0000-0003-2472-4006 [MH], 0000-0003-0612-906X [TE]

[4] University of Cologne, Institute of Prehistoric Archaeology, Bernhard-Feilchenfeld-Str. 11, 50969 Köln, Germany; ORCID: 0000-0002-5021-3341

Abstract - The well-known Upper Palaeolithic open-air site of Kammern-Grubgraben (Lower Austria) is so far the only Central European Last Glacial Maximum (LGM) site with preserved bone industry. This contribution presents the antler, ivory, and bone artefacts recovered during the 1985–1994 excavations. Among several thousand marrow-fractured osseous fragments, only 65 pieces, most of which are attributable to the 23.5–22 ka calBP main occupation, were identified as artefacts related to tool production. Shed antler, predominantly from reindeer, mammoth ivory, and longbones of large mammals served as raw materials. Transversal sectioning and production of pre-forms were carried out exclusively by direct percussion, and pre-forms were modified into tools by invasive longitudinal scraping. Eyed needles, predominantly produced on bone, are the most frequent tool type, followed by projectile points. Noticeable are two perforated batons. The osseous industry of Grubgraben mirrors its intermediate geographic location in the cultural landscape of the LGM: whereas massive-based projectile points and perforated rods connect it to the Eastern European early Epigravettian sphere, a projectile point with a single-bevelled base finds parallels in the Western European Badegoulian. Debitage by fracturing and eyed needles appear to be common traits of many LGM traditions and hence attest to a quick dissemination of certain typo-technological features throughout Europe. Similar observations can be made regarding the lithic industry. Of note is a decorated perforated baton from the uppermost archaeological horizon AL1. Although we consider the single, conspicuously young radiocarbon date of 20.5 ka calBP from AL1 as unreliable, the perforated baton and peculiarities in both the lithic industry and the faunal record nevertheless suggest another later, early post-LGM occupation at Grubgraben. This might relate to the 19–18 ka calBP, early Middle Magdalenian that is attested 300 km to the north at Maszycka cave in Poland. Like other Central European sites north of 47°, Grubgraben does not provide any conclusive evidence for human presence during the second half of the LGM (22–19 ka calBP), and thus the precise conduct of the post-LGM recolonisation of Central Europe remains an open question.

Zusammenfassung *- Die bekannte jungpaläolithische Freilandfundstelle Kammern-Grubgraben (Niederösterreich) ist gegenwärtig die einzige mitteleuropäische Station aus dem Letzten Glazialen Maximum (LGM) mit einer erhaltenen organischen Industrie. Dieser Beitrag stellt die Geweih-, Knochen- und Elfenbeinartefakte aus den Grabungen 1985–1994 vor. Unter mehreren tausend anthropogen zerschlagenen Fragmenten können nur 65 Stücke eindeutig mit Werkzeugproduktion in Verbindung gebracht werden, von denen die meisten der Hauptbelegungsphase 23,5–22 ka calBP zugehörig sind. Abwurfstangen, hauptsächlich vom Rentier, Mammutelfenbein und Langknochen von Großsäugern dienten als Rohmaterial. Transversale Zerlegung und Grundproduktion wurden ausschließlich durch direkte Perkussion realisiert und die Grundformen wurden dann durch intensives longitudinales Schaben zu Geräten modifiziert. Nadeln mit Öhr, typischerweise aus Knochen, sind der häufigste Gerätetyp, gefolgt von Geschossspitzen. Hervorzuheben sind auch zwei Lochstäbe. Die organische Industrie vom Grubgraben spiegelt die geografische Mittlerposition der Fundstelle in der kulturellen Landschaft des LGM wider: Während Geschossspitzen mit massiver Basis und Lochstäbe eine Verbindung zum frühen Epigravettien*

*corresponding author

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Osteuropas herstellen, findet eine Geschossspitze mit einfach abgeschrägter Basis die besten Parallelen im westeuropäischen Badegoulien. Verarbeitung organischer Rohmaterialien durch Perkussion sowie Nadeln mit Öhr scheinen charakteristisch für viele Traditionen des LGM zu sein und sprechen somit für eine schnelle Ausbreitung bestimmter typo-technologischer Merkmale innerhalb Europas. Das Gleiche kann für die lithischen Industrien festgestellt werden. Besonders hervorzuheben ist ein dekorierter Lochstab aus dem obersten archäologischen Horizont AL1. Obwohl wir ein einzelnes, bemerkenswert junges ^{14}C-Datum von 20,5 ka calBP aus AL1 als unzuverlässig ansehen, deuten der dekorierte Lochstab sowie Auffälligkeiten der lithischen Industrie und der Faunenzusammensetzung nichtsdestotrotz auf eine weitere, jüngere Besiedlungsepisode vom Grubgraben unmittelbar nach dem LGM hin. Diese könnte mit dem frühen Mittelmagdalénien um 19–18 ka calBP in Verbindung zu bringen sein, welches 300 km nördlich in der Maszycka-Höhle (Polen) nachgewiesen ist. Wie auch die anderen mitteleuropäischen Fundplätze nördlich von 47° liefert Kammern-Grubgraben keinen Hinweis auf menschliche Anwesenheit während der zweiten Hälfte des LGM (22–19 ka calBP). Somit bleibt der genaue Verlauf der Wiederbesiedlung Mitteleuropas nach dem LGM weiterhin ungeklärt.

Keywords - Late Upper Paleolithic, Last Glacial Maximum, Central Europe, Osseous technology, Badegoulian, Epigravettian

Spätes Jungpaläolithikum, Letztes Glaziales Maximum, Mitteleuropa, Organische Technologie, Badegoulien, Epigravettien

Introduction

The Last Glacial Maximum in Eastern Central Europe

The Last Glacial Maximum (henceforth, LGM) sensu stricto (c. 24–19 ka calBP – Mix et al. 2001) is a phase of particular interest in European Palaeolithic research, because it seemingly marks a caesura in the cultural development of Europe reflecting a rupture in long-distance contacts (e.g. Anghelinu et al. 2021; Ducasse et al. 2017; 2021; Händel et al. 2021; Housley et al. 1997; Klein et al. 2021; Küßner & Terberger 2006; Lengyel et al. 2021; Maier et al. 2021a; Montet-White 1994; Nerudová & Neruda 2015; Połtowicz-Bobak & Bobak 2020; Reade et al. 2020; Škrdla et al. 2021; Terberger 2013; Terberger & Street 2002; Verpoorte 2004). In the course of the last decade, the notion of a catastrophic climatic event that terminated the thriving Gravettian culture and lead to a depopulation of major parts of Europe has given way to a more differentiated view, stressing that the climate-related demographic crisis started earlier, namely during the Late Gravettian (c. 29–25 ka calBP). The following LGM was in fact rather a phase of reconsolidation in Western Europe, while populations in Central Europe remained at a low level (Bocquet-Appel & Demars 2000; Bocquet-Appel et al. 2005; French 2021; Klein et al. 2021; Maier 2017; Maier & Zimmermann 2017; Maier et al. 2021a, b; 2022). After four millennia of abandonment, mid- and western Central Europe witnessed sporadic excursions by hunter-gatherer populations (Küßner & Terberger 2006; Leesch & Müller 2012; Sedlmeier 2010; Terberger & Street 2002), probably related to the favourable warming phase of Greenland Interstadial 2 around 23.3–22.8 ka calBP (Maier et al. 2020; Reade et al. 2020; Terberger 2013).

Eastern Central Europe, in contrast, was apparently never completely depopulated. Despite very low population densities, there is evidence of hunter-gatherer presence south of 47°N in Lower Austria, Moravia, Southern Poland and the Carpathian Basin in the Late Gravettian and into the first half of the LGM (Lengyel et al. 2021; Maier & Zimmermann 2017; Montet-White 1994; Nerudová & Neruda 2015; Nerudová et al. 2021; Škrdla et al. 2021; Terberger 2013; Terberger & Street 2002; Verpoorte 2004). Like western and mid-Central Europe, however, sites from these regions have to date not produced reliable radiocarbon measurements for the second half of the LGM between 22 and 19 ka calBP (Maier et al. 2020, 2021b; Nerudová & Neruda 2015: Fig. 2; Škrdla et al. 2021: Tab. 5; Lengyel & Wilczyński 2018: Fig. 1). Traces of human occupation during the late LGM are only preserved in the Carpathian Basin (Lengyel et al. 2021: Fig. 7).

It is debated whether this gap in the archaeological record indicates actual absence of humans owing to unfavourable climatic conditions (cf. Lengyel et al. 2021; Verpoorte 2004) or rather relates to the current state of research (cf. Jöris 2021; Połtowicz-Bobak & Bobak 2020). In any case, this finding has considerable relevance for the current discussion of the recolonisation of eastern Central Europe during the Late Upper Palaeolithic and the emergence of the widespread Magdalenian techno-complex, which is attested in Western Europe from about 20.5 ka calBP onwards (Langlais et al. 2015). The earliest Magdalenian site east of the Rhine is currently Munzingen in the German Upper Rhine Plain, and dates to around 19 ka calBP. Typo-technologically the assemblage is in accordance with the Lower Magdalenian (Pasda 2017). Chronologically it is followed by the early Middle Magdalenian Maszycka cave in the Polish Jura at around 18.5 ka calBP, which according to archaeological and palaeogenetic evidence was occupied by humans of Western European origin (Kozłowski et al. 2012; Pfeifer 2022; Posth et al. 2023: 122). The late Middle Magdalenian occupations of Balcarka cave in Moravia and the open-air site Kamegg in Lower Austria can possibly be dated to around 17 ka calBP (Händel et al. 2021; Valoch & Neruda 2005). By 16/15 ka calBP, the Upper Magdalenian is fully established in the middle mountain zone with several hundred sites between the Rhine in the west and the San in the east (Kozłowski et al. 2012; Kretschmer 2015; Maier 2015; Maier et al.

2020; Połtowicz-Bobak 2013; Valoch 2001; Valoch & Neruda 2005). The long-lived unidirectional recolonisation scenario in which post-LGM Central Europe was resettled exclusively by Magdalenian populations from Western Europe over a longer period of time (e.g. Housley et al. 1997; Kozłowski et al. 2012; Svoboda et al. 1996; Valoch 1996) is being challenged by an increasing number of sites in eastern Central Europe with early dates, most of which are archaeologically assigned to the Epigravettian (Lengyel et al. 2021; Nerudová & Neruda 2014; Nerudová et al. 2022; Wilczyński 2009). It is therefore argued in favour of excursions by hunter-gatherers of south-eastern origin into eastern Central Europe towards the end of the LGM or immediately thereafter (Lengyel et al. 2021; Kretschmer 2015: 122; Maier 2015: 237ff.). Recently, a case is frequently made for the coexistence of Epigravettian and Magdalenian in southern Poland and Moravia during a considerable period of time (Łanczont et al. 2021; Nerudová & Neruda 2014; Połtowicz-Bobak 2020; Połtowicz-Bobak & Bobak 2020; Wiśniewski et al. 2017), but this view is not universally accepted (cf. Lengyel et al. 2021: 21).

The site of Kammern-Grubgraben

One of the best-known LGM sites in eastern Central Europe is Grubgraben in Lower Austria (Fig. 1). The open-air site in the municipality of Hadersdorf-Kammern is situated between two hills, the Heiligenstein in the west and the Geißberg to the east. The protected basin is open to the south where, at a distance of just under one kilometre, the Kamp river flows towards the Danube (Fig. 2). Already discovered in 1870, the site was subjected to several minor unsystematic investigations, before in 1985 large-scale excavations were initiated by Friedrich Brandtner (Neugebauer et al. 2016). The first part of the field campaigns from 1985–1990 were conducted by Anta Montet-White (1988, 1990; Brandtner 1989), the second from 1993–1994 by Brandtner and Bohuslaw Klíma (Brandtner 1996) with a continuous contribution of Paul Haesaerts (Haesaerts 1990; Haesaerts & Damblon 2016), who undertook systematic borehole soundings and recorded the profiles. Five superimposed archaeological layers (henceforth, AL) were distinguished, all of which were located in loess sediment (Fig. 3): "AL1, the latest occupation with significantly fewer and more dispersed structures and finds; AL2–4 representing the main occupation phase with extensive stone slab features and rich find inventories; and AL5 with only few scattered finds exposed but in the northeast of the excavated area" (Händel et al. 2021: 138). Owing to differing standards of documentation applied by Montet-White on the one hand and Brandtner / Klíma on the other, the attribution of finds to a specific unit or archaeological horizon is unfortunately not possible in all cases (Neugebauer et al. 2016: 229f.).

In 2015, fieldwork at Grubgraben was resumed by the Austrian Archaeological Institute and is still ongoing. Excavations were conducted not only on the previously investigated vineyard terrace but also on the adjacent lower one. Two archaeological horizons (henceforth, AH), AH101 and AH102, were distinguished on the

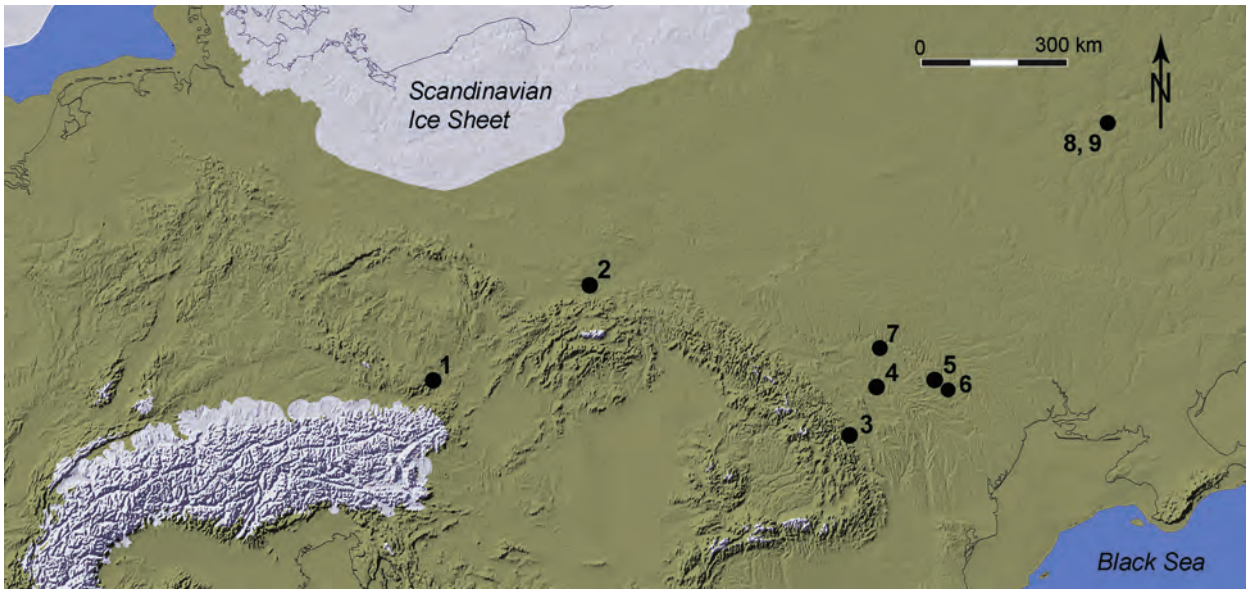

Fig. 1. Central and Eastern Europe during the LGM with maximal extension of the Scandinavian and Alpine Ice Sheets in GS-3 and sites with osseous industries. 1 – Kammern-Grubgraben (AT), 2 – Maszycka (PL), 3 – Poiana Cireşului-Piatra Neamț (RO), 4 – Cotu-Miculinți (RO), 5 – Cosăuți (MD), 6 – Raşcov 8 (MD), 7 – Molodova 5 (UA), 8 – Byki 1, 9 – Byki 7 (RU). Reference grid ETRS89. Compiled by ZBSA https://zbsa.eu/last-glacial-maximum/ (references therein). Modified by the authors.

Abb. 1. *Mittel- und Osteuropa während des LGM mit maximaler Ausdehnung der Skandinavischen und Alpinen Eisdecke in GS-3 und Fundstellen mit organischen Industrien. 1 – Kammern-Grubgraben (AT), 2 – Maszycka (PL), 3 – Poiana Cireșului-Piatra Neamț (RO), 4 – Cotu-Miculinți (RO), 5 – Cosăuți (MD), 6 – Raşcov 8 (MD), 7 – Molodova 5 (UA), 8 – Byki 1 (RU), 9 – Byki 7 (RU). Gitter ETRS89. Erstellt durch das ZBSA https://zbsa.eu/last-glacial-maximum/ (mit entsprechenden Quellen). Verändert durch die Autoren.*

Fig. 2. Open-air site of Kammern-Grubgraben (Lower Austria). View of the site (marked by oval) from the north with the Danube plain in the background. Photo S.J. Pfeifer.
Abb. 2. *Freilandfundstelle Kammern-Grubgraben (Niederösterreich). Blick auf die Fundstelle (rotes Oval) von Norden mit der Donauebene im Hintergrund. Foto S.J. Pfeifer.*

lower terrace, while excavations on the upper terrace provided three horizons, AH1–3. The excavators come to the conclusion "that AH1 and AH101 correspond to AL1, and A2 and AH 102 to AL2–3(4) of the previous excavations" (Händel et al. 2021: 139), while AH3 may correspond to AL5. The presence of large stone structures and combustion features in AH2 and AH102 confirms earlier observations. In contrast, intense reworking and re-deposition of sediments is characteristic for the upper layers AH1 and AH101, and there is no evidence of in situ structures as previously described for AL1 (ibid: 149). Multiple new radiocarbon measurements produced calibrated ages between 23.5 and 22 ka calBP and thus correspond to former results that place the main occupations at Grubgraben posterior to GS-3 (ibid: Tab. 7; Haeserts et

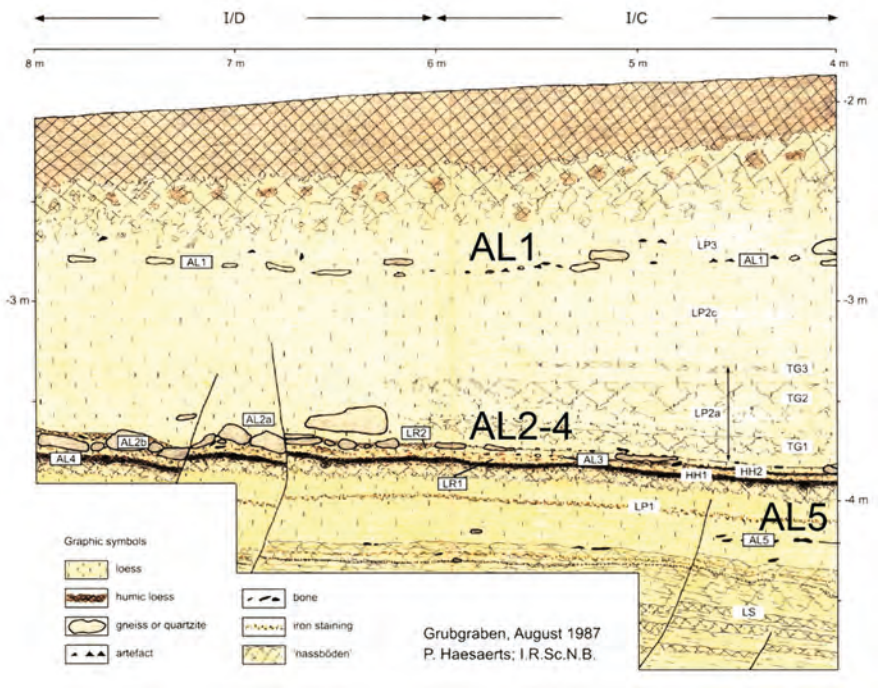

Fig. 3. Kammern-Grubgraben. Western wall of squares I/D and I/C, excavation A. Montet-White, with archaeological layers AL1–5 (from Haeserts & Damblon 2016).
Abb. 3. *Kammern-Grubgraben. Westprofil der Quadratmeter I/D und I/C, Grabung A. Montet-White, mit den archäologischen Horizonten AL1–5 (aus Haeserts & Damblon 2016).*

al. 2016; Lengyel et al. 2021: 9, Tab. 2, Fig. 4) and probably into GI-2 (Händel et al. 2021: 152) (Fig. 4).

The main occupation layers AL2–4 yielded high numbers of animal bones dominated by reindeer (West 1997) as well as a considerable amount of fossil molluscs regarded as personal adornments, mainly dentalia but also notched or perforated snails and bivalves (Neugebauer et al. 2016: Pl. 7). The lithic artefact spectrum is characterised by a high variability of core concepts, the dominance of flakes over blades and the production of bladelets, often of very small dimensions. The tools are strongly dominated by laterally retouched pieces, followed by scrapers. Noteworthy is also the presence of marginally retouched micro-bladelets, fine borers and raclette-like pieces. Parallels to the lithic industry at Grubgraben exist on the one hand at LGM sites in eastern Central and Eastern Europe, on the other hand in Late Badegoulian assemblages in Western Europe (Demidenko et al. 2019; Händel et al. 2021: 6ff.; Lengyel et al. 2021; Montet-White 1990, 1994; Neugebauer et al. 2016: 232ff., Pl. 9–13; Terberger 2013; Williams 1998: 12). The typologically diverse osseous industry was frequently acknowledged for the presence of eyed bone needles, antler and mammoth ivory points, a flute from a reindeer tibia, and a proposed spear thrower hook (e.g. Brandtner 1989; Händel et al. 2021; Neugebauer et al. 2016). "Rough working traces" were reported on antler (Neugebauer et al. 2016: 213).

The clearly distinguishable, uppermost find layer AL1 differs from the main occupation layers AL2–4 by the presence of a significantly higher percentage of backed bladelets (Händel et al. 2021: 143; Lengyel et al. 2021:

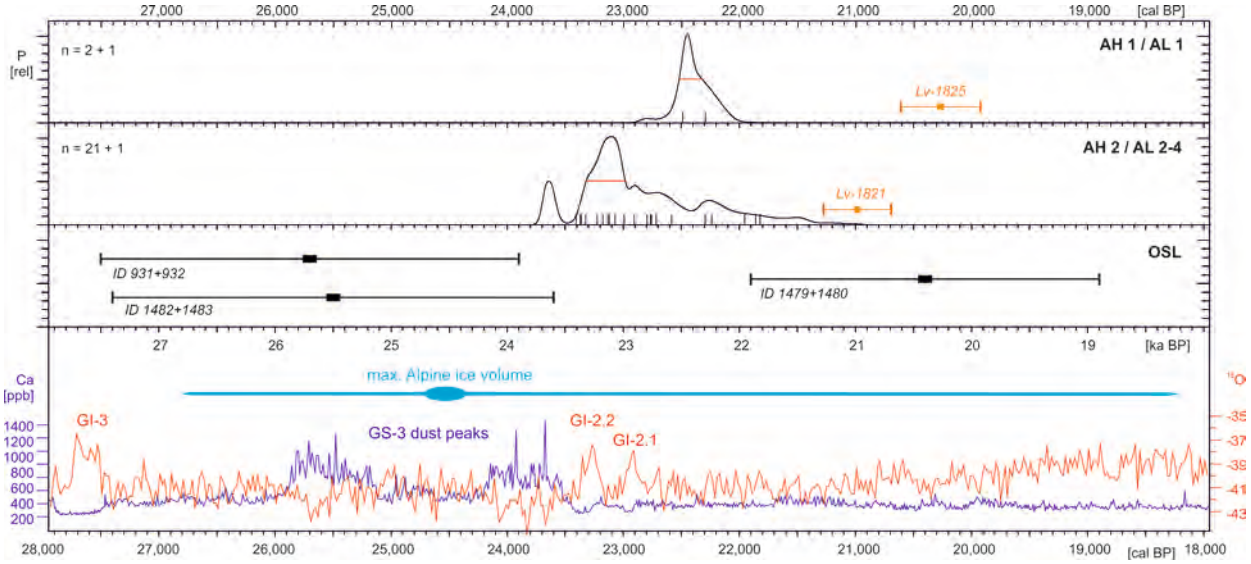

Fig. 4. Chronostratigraphic model of the main archaeological contexts/occupations at Kammern-Grubgraben with ^{14}C ages and luminescence ages. The model shows that occupation episodes AH1 and AH2 succeed GS-3 dust deposition. AH2 clearly coincides with GI-2, whereas AH1 appears to be slightly later. Radiocarbon and luminescence data derive from Händel et al. (2021, Tab. 7 & 8). Graph produced with CalPal 2023.1, https://doi.org/10.5281/zenodo.7215742 (Weninger & Jöris 2008) showing sum plots of probability distributions of calibrated ^{14}C dates based on IntCal20 calibration curve (Reimer et al. 2020). Calibrated ^{14}C ages are grouped by assigned archaeological layers. Attribution of layers is based on stratigraphic observations in Händel et al. (2021): AH1/AL1 & AH2/AL2-4. The two outlier ages not included in the sum plots are given with error bars in orange (Lv-1821 & Lv-1825). The red horizontal bars in the sum plot curves mark a P [rel] = 50 % threshold. OSL ages are plotted as average values for neighbouring sample doublets (cf. Händel et al. 2021). Average values determined by applying formula B.23 of Aitken (1985, Appendix B): ID 931 & 932: 25.7 ± 1.8 ka and ID 1482 & 1483: 25.5 ± 1.9 ka from beneath AH2; ID 1479 & 1480: 20.4 ± 1.5 ka from above AH1. All uncertainties represent 1σ. GICC05 timescale (Greenland Ice Core Chronology 2005, 15–42 ka; 20 yr δ 18O, http://www.iceandclimate.nbi.ku.dk – Andersen et al. 2006) and GISP2 Ca (GISP2 Ca Glaciochemical Data 0–70 ka calBP; Mayewski et al. 1997) are plotted as implemented in CalPal 2023.1. INTIMATE event stratigraphy refers Rasmussen et al. (2014) and time of maximum volume of Alpine glaciation is given according to Seguinot et al. (2018, Fig. 4b) together with timespan when modelled total ice volume > 0.2 m s.l.e. (metres of sea level equivalent) in MIS2. Illustration M. Händel.

Abb. 4. *Chronostratigrafisches Modell der Hauptbelegungsphasen/archäologischen Kontexte von Kammern-Grubgraben mit ^{14}C- und Lumineszenz-Altern. Das Modell zeigt, dass die Belegungsphasen in AH1 und AH2 auf die Staubablagerungen von GS-3 folgen, wobei AH1 etwas jünger zu sein scheint. Die Radiokarbon- und Lumineszenzdaten stammen aus Händel et al. (2021, Tab. 7 & 8). Der Graph wurde mit CalPal 2023.1, https://doi.org/10.5281/zenodo.7215742 (Weninger & Jöris 2008) produziert und zeigt Summenplots von Wahrscheinlichkeitsverteilungen kalibrierter ^{14}C-Daten basierend auf der IntCal20 Kalibrationskurve (Reimer et al. 2020). Die kalibrierten ^{14}C-Alter sind nach zuweisbaren archäologischen Schichten gruppiert. Die Zuweisung der Schichten basiert auf den stratigraphischen Beobachtungen in Händel et al. (2021): AH1/AL1 & AH2/AL2-4. Die beiden outliers, die nicht in den Summenplots enthalten sind, sind mit orangefarbenen Fehlerbalken angegeben (Lv-1821 & Lv-1825). Die roten horizontalen Balken in den Summenkurven markieren einen Schwellenwert von P [rel] = 50 %. Die OSL-Alter sind als Durchschnittswerte für benachbarte Proben-Doubletten aufgetragen (vgl. Händel et al. 2021). Die Durchschnittswerte wurden durch Anwendung der Formel B.23 von Aitken (1985, Anhang B) ermittelt: ID 931 & 932: 25,7 ± 1,8 ka und ID 1482 & 1483: 25,5 ± 1,9 ka von unterhalb von AH2; ID 1479 & 1480: 20,4 ± 1,5 ka von oberhalb von AH1. Alle Unsicherheiten entsprechen 1σ. GICC05 Zeitskala (Greenland Ice Core Chronology 2005, 15-42 ka; 20 yr δ 18O, http://www.iceandclimate.nbi.ku.dk - Andersen et al. 2006) und GISP2 Ca (GISP2 Ca Glaciochemical Data 0-70 ka calBP; Mayewski et al. 1997) sind wie in CalPal 2023.1 implementiert aufgetragen. Die INTIMATE-Ereignisstratigraphie bezieht sich auf Rasmussen et al. (2014) und der Zeitpunkt des maximalen Volumens der alpinen Vergletscherung ist nach Seguinot et al. (2018, Abb. 4b) zusammen mit der Zeitspanne angegeben, in der das modellierte Gesamteisvolumen > 0,2 m s.l.e. (Meter Meeresspiegeläquivalent) im MIS2 war. Illustration M. Händel.*

Tab. 5; Montet-White 1988: 216), and a decorated perforated baton that was found close to a combustion feature in 1989 (Brandtner 1989: Fig. 8) (Fig. 5). In addition, Montet-White (1994: 499) reports "bone points with quadrangular cross-sections and double bevelled bases". As already pointed out by Brandtner (1989: 26), these features would rather be in accordance with the Magdalenian. Based on a conspicuously young – conventional – radiocarbon measurement on bone of 16,800 ± 280 BP (20.9–19.6 ka calBP – Lv-1825), Maier (2015: 240) and Terberger (2013: 433) proposed a Late Upper Palaeolithic occupation event at Grubgraben, which would be contemporaneous with the Lower Magdalenian in Western Europe (Langlais et al. 2015) and hence substantially pre-date the ~18.5 ka calBP Magdalenian occupations of Maszycka cave in the Polish Jura (Kozłowski et al. 2012) as well as the 18.7–17.8 ka calBP, likely Epigravettian occupations in the Brno-Štýřice area in Moravia (Nerudová & Neruda 2014; Nerudová et al. 2022), both of which are regarded as the earliest reliable post-LGM sites in eastern Central Europe north of the Carpathian Basin (Lengyel et al. 2021; Maier et al. 2020). Recent AMS measurements for AL1 and AH1, however, produced ages of 23–22.1 ka calBP, which is slightly younger than the range of dates obtained for the subjacent main occupational layers AL 2–4 (Händel et al. 2021: Tab. 7; Lengyel et al. 2021: Tab. 2) (Fig. 4), but still far older than the single conventional date. Owing to its stratigraphic position well above the densely packed main occupational layers, its complex formation history and the typological peculiarities, AL1/AH1 is currently interpreted as a palimpsest in which the presence of younger occupations is likely, yet hitherto impossible to pinpoint in the recent excavations (Händel et al. 2021: 153).

Objectives of the study

The aim of this study is to present and evaluate the osseous industry of Grubgraben originating from the 1985–1994 excavations. To date, this is the only LGM site with preserved bone, antler and ivory tools in Central Europe and therefore of crucial importance for our understanding of a substantial part of the toolkit of hunter-gatherers during this time period (Langlais et al. 2021).

The bone, antler and ivory artefacts are assessed from a technological and typological perspective, and the operation chains of different tool types reconstructed, where possible. One focal question is how the osseous industry relates to the observations made on the lithic industry regarding the regional and supra-regional similarities and differences of Grubgraben to the Eastern European Epigravettian, and to the Western European Badegoulian (Ducasse et al. 2021; Händel et al. 2021; Montet-White 1994; Terberger 2013; Terberger & Street 2002). Another major question is whether the former typo-technological distinction between the main occupational layers AL2–4 (LGM) and AL1 (early post-LGM?) can be reproduced and further specified. As outlined above, evidence of a component at Grubgraben equivalent to the Lower Magdalenian would have major implications for the recolonisation of eastern Central Europe during the Late Upper Palaeolithic (cf. Terberger 2013: Figs. 2 & 23).

Materials and methods

While the find material recovered during the excavations by Montet-White was shipped to the US and later successively repatriated to Austria over a

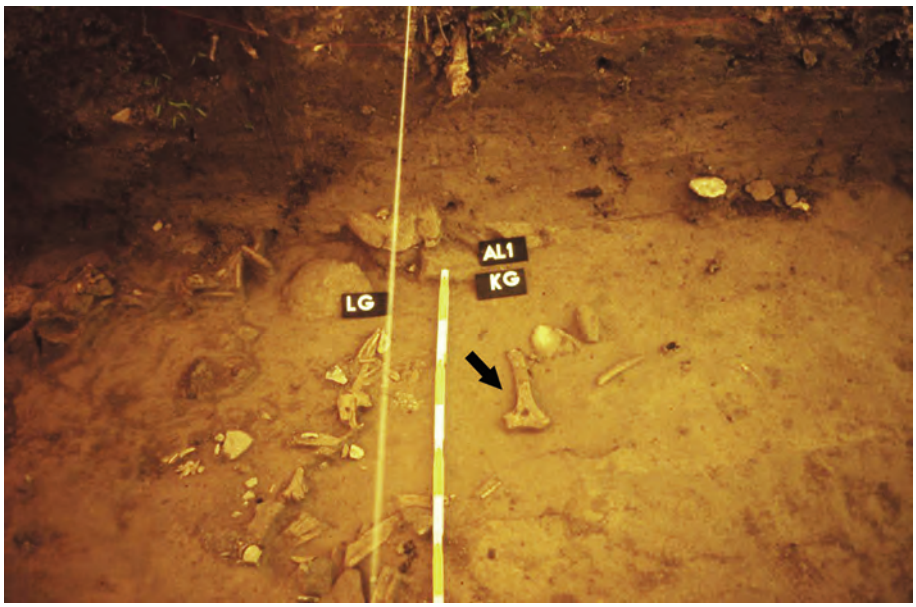

Fig. 5. Kammern-Grubgraben. AL1 during excavation in 1989 with perforated baton in situ (arrow). Photo Austrian Academy of Sciences.
Abb. 5. *Kammern-Grubgraben. AL1 während der Ausgrabung 1989 mit Lochstab in situ (Pfeil). Foto Österreichische Akademie der Wissenschaften.*

longer period of time, the finds from the later campaign led by Brandtner and Klíma were stored in Brandtner's property until his death in 2000. The finds were subsequently returned to the facilities of the Federal State of Lower Austria and partially inventorised by Margit Bachner in the early 2000s. From 2013–2015, a large-scale inventory project was carried out by the Austrian Archaeological Institute and the Universities of Erlangen and Cologne, during which all accessible finds were recorded in an MS Access object database (Neugebauer et al. 2016). Currently, this database has around 23,800 entries.

After accessing this object database, all storage boxes with bone, ivory and antler objects originating from the 1985–1994 excavations were systematically screened in the facilities of the Austrian Archaeological Institute at Krems (Lower Austria). Further and previously unrecorded osseous material from Montet-White's excavations, repatriated from the University of Kansas in spring 2021, was also searched, but only yielded one single artefact. This work was carried out in August 2021. The artefacts currently on display in the MAMUZ Museum (Asparn/Zaya, Lower Austria), Hadersdorf (Lower Austria), Krahuletz Museum (Eggenburg, Lower Austria) and Haus der Geschichte (St. Pölten, Lower Austria) were examined in February and September 2022 (Supporting Information SI1-SI4).

Among several thousand osseous fragments, many of which are marrow-fractured (cf. West 1997), only 65 relate to tool production. This low number is surprising considering earlier statements and may also be the result of inappropriate treatment, storage, and transport of the osseous material in the early years, which may have led to increased fragmentation to the extent that artefacts are not any longer recognisable (cf. Neugebauer et al. 2016: 231). The unsystematic screening of the sediment during the campaigns probably resulted in many small fragments of needles being overlooked. Owing to consequent wet screening, the new excavations, despite covering a much smaller area, constantly furnish small needle fragments (Händel et al. 2021).

Forty-one artefacts can be attributed to a specific archaeological layer, and almost all of them (N = 40) derive from the main occupation layers AL2–4. Only a single specimen – the decorated perforated baton – originates from AL1 (Fig. 5). Each artefact was examined using a magnifying glass and a Dinolite Edge™ hand-held digital microscope with an emphasis on manufacturing traces and post-depositional alterations. Surface preservation was classified following Borao Álvarez et al. (2016) and Pfeifer (2014). Fractures were characterised according to Pétillon (2006), Pétillon and Averbouh (2012), and Pfeifer (2016). Fractures in fresh condition relating to tool manufacture or use, and post-depositional breaks were distinguished. Refitting of fragments was successful in the cases of a large ivory flake and an ivory projectile point. Each artefact was measured with digital callipers, recorded in a detailed attribute system and photographed. Cross sections were drawn.

Results

Surface preservation of osseous artefacts is overall good with 26 pieces attributed to class 1 (very good), 32 to class 2 (good) and only seven to class 3 (bad). None of the artefacts show visible evidence of the impact of fire.

The largest raw material class of osseous artefacts at Grubgraben is antler, represented by 25 pieces weighing together around three kilograms. Twenty larger pieces were identified as reindeer (*Rangifer tarandus* Linnaeus), and two pieces as red deer (*Cervus elaphus* Linnaeus). Eleven artefacts, as well as 60 fragments where clear working traces are not identifiable due to bad preservation, are made of mammoth (*Mammuthus primigenius* Blumenbach) ivory. The ivory objects recovered by the 1985–1994 excavations weigh around 2.5 kg. Twenty-nine artefacts were produced on bones of large mammals.

The faunal remains are strongly dominated by reindeer, followed by horse (Tab. 1). So far, there is no evidence for the presence of a complete mammoth carcass. Only ivory and single bones were introduced, the latter possibly for fat and marrow extraction. The anthropic fracturing of the few mammoth bones from Grubgraben cannot be considered an argument for mammoth hunting, since small quantities of mammoth bones were frequently retrieved from permafrost during the Late Upper Palaeolithic (Gaudzinski et al. 2005). Also, the mammoth population in the northern mid-latitudes of eastern Central Europe was in a decline

Species	AL2–4	AL1	Total
Mammuthus primigenius	1	1	2
Bison sp.	2	-	2
Bos primigenius	-	1	1
Capra ibex	3	1	4
Cervus elaphus	2	-	2
Equus sp.	22	10	32
Rangifer tarandus	163	12	175
Ursus arctos	1	-	1
Canis lupus	2	1	3
Gulo gulo	1	-	1
Vulpes lagopus	1	-	1
Vulpes vulpes	1	-	1
Anser sp.	1	-	1
Lepus sp.	5	2	7
Citellus citellus	1	-	1
MNI total	206	28	234

Tab. 1. Kammern-Grubgraben. MNI of animal species of the 1985–1994 excavations. Only skeletal material that can be assigned to archaeological layers (AL) is included.
Tab. 1. *Kammern-Grubgraben. MNI der Tierarten aus den Grabungen 1985–1994. Es wurde nur Skelettmaterial berücksichtigt, das archäologischen Horizonten (AL) zugeordnet werden kann.*

during the LGM (Nadachowski et al. 2018). Current evidence therefore speaks for acquisition of mammoth remains through collecting, likely from permafrost deposits.

The animal species at Grubgraben seem to indicate a change in vegetation and thus probably a change in climatic conditions from AL2–4 to AL1. However, it must be noted that the amount of underlying data differs greatly between the layers. Reliable statements are therefore only possible for species represented by large numbers, such as reindeer and horse. In the uppermost layer AL1, a decrease in reindeer can be observed and at the same time an increase in horse. Other species are represented only by small numbers. While bison is present in the earlier layers AL2–4, it is no longer detectable in AL1, but instead aurochs. Thus, the herbivores tentatively suggest a change from colder and drier conditions in AL2–4 to warmer conditions in AL1. Detailed analyses to the faunal remains of Kammern-Grubgraben, including stable isotopes, are still ongoing.

The osseous artefacts can be subdivided into raw material blocks and production waste on the one hand, and finished tools or preforms on the other (Tab. 2). The second category is twice as large as the first, possibly due to the high post-excavation fragmentation rate of the osseous material, limiting the recognition of production waste. At Grubgraben, there is no evidence of debitage produced by longitudinal grooving sensu Clark (1953). Regardless of raw material and artefact type, osseous preforms were exclusively prepared by direct percussion (cf. Borao Álvarez et al. 2016; Ducasse et al. 2021; Pétillon & Ducasse 2012).

Antler artefacts

According to the anatomical sections represented in the artefact material, at least 16 individual antler beams were brought to the site, 15 originating from reindeer and one from red deer. In ten cases, the pedicle was preserved, which indicates the predominant use of shed antlers (Figs. 6: 1 & 3, 7: 2 & 10: 4). Both, dimensions and compacta thickness, which ranges from 0.6–0.9 cm, clearly speak for antlers of adult males (Averbouh 2000; Pfeifer 2016) (SI 1).

Raw material blocks are represented by 14 pieces, located in the basal–distal part of the beam. Their preserved lengths are 21.5–40.2 cm. In three cases, the basal and in eleven cases, the distal parts were broken off intentionally, leaving typical elongated tongue-shaped fracture planes (Fig. 6; SI 1). In ten cases, the brow and bez tines were broken off, but that does not necessarily relate to human action since fractures of bez tines with small diameters occur very often naturally during the rutting season (Pfeifer 2014). Removed tines were never used as preforms for tools, and thus they can be classified as production waste. One terminal fracture on a reindeer antler is sediment-related. In seven cases, the fractures on main beam and tines cannot be characterised due to poor preservation caused by weathering or post-sedimentary decomposition processes.

In two cases, both on red deer antler, the basal part and a terminal tine were removed by chopped, circular notches (Fig. 7). Antler debitage aimed on the one hand at obtaining elongated blanks from the main beam by direct percussion (Fig. 8). On the other hand, transverse beam segments were produced by the aid of chopped circular notches (Figs. 7 & 10: 5).

Antler tools are represented by eight pieces (SI 2 & SI 3):

1. Inv.nr 7970, AL3 (Fig. 9). Long point with oval cross section made on a blank that was obtained by direct percussion and shaped by extensive longitudinal scraping. As the proximal part is still the un-worked blank, the object is probably a semi-finished projectile point.
2. Inv.nr 6118, AL2–4 (Fig. 10: 1). Distal part of an elongated pointed antler tool with an oval cross section, probably a projectile point.
3. Inv.nr 8072, AL3 (Fig. 10: 2). Distal part of an elongated pointed antler tool with an oval cross section, probably a projectile point.
4 Inv.nr 7971 (Fig. 10: 5). Short transverse segment detached from the main beam by circular notches and extensively modified by chopping to create tapering ends. The deep longitudinal cleft, the forked upper end and the missing spongiosa may result from taphonomic processes that regularly lead to cracking and spongiosa decay (cf. Pfeifer 2016). If the morphology is, however, the result of human modification, an interpretation as handle or hafting device comes to mind. Similar transversal segments from antler with splits and hollowed-out sections of

Raw material blocks and production waste (N = 22)				
Antler raw material blocks	Prepared antler blanks	Antler manufacturing waste	Ivory manufacturing waste	Waste from bone needle production
14	1	2	3	2

Finished tools and preforms (N = 43)				
Projectile points	Needles	Pointed tools	Perforated batons	Other tools
8	21	8	2	4

Tab. 2. Kammern-Grubgraben. Osseous artefacts of the 1985-1994 excavations.
Tab. 2. *Kammern-Grubgraben. Organische Artefakte aus den Ausgrabungen 1985–1994.*

Fig. 6. Kammern-Grubgraben, AL2–4. Raw material blocks from reindeer antler. Note oblique, tongue-shaped fracture planes and negatives of four small flakes on one of the pieces (No. 4 – arrows). Repository Austrian Academy of Sciences. Photos S.J. Pfeifer.
Abb. 6. *Kammern-Grubgraben, AL2–4. Rohmaterialblöcke aus Rentiergeweih. Zu beachten die schrägen, zungenförmigen Bruchflächen sowie Negative von vier kleinen Abschlägen an einem der Stücke (Nr. 4 – Pfeile). Depot Österreichische Akademie der Wissenschaften. Fotos S.J. Pfeifer.*

unclear genesis interpreted as "tool hafts" are reported from the Late Gravettian open-air site of Moravany-Lopata II in Slovakia (Kozłowski 1998: 90ff.).

5. Inv.nr 6116, AL2–4 (Fig. 10: 3). Pointed antler tool made on an elongated splinter obtained by percussion.
6. Inv.nr 8248, AL2 (Fig. 10: 4). Basal section of a small shed antler with the brow tine still partially in place. The fracture of the bez tine cannot be further characterised. The proximal part of the beam was removed and the fracture plane subsequently smoothed. Its surface is polished from manufacture, or by use. Although it cannot be ruled out that this modification happened when the antler was still attached to the skull of the living animal – the main beams of reindeer antler do occasionally break from intravital use and fracture planes subsequently become rounded and polished (Pfeifer 2014) – both the position of the fracture and the invasive rounding speak in favour of an anthropogenic origin, hence qualifying the object as a tool.
7. Inv.nr 3316, AL3 (Fig. 11). Distal end of a perforated baton made from a transversal segment of antler. The whole surface is smoothed and the perforation

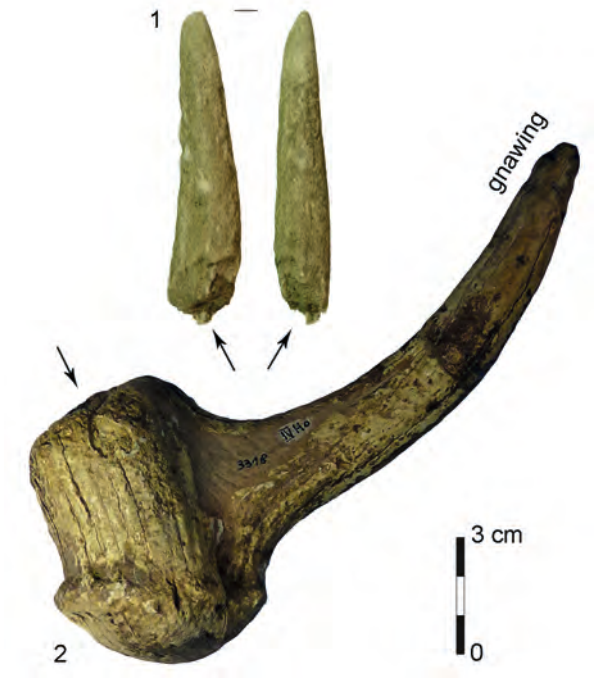

Fig. 7. Kammern-Grubgraben, AL3. Manufacturing debris from red deer antler. Removed tine (1) and removed basal section (2). Note chopped, circular notches (arrows). Repository Austrian Academy of Sciences. Photos S.J. Pfeifer.
Abb. 7. *Kammern-Grubgraben, AL3. Produktionsabfall aus Rothirschgeweih. Abgetrennte Sprosse (1) und abgetrennter basaler Abschnitt (2). Zu beachten gehackte, ringförmige Kerben (Pfeile). Depot Österreichische Akademie der Wissenschaften. Fotos S.J. Pfeifer.*

Fig. 8. Kammern-Grubgraben, AL2–4. Long reindeer antler blank obtained by direct percussion. Repository Austrian Academy of Sciences. Photos S.J. Pfeifer.
Abb. 8. *Kammern-Grubgraben, AL2–4. Langer Span aus Rengeweih, der durch direkte Perkussion hergestellt wurde. Depot Österreichische Akademie der Wissenschaften. Fotos S.J. Pfeifer.*

was executed from both sides, resulting in an hourglass-like profile typical for LUP perforated batons (e.g. Pfeifer 2016: Pl. 11–13). The piece displays use-related fractures at the perforation the planes of which meet at an acute angle creating a beak-like morphology. This probably fostered its previous interpretation as spear thrower hook (Neugebauer-Maresch et al. 2016).

8. Inv.nr 7852, AL1 (Fig. 12). Complete, 187 mm long perforated baton decorated with an incised row of diamonds on the shaft filled with short parallel lines and a group of parallel lines at the base of the removed bez tine. This piece is the only osseous artefact from AL1. Double-bevelled projectile points as briefly mentioned by Montet-White for AL1 were not identified in the material.

It is apparent that the low number of antler tools or preforms at Grubgraben contrasts with the quantity of high-quality raw material blocks. One explanation would be that collected antlers were stored at the site for later use, as hypothesised for other LUP assemblages (Pfeifer 2016: 79). Interestingly, the excavation records state that the majority of antler artefacts classified as raw material blocks were encountered vertically embedded in the surface of AL3 (Neugebauer-Maresch et al. 2016: Pl. 6). Brandtner and Klíma (1995) hence interpret these antler objects as tent pegs used to hold the ropes of a proposed dwelling structure. Be that as it may, it can certainly be stated that the long, tongue-shaped fractures observed on several pieces would favour driving them into the ground. The negatives of flakes on one piece might hence not be intentional but the result of vigorous hammering (Fig. 6: 4). Thus, a dual function of these antlers as raw material for tool production on the one hand and constructional elements of whatever kind on the other appears conceivable.

Ivory artefacts

Ivory was likely extracted from permafrost deposits. The inventory includes no clear raw material blocks. Based on 60 fragments lacking unambiguous working traces that were parts of larger tusk segments that had undergone weathering and lamellar decomposition, it can be assumed that raw material blocks had been brought into the site. Prepared blanks are not present in the material, but three flakes, one of which is almost complete, indicate preparation of pre-forms by direct percussion (Fig. 13; SI 1).

Ivory preforms were modified into tools by longitudinal scraping. Eight tools were identified (SI 2 & SI 4):

Fig. 9. Kammern-Grubgraben, AL3. Semi-finished reindeer antler point made on a blank. Arrow indicates percussion mark from blank preparation. Repository Austrian Academy of Sciences. Photos S.J. Pfeifer.

Abb. 9. *Kammern-Grubgraben, AL3. Halbfabrikat einer Spitze aus einem Rengeweih-Span. Der Pfeil zeigt auf eine Schlagmarke von der Spanherstellung. Depot Österreichische Akademie der Wissenschaften. Fotos S.J. Pfeifer.*

1. Inv.nr 8134, AL3 (Fig. 14: 1). Stocky projectile point reconstructed from several fragments. Spindle-shaped, with a rounded tip and oval cross section. The base bears hafting striations. It is broken, but its notable taper in all symmetry planes suggests an original morphology akin to a massive base (cf. Demay et al. 2016: Fig. 17; Pétillon et al. 2011).
2. Inv.nr 6112, AL2–4 (Fig. 14: 2). Slender projectile point with a single-bevelled base without hafting striations and a round cross section.
3. Inv.nr 7972, AL3 (Fig. 14: 4). Basal–proximal fragment of a slender projectile point with hafting striations. The cross section is oval and the base morphology unknown. Of note is a use-related bevelled break in the proximal section.
4. Inv.nr 6113, AL2–4 (Fig. 14: 5). Mesial–distal fragment of a projectile point with an oval cross section. It features working traces of longitudinal scraping and a bevelled break.
5. Inv.nr 102205, AL3 (Fig. 14: 6). Mesial–distal fragment of a projectile point consisting of two fragments. It is much smaller than the others and has a round cross section.

6 and 7. (Inv.nr 102912 & no inf., AL 2–4) are mesial–distal fragments of needles (Tab. 3; Fig. 16: 8 & 12).

8. Inv.nr 8133, AL3 (Fig. 14: 3). Elongated, straight-sided rod consisting of two fragments with an oval cross section. The original length exceeded 15 cm. One end is intentionally rounded. An interpretation as projectile point with a clumsy massive base is possible, but there are also elongated osseous tools with rounded ends that are interpreted as retouchers (Pétillon & Chauvière 2017). The piece from Grubgraben, however, lacks the typical spatially confined percussion scars and thus its typological classification remains uncertain.

Bone artefacts

Seven irregular pointed tools from AL2–4 were made from bone flakes (Inv.nr 6117, 6052, 6057, 6192, 7003, 102493, 102008/3; Fig. 15: 1-7; SI 2). The tip of one of these is broken by use as evidenced by a bevelled break (Fig. 15: 1). Their overall morphologies suggest an interpretation as awls (cf. Pétillon & Chauvière 2017).

Nineteen bone needles were recovered, eight of which have an eye drilled from both sides into the flattened proximal end (Tab. 3; Fig. 16: 1-5 & 16). Three pieces have no eye but a slightly swelled proximal end with an oval cross section (Fig. 16: 6 & 7; SI 4). The production of bone needles at Grubgraben can be reconstructed as follows: an elongated flake of a large mammal bone, abundant by-product from extensive marrow fracturing, was shaped by extensive longitudinal scraping into a needle preform. Hereby, the unworked end of the flake served as handle. As the desired dimensions were approached, the preform was snapped off, leaving a characteristic waste piece (Fig. 16: 17 & 18), and then reduced to its final dimensions. Drilling the eye was either done while the preform was still attached to the flake, or in a last step. The needles from Grubgraben vary considerably in size; the longest complete piece is twice as long as the shortest and the widest twice as wide as the narrowest (Figs. 16 & 17). Likewise, the inner diameters of the eyes range from 1–2 mm. Owing to such varying dimensions, which correspond to contemporaneous Badegoulian assemblages from Western Europe (d'Errico et al. 2018), the needles from Grubgraben clearly had different applications. The smaller specimens are suitable for producing fine and tight seams, while the large ones only allowed relatively coarse sewing tasks. Aside from the production of clothing, needles were certainly also used to attach the hundreds of dentalia, perforated molluscs, animal teeth, and stone pendants recovered at the site (Neugebauer et al. 2016: Pl. 7) onto their carriers.

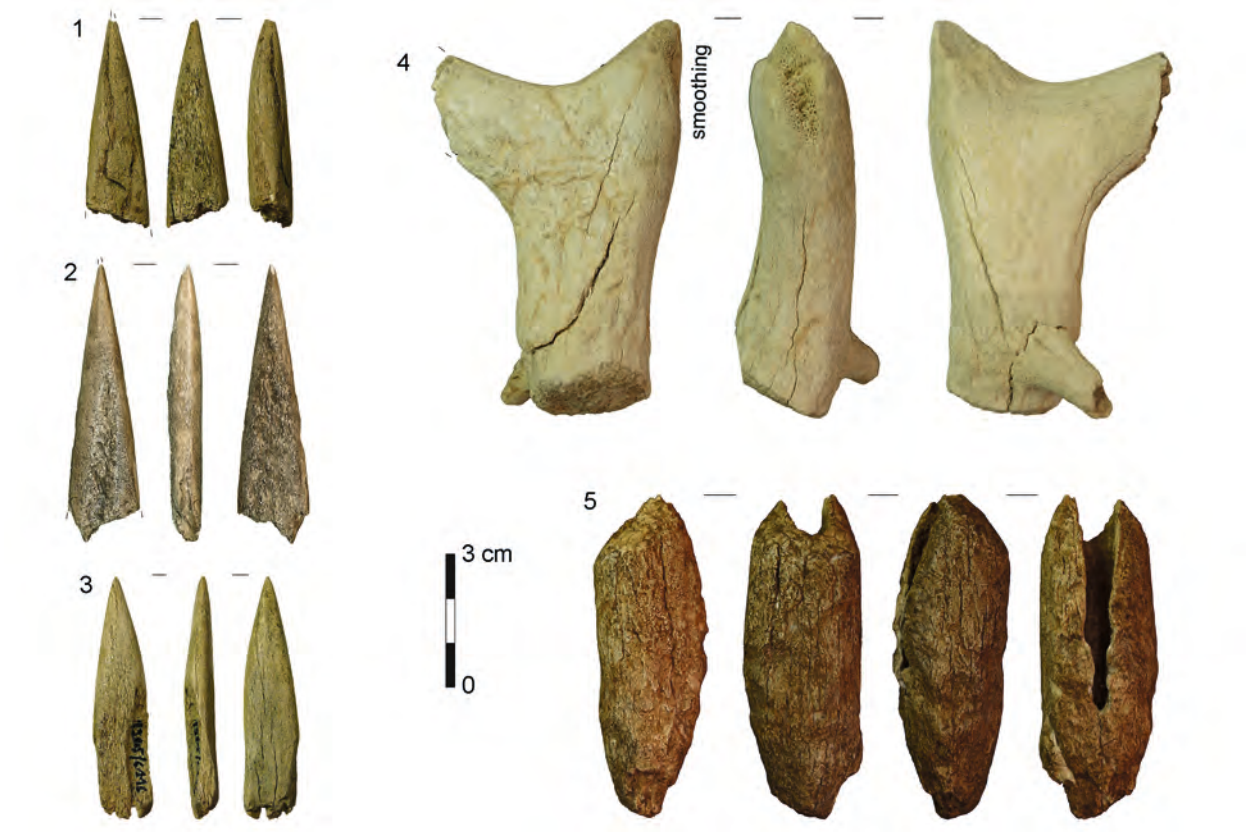

Fig. 10. Kammern-Grubgraben, AL2–4. Pointed tools (1–3) and unspecified tools (4-5) from antler. 1-3: Krahuletzmuseum Eggenburg, 2: Haus der Geschichte St. Pölten, 4.5: Repository Austrian Academy of Sciences. Photos S.J. Pfeifer.
Abb. 10. *Kammern-Grubgraben, AL2–4. Spitze Geräte (1–3) und unklassifizierte Geräte (4-5) aus Geweih. 1-3: Krahuletzmuseum Eggenburg, 2: Haus der Geschichte St. Pölten, 4.5: Depot Österreichische Akademie der Wissenschaften. Fotos S.J. Pfeifer.*

Grubgraben is well-known for a flute recovered from AL3 likely made from the tibia of a juvenile reindeer (Fig. 15: 8). The fragmented piece which is 165 mm long was already presented and discussed in detail (Einwögerer & Käfer 1998). Re-examination confirmed the clear artificial character of the three very regular holes, the surfaces of which display regular parallel striae indicative of rotational movement of the tool while creating them. The small deviation of the individual hole diameters and the great similarity of the micromorphology of all holes speak for the use of a single drilling tool to standardise all three holes in a final work step. The fractures on both ends were doubtlessly initiated when the bone was still fresh, either before it was made into a flute or afterwards. The second option appears more likely as the irregular morphology of the broken ends certainly would not favour its playability. That, again, implies that the artefact was originally longer and possibly had more holes (cf. Einwögerer & Käfer 1998: 28).

Fig. 11. Kammern-Grubgraben, AL3. Fragment of perforated baton. Krahuletzmuseum Eggenburg. Photos S.J. Pfeifer.
Abb. 11. *Kammern-Grubgraben, AL3. Fragment eines Lochstabs. Krahuletzmuseum Eggenburg. Fotos S.J. Pfeifer.*

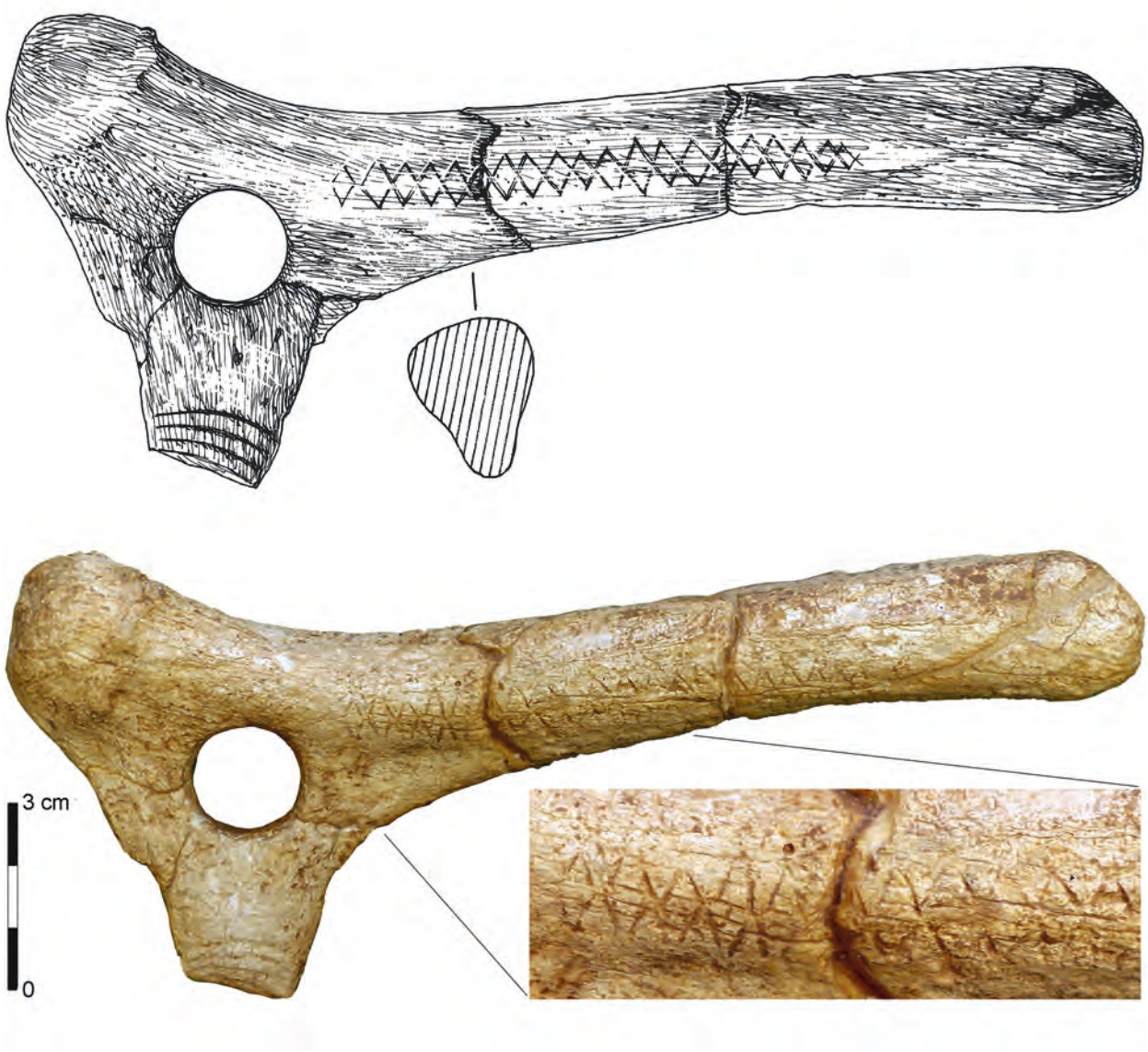

Fig. 12. Kammern-Grubgraben, AL1. Decorated perforated baton. MAMUZ Museum Asparn. Drawing from Brandtner 1989, Abb. 9; Photos S.J. Pfeifer.
Abb. 12. *Kammern-Grubgraben, AL1. Dekorierter Lochstab. MAMUZ Museum Asparn. Zeichnung aus Brandtner 1989, Abb. 9; Fotos S.J. Pfeifer.*

Discussion

Based on the archaeological remains, the processing of antler, ivory, and bone into tools during the LGM occupation of Kammern-Grubgraben can be reconstructed fairly well, and recurrent patterns can be recognised. For antler and ivory, it is clear that the raw material – large, shed antlers and tusks from permafrost deposits – was purposefully procured. In contrast, the acquisition of longbone was probably linked to the intense marrow fracturing of bones of large mammals and therefore, opportunistic. Regardless of the raw material, segmentation of raw material blocks and preparation of preforms were realised exclusively by direct percussion while exploitation by longitudinal grooving is absent. Subsequent volume reduction and modification were achieved exclusively by invasive longitudinal scraping. The strict adherence to these technological norms is especially obvious in needle production, where large bone and ivory splinters were meticulously scraped down to tiny dimensions. Perforation, which is relevant for the production of perforated batons and eyed needles has a single variance, bifacial rotation. The emphasis of osseous production clearly lies on pointed tools, predominantly sewing needles and projectile points for hunting large mammals.

The Eastern European perspective

Central European sites dated to a similar timeframe as Grubgraben have unfortunately not yielded any osseous industries (Lengyel et al. 2021), but there is data from sites located farther east (Anghelinu et al. 2021: 253) (Fig. 1): The roughly contemporaneous, Early Epigravettian horizons of the open-air site of Poiana Cireşului-Piatra Neamţ in the Eastern Carpathians (Romania) furnished awls, bones decorated with notches as well as two mammoth ivory projectile points

Fig. 13. Kammern-Grubgraben, AL2–4. Mammoth ivory flakes. Repository Austrian Academy of Sciences. Photos S.J. Pfeifer.
Abb. 13. *Kammern-Grubgraben, AL2–4. Abschläge aus Mammutelfenbein. Depot Österreichische Akademie der Wissenschaften. Fotos S.J. Pfeifer.*

likely with massive bases (Cârciumaru et al. 2006). At the open-air site Cotu-Miculinţi in the Prut valley (Romania), the main occupational layers II and III contained a reindeer antler projectile point with longitudinal grooves, three barbed antler points two of which have a central perforation at the base, and a perforated baton (Noiret 2009: Figs. 132-125). The main occupations are reported to be younger than 23 ka calBP (Noiret 2009: 163), but this is a rough age estimate based on two radiocarbon dates with high standard deviations obtained on material from the subjacent layers V and VII (cf. Noiret 2009: Tab. 59). Recently, excavations at the site have been resumed by the Valahia University of Târgovişte and the Austrian Archaeological Institute which should be able to address chronological questions in the nearer future. At the open-air site Raşcov 8 in the Middle Dniester valley (Republic of Moldova), a large mammoth ivory projectile point with two juxtaposed longitudinal grooves was recovered from layer 3. The LGM occupations likely date to 25–21 ka calBP, but more precise age determinations are hitherto lacking (Demay et al. 2021). The same applies to archaeological layers 6–3 of the large open-air site Molodova 5, also located in the Middle Dniester valley (Ukraine), that furnished antler and ivory points with massive bases and occasionally longitudinal grooves as well as perforated batons (Noiret 2009: 197f.). At the open-air site Cosăuţi, also located in the Middle Dniester valley (Republic of Moldova), a long stratigraphic sequence with multiple Early Epigravettian occupations has been dated to 23–20 ka calBP (Noiret 2009: Tab. 59). The rich osseous industry is characterised by eyed bone needles, awls, smoothers, perforated batons, projectile points made from reindeer antler and ivory with massive bases, rounded cross sections and occasionally longitudinal grooves, as well as one big barbed antler point with a basal perforation from uppermost horizon 1b, akin to the pieces from Cotu-Miculinţi (Borziac 1993; Borziac et al. 1998; Covalenco and Croitor 2016; Noiret 2009: 219ff.). Segmentation of raw material blocks at Cosăuţi and the preparation of blanks for projectile points and needles were usually realised by longitudinal grooving (Fig. 18). The detailed studying of the osseous industries from these Eastern European Epigravettian sites is still ongoing, but based on the current state of work, it can be concluded that eyed needles, perforated batons, awls and massive-based projectile points are types that also occur at Grubgraben; however, their manufacture technology, provided information is available, is markedly different.

Massive-based projectile points are deeply rooted in the eastern Gravettian. The type is attested at Pavlov (Brühl 2005), Předmostí (Klíma 1990), and Dolní Věstonice (Klíma 1983) in Moravia, at Krems-Wachtberg and Langenlois in Lower Austria (Einwögerer et al. 2008), and towards the end of the Gravettian at Moravany-Lopata II in Western Slovakia (Kozłowski 1998: Figs. 47-47) as well as at Dorochivtsy III and Obollonia in the Dniester and Desna valleys (Ukraine), respectively (Demay et al. 2016: Figs. 16 & 27). Its presence at the Magdalenian open-air site of Kamegg (Lower Austria) and Balcarka cave in the Moravian Karst (Maier et al. 2020), both with proposed occupations around 17 ka calBP (Händel et al. 2021: 153 & Tab. 7; Valoch & Neruda 2005), coincides with the re-appearance of the massive base morphology in the Franco-Cantabrian late Middle Magdalenian after two millennia of absence (Pétillon 2016). Increased contacts between Western Europe and eastern Central Europe

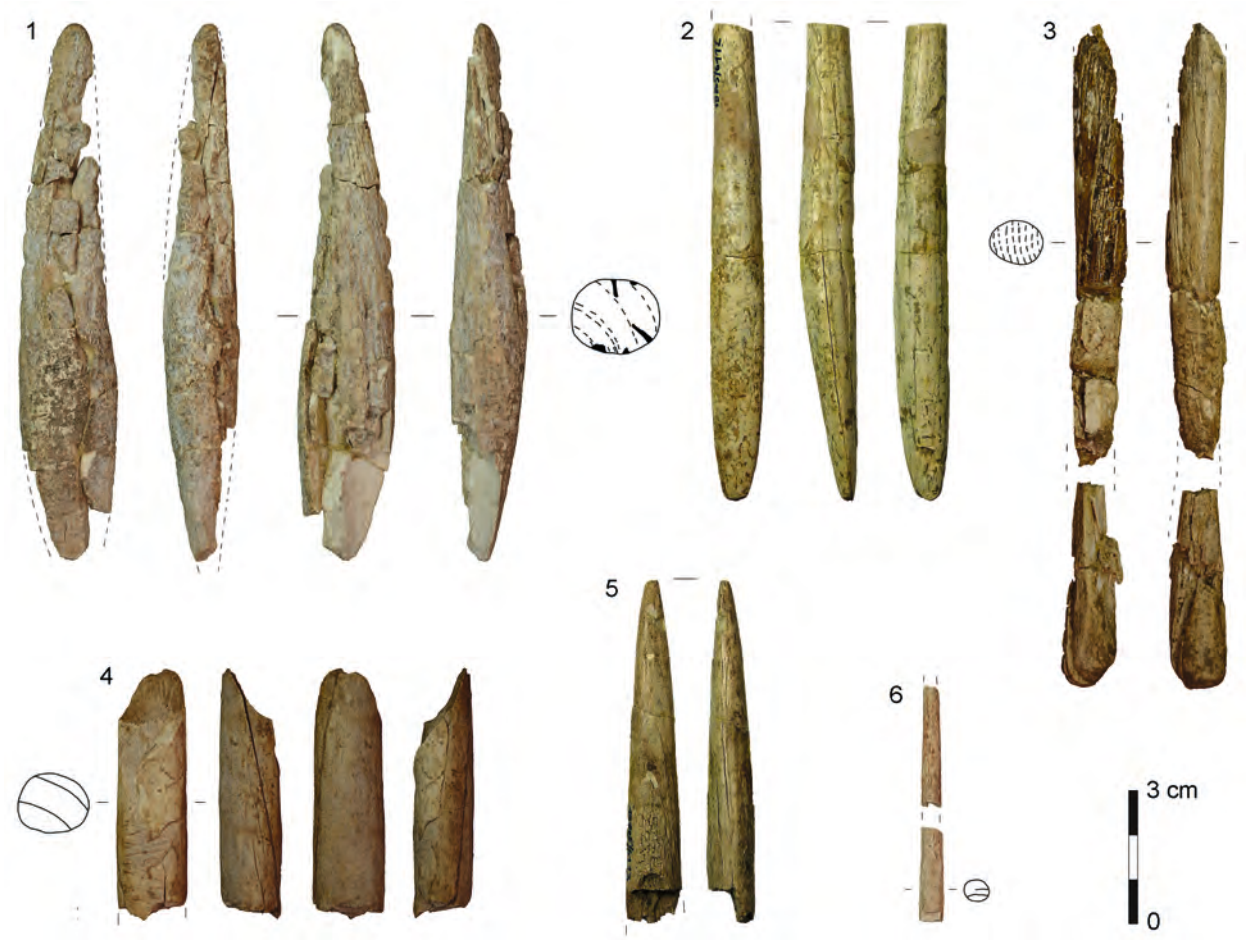

Fig. 14. Kammern-Grubgraben, AL2–4. Projectile points (1.2.4–6) and straight-sided rod (3) from mammoth ivory. 1-3.4.6: Repository Austrian Academy of Sciences, 2.5: Krahuletzmuseum Eggenburg. Photos S.J. Pfeifer.
Abb. 14. *Kammern-Grubgraben, AL2–4. Projektilspitzen (1.2.4–6) und Stab (3) aus Mammutelfenbein. 1-3.4.6: Depot Österreichische Akademie der Wissenschaften, 2.5: Krahuletzmuseum Eggenburg. Fotos S.J. Pfeifer.*

are also testified by points decorated with trapezoidal protuberances and engraved horse mandible spatulae (Lucas 2021; Maier et al. 2020; Pétillon & Sacchi 2013; Pfeifer 2017).

The importance of mammoth ivory at Grubgraben, in particular for projectile points, is another common trait of the Upper Palaeolithic in eastern Central Europe, where this raw material is very characteristic for the Gravettian (Maier et al. 2021b: 232) but still regularly used in the Magdalenian (Boroń 2010; Kozłowski et al. 1993; Müller et al. 2019; Pasda & Pfeifer 2019; Pfeifer 2022). The abundance of ivory in this region during the Pleniglacial, acquired both by hunting and collecting (Gaudzinski et al. 2005), and its favourable properties probably account for its widespread use (Pfeifer et al. 2019).

Eye–distal	Eye–mesial	Proximal–distal	Proximal–mesial	Mesial–distal	Mesial
4	4	1	3	5	4

Tab. 3. Kammern-Grubgraben. Preserved sections of bone and ivory needles (N = 21).
Tab. 3. *Kammern-Grubgraben. Erhaltene Abschnitte von Nadeln aus Knochen und Elfenbein (N = 21).*

The Western European perspective

With preforms produced exclusively by direct percussion and longitudinal scraping, eyed bone needles, various pointed tools and a single-bevelled projectile point, the osseous industry from Grubgraben on the other hand compares well to early Badegoulian assemblages in Western Europe dating to 23.5–22 ka calBP (Aura et al. 2012; Borao Álvarez et al. 2016; Chauvière et al. 2017; de la Rasilla Vives et al. 2019; Ducasse et al. 2017, 2019, 2020, 2021; Pétillon & Averbouh 2012; Pétillon & Chauvière 2017; Pétillon & Ducasse 2012; Terberger 2013), hence confirming previous observations made on the lithic industry. A distinctive type lacking at Grubgraben is the bi-pointed "self-barbed point" (Pokines & Krupa 1997), a particularly long-lived tool that apparently was in use from c. 23–16 ka calBP and hence from the early Badegoulian to the late Middle Magdalenian (Ducasse et al. 2021; Pétillon 2016; Pétillon & Ducasse 2012). Self-barbed points, however, have not yet been found east

Fig. 15. Kammern-Grubgraben, AL2–4. Pointed tools (1–7) and flute (8A & B) from bone. Note bevelled break and chopped, lateral groove (1 – arrows). 1-2.4–6: Repository Austrian Academy of Sciences, 3: Krahuletzmuseum Eggenburg, 8: Haus der Geschichte St. Pölten, 9: MAMUZ Museum Asparn. Photos S.J. Pfeifer & T. Einwögerer. X-ray 8B is courtesy of N. Sautner, Department of Prehistoric and Historical Archaeology, University of Vienna, edited by T. Einwögerer.

Abb. 15. *Kammern-Grubgraben, AL2–4. Spitze Geräte (1–7) und Flöte (8A & B) aus Knochen. Zu beachten der zungenförmige Bruch und die gehackte, laterale Kerbe (1 – Pfeile). 1-2.4–6: Depot Österreichische Akademie der Wissenschaften, 3: Krahuletzmuseum Eggenburg, 8: Haus der Geschichte St. Pölten, 9: MAMUZ Museum Asparn. Fotos S.J. Pfeifer & T. Einwögerer. Röntgenaufnahme 8B (Urheber: N. Sautner, Abteilung Prähistorische und Historische Archäologie der Universität Wien) wurde durch T. Einwögerer bearbeitet.*

Fig. 16. Kammern-Grubgraben, AL2–4. Needles (1–15) and production waste (17-18). 16: close-up of drilled eye of Nr 4. Note fractures from detachment of needle pre-form from debris (17 – arrows). 1.7.9.11–18: Repository Austrian Academy of Sciences. 2–6.8.10: Krahuletzmuseum Eggenburg. Photos S.J. Pfeifer.
Abb. 16. *Kammern-Grubgraben, AL2–4. Nadeln (1–15) und Produktionsabfall (17-18). 16: Detailaufnahme des gebohrten Öhrs von Nr. 4. Zu beachten die Frakturen von Abtrennung der Nadel vom Produktionsabfall (17 – Pfeile). 1.7.9.11–18: Depot Österreichische Akademie der Wissenschaften 2–6.8.10: Krahuletzmuseum Eggenburg. Fotos S.J. Pfeifer.*

of the Rhine (cf. Maier et al. 2020: Suppl. Tab. 3; Pfeifer 2021), and therefore appear to be just as much a regional phenomenon as the large perforated barbed points of the Eastern European early Epigravettian that were not used west of the Prut valley. In return, the fragment of a perforated baton from the LGM horizon at Grubgraben has no parallels in Western Europe where this distinct tool type is absent from Badegoulian assemblages (Pétillon & Ducasse 2012; Rigaud 2001: 101f.).

Magdalenian occupations at Grubgraben?

The perforated baton from AL1 deserves further discussion, not just because it is the only surviving osseous artefact from this layer but also because of its decoration (Fig. 12). A similar row of filled diamonds is found on a bone smoother (*lissoir*) from Grappin cave in the French Jura which is dated to the early Middle Magdalenian (c. 19–18 ka calBP) and assigned to the distinct facies *à navettes* (Allain et al. 1985; Malgarini 2014: Fig. 174: 5). The previously introduced Maszycka cave in Southern Poland is assigned to the same facies and notably furnished a perforated baton as well (Kozłowski et al. 2012; Pfeifer 2022: Fig. 16). The procurement patterns of lithic raw materials at Grubgraben show a preferred orientation towards the

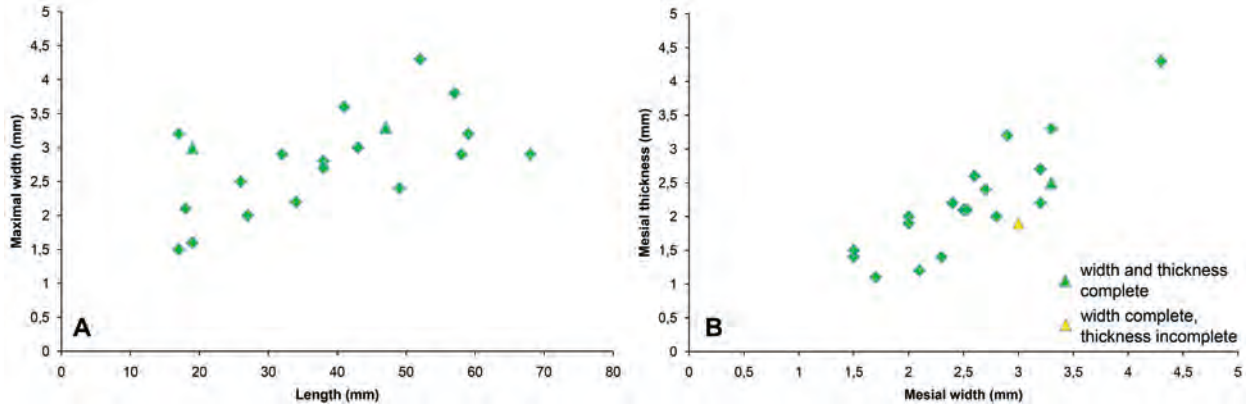

Fig. 17. Kammern-Grubgraben. Metric data of needles. **A**: Length and width of all fragments. Diamond: bone, triangle: ivory. N = 21. **B**: Mesial width and thickness. Diamond: bone, triangle: ivory. N = 21.
Abb. 17. *Kammern-Grubgraben. Metrische Daten der Nadeln. **A**: Länge und Breite aller Fragmente. Rhombe: Knochen, Dreieck: Elfenbein. N = 21. **B**: Breite und Dicke im medialen Bereich: Rhombe: Knochen, Dreieck: Elfenbein. N = 21.*

Fig. 18. Exploitation of raw material blocks by longitudinal grooving at LGM site of Cosăuți (Republic of Moldova). Detached reindeer antler tines (1-2), bone needle blanks (3), prepared reindeer antler blank (4), bone needle cores on large mammal bones (5-6). Repository National Museum of History of Moldova. Photos S.J. Pfeifer.

Abb. 18. *Zerlegung von Rohmaterialblöcken durch longitudinale Rillentechnik an der Fundstelle Cosăuți (Republik Moldau). Abgetrennte Rengeweihsprossen (1-2), Späne für Nadelproduktion aus Knochen (3), Span aus Rengeweih (4), Nadelkerne aus Knochen von Größsäugetieren (5-6). Depot Nationalmuseum der Geschichte Moldaus. Fotos S.J. Pfeifer.*

northeast in all archaeological horizons, including AL1/AH1. Some chert was obviously acquired in the Krakow-Częstochowa Upland where Maszycka is located (Händel et al. 2021: 145 & Fig. 10). The presence of early post-LGM occupations at Grubgraben related to the Magdalenian is thus not unlikely and backed up by the faunal remains of AL1 that could indicate somewhat warmer and more humid conditions (see above). Evidence points towards the early Middle Magdalenian, as previously suggested by Montet-White (1994: 499) based on the antler points with double-bevelled bases from AL1 that have apparently been lost. Alternatively, an Upper Magdalenian occupation can be taken into account. Farther north, the Upper Magdalenian is well attested at around 15 ka calBP in Moravia and southern Poland (Maier 2015; Połtowicz-Bobak 2020; Valoch 2001, 2010; Valoch & Neruda 2005) and the assemblage from the uppermost layer of Gudenushöhle cave site in the vicinity of Grubgraben with double-bevelled points and a perforated rod can likely be dated to the Upper Magdalenian as well (Neugebauer-Maresch 1999: 94f.; Obermaier & Breuil 1908: Pl. 3). There is, however, no hint in the osseous industry of Grubgraben that would back up the notion of an occupation corresponding to the Lower Magdalenian, as previously assumed based on the single conventional ^{14}C date from AL1 (see above) (Fig. 4).

Information from the lithic assemblage

To date, the lithic material of the new excavations from AH1/AH101 and AH2/AH102 has only been studied in parts and research is still ongoing. The so far obtained observations are in accord with those for the previous excavations, including the generally higher number of finds in AH2/AH102 and the core technology (Montet-White 1990; Neugebauer-Maresch et al. 2016; Händel et al. 2021). A characteristic feature of the lithic assemblage is the large variety of technological concepts applied for the production of flakes, blades, and bladelets with primary cores on raw volumes and cores-on-flakes. Primary cores for flakes regularly show the opportunistic use of suitable striking angles. Exhausted specimens thus often display multiple striking and reduction faces. Blade cores, in contrast, usually employ crested blades and core tablets in a more standardized fashion. Cores-on-flakes were mostly used for the production of bladelets obtained in short sequences from the distal edge, the lateral edges, or the (usually distal) volume of the blanks ("carinated cores"). Here differences in the dimension of the blanks can be observed between AH1/AH101 and AH2/AH102. Further notable differences are that backed bladelets are predominantly found in AH1, while retouched micro-bladelets are exclusive to AH2. It thus becomes apparent that the lithic assemblages from AH2 and AH102 are more similar to each other than to the AH1 assemblage, both technologically and typologically and typological similarities can be attested for AH1 and AL1, as well as for AH 2/102 and AL2–4 (for details see Händel et al. 2021).

The lithic assemblage of the main occupation phase at Kammern-Grubgraben exhibits similarities to other sites in western Central Europe, such as Rosenburg in Lower Austria (Ott 1996), Mohelno-Plevovce in Moravia (Škrdla et al. 2016), Kašov I in Slovakia (Bánesz et al. 1992), Stránská skála IV in Moravia (Svoboda & Novák 2004) and eastern Central Europe, for instance Anetovka I or Muralovka (Demidenko et al. 2019). The occurrence of fine borers, raclette-like artefacts, and pieces with heavy lateral retouch, however, sets Kammern-Grubgraben also a bit apart from some of these assemblages, but underlines similarities to the (Late) Badegoulian assemblages in France, such as the roughly contemporaneous sites of Le Cuzoul de Vers or Lassac (Ducasse 2010), which also show strong technological similarities. Ságvár in Hungary also shows comparable technological and typological characteristics (Lengyel 2018), but the notable presence of backed bladelets seems closer to AH1/101 respectively AL1.

Thus, the signals of the lithic assemblage regarding regional and supra-regional similarities and as well as differences between AH1/101 respectively AL1 and AH2/102 respectively AL2–4 are in good agreement with those from the osseous industry.

Conclusion

The osseous industry of AL2–4 at Grubgraben shares characteristics of both the Eastern European Epigravettian and the Western European Badegoulian, without being clearly assignable to either of these entities. This intermediate position matches observations on the lithic industry (Händel et al. 2021; Terberger 2013, but see Lengyel et al. 2021 for a different view) and corresponds to the geographic setting of the site "between east and west".

Continuity and breaks in the development of osseous technology in eastern Central Europe from the LGM to the Magdalenian

A comparison of the osseous industry from AL2–4 at Grubgraben to the earliest known post-LGM site in eastern Central Europe, Maszycka cave (Fig. 1), shows clear continuities, but also marked ruptures. The osseous industry from Maszycka has recently been studied by one of us (Pfeifer 2022), and the results largely confirm previous observations (Kozłowski et al. 1993, 2012). Despite an age difference of more than four millennia, Grubgraben and Maszycka share two important aspects: a) the importance of mammoth ivory for tool production, especially projectile points (Pfeifer 2022: Figs. 8 & 9), and b) sewing technology attested at Maszycka by a bone needle blank (Pfeifer 2022, Fig. 2: 5). As outlined above, mammoth ivory played an important role throughout the LUP in the eastern parts of Central Europe and in Eastern Europe. The recovery of the Central European mammoth population soon after the LGM (Nadachowski et al. 2018) provided

access to fresh raw material, in addition to material preserved in permafrost deposits.

Eyed bone needles were continuously used throughout the LUP in Western, Central, and Eastern Europe (d'Errico et al. 2018; Demidenko 2020; Ducasse et al. 2021; Iakovleva 2016; Maier 2015; Noiret 2009; Nuzhny 2005, 2015). The first widespread dissemination of these tools during the LGM facilitated the execution of very precise sewing tasks, in particular for tight seams in complex, weather-proof clothing, boots and dwelling coverings (Terberger 2013) as well as the application of perforated mollusks and teeth.

Marked discontinuities can be observed for manufacture technology. At Maszycka, there is ample evidence of bone, antler and ivory working by longitudinal grooving, while preform production by direct percussion as attested at Grubgraben is absent. A similar technological shift "from flakes to grooves" took place at the Badegoulian/Magdalenian transition in Western Europe at around 20 ka calBP (Pétillon & Ducasse 2012), and around the same time, longitudinal grooving for osseous blank production is also reported from Byki 1 and 7 in the Seim basin in Western Russia (Akhmetgaleeva & Burova 2021: 312) (Fig. 1). It thus appears that exploitation of osseous raw material blocks by longitudinal grooving, which was known in the Western European Gravettian (Goutas 2009) but was completely absent in the Badegoulian, had again spread throughout Europe by 20/19 ka calBP. Since this technique is attested during the second half of the LGM at Cosăuți (Fig. 18), it can be hypothesized that it was re-introduced to Central and Western Europe from the east.

Linked to the onset of the Magdalenian in eastern Central Europe, new osseous tool types occur at Maszycka cave: smoothers (*lissoirs*), *navettes*, as well as double-bevelled projectile points (Pfeifer 2022). Again, this is congruent with the development in the west (Allain et al. 1985; Langlais et al. 2017; Sécher 2020). The increasing supra-regional exchange of ideas and concepts after the end of the LGM is particularly striking in the simultaneous emergence of stylised female depictions in both Western and Eastern Europe at around 19 ka calBP (Jöris 2021). Since perforated batons are continuously present in eastern Central and Eastern Europe during the LGM but absent in the Badegoulian, it is possible that this tool type, like the longitudinal grooving technique, was introduced to the toolkit of the Western European Magdalenian from the east. This tentative hypothesis is in line with recent palaeogenetic evidence of major human movements from southeast to southwest Europe towards the end of the LGM (Fu et al. 2016; Posth et al. 2023; Villalba-Mouco et al. 2019). The diversity of bevel-based osseous points of the Magdalenien (cf. Pétillon 2016), in return, apparently never caught on in the Late Epigravettian sphere, where points continued to be made with massive bases exclusively (Gavrilov 2021; Iakovleva 2016).

Perspectives for future work

Like the lithic industry, the osseous artefact assemblage of the LGM at Grubgraben is found to share characteristics with contemporaneous sites both of the Badegoulian in Western and the Epigravettian in Eastern Europe without clearly belonging to either of these techno-complexes. To enable a discussion of similarities and differences in more depth and to understand the typo-technological development of LUP osseous industries from a pan-European perspective, the rich assemblages from Eastern Europe should continue to be studied systematically and then put into supra-regional context (e.g. Akhmetgaleeva 2015; Akhmetgaleeva & Burova 2021; Demay et al. 2016, 2021).

The osseous industry of Grubgraben did not produce any evidence of occupations contemporaneous to the Lower Magdalenian, and hence the gap in the Central European archaeological record between 22 and 19 ka calBP persists. It is up to future excavations at Grubgraben and other LGM and early post-LGM sites as well as radiometric age determinations on distinct osseous artefacts to show whether this reflects prehistoric reality. Also, the production of more ^{14}C dates for the uppermost horizons AL1/AH1/AH101 are desirable to test the proposed post-LGM component. Based on the current state of knowledge, conclusive statements on the timing, geographic origins and archaeological signatures of the recolonisation of the northern mid-latitudes after the LGM cannot be made. However, the clear Western European genetic and archaeological relation of the Magdalenian occupation of Maszycka cave around 18.5 ka calBP on the one hand, and the sudden appearance of typo-technological novelties in Western Europe with presumably Eastern European roots around 20.5 ka calBP on the other suggest that more complex processes had been at work than a continuous, east-oriented expansion process of humans and their associated culture.

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