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The Late Upper Palaeolithic human remains from Neuwied-Irlich, Germany. A rare find from the Late Glacial of Central Europe

Die spätpaläolithischen Menschenreste aus Neuwied-Irlich, Deutschland. Ein seltener Fund aus dem Spätglazial Mitteleuropas

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ABSTRACT - Human remains from the Late Upper to Final Palaeolithic of Central Europe are scarce. In 1953, some human bones, covered with red ochre, and associated artefacts were discovered in material taken from a sand pit near the village of Irlich, Central Rhineland (Rhineland-Palatinate, Germany). The finds were stored in a local museum archive. In 2000, the finds were re-discovered and subsequently analyzed with macroscopic, radiologic, and light microscopic techniques. AMS radio-carbon dating of the bones revealed calibrated ages of 14.5 to 13.9 ky BP. The artefacts found with the human remains consist of an antler point, two flint artefacts (backed bladelet, burin spall), and a red deer incisor with ten horizontal grooves on the root and a perforation near the tip of the root. The human bones are assumed to represent four individuals, one young adult and three children of between 6 - 12 months, 4 - 8 years, and 8 - 12 years of age, respectively. An intact femur and a distal ulna of the adult individual exhibit pathological changes to the bone surfaces, probably caused by a chronic vitamin C deficiency. The scanty record of human skeletal remains from the Late Upper and Final Palaeolithic of Central Europe makes even poorly documented and fragmented material an important source of information. The finds from Irlich are assumed to represent intentional burials that took place some time before the Laacher See eruption. Re-investigations at the site are not possible due to mining activities during the last decades.

ZUSAMMENFASSUNG - Bisher liegen aus Mitteleuropa nur sehr wenige menschliche Überreste aus dem späten Jungpaläolithikum und dem Endpaläolithikum vor. 1953 wurden in Material aus einer Sandgrube bei Irlich, Rheinland-Pfalz, einige menschliche Knochen mit Anhaftungen von rotem Ocker, sowie mehrere assoziierte Artefakte gefunden. Die Funde wurden im örtlichen Museumsarchiv (Kreismuseum Neuwied) gelagert und gerieten in Vergessenheit. Im Jahr 2000 wurden sie wiederentdeckt und mittels makroskopischer, radiologischer und lichtmikroskopischer Techniken untersucht. Mehrere AMS-¹⁴C-Datierungen an den Knochen ergaben übereinstimmend ein kalibriertes Alter zwischen 14'500 und 13'900 Jahren BP. Die Artefakte bestanden aus einer Geweihspitze, zwei Flintartefakten (Rückenmesser und Stichellamelle) und einem Rothirschzahn (Inzisivus) mit einer Durchbohrung an der Wurzelspitze und zehn horizontal verlaufenden Rillen an der Wurzel. Auf der Basis der deutlich unterschiedlichen Sterbealter, die an den Knochen geschätzt wurden, wird vermutet, dass die menschlichen Knochen von vier Individuen (Irlich 1 - 4) stammen, einem adulten Individuum und drei Kindern im Alter zwischen 6 und 12 Monaten, 4 und 8 Jahren und 8 und 12 Jahren. An dem intakten Femur und dem distalen Radiusfragment des erwachsenen Individuums (Irlich 1) sind pathologische Veränderungen in Form periostaler Knochenneubildungen vorhanden, die möglicherweise Folgeerscheinungen eines Vitamin C-Mangels darstellen. Wegen der Unvollständigkeit des Skelettes ist eine zuverlässige Diagnose aber nicht möglich. Aufgrund der Seltenheit von Funden menschlicher Überreste aus dem Spätglazial sind selbst fragmentarische Funde wie die vorliegenden wertvolle Informationsquellen. So wird vermutet, dass es sich bei den Funden um die Überreste einer intentionellen Bestattung aus der Zeit kurz vor der Laacher See-Eruption handelt. Eine Nachuntersuchung an der Fundstelle ist wegen des fortgeschrittenen Sandabbaus nicht möglich.

*corresponding author

KEYWORDS - Burials, Central Rhineland, Final Palaeolithic, Laacher See tephra, Late Glacial Interstadial, Paleopathology
Bestattungen, Mittelrheingebiet, Endpaläolithikum, Laacher See Tephra, Spätglaziales Interstadial, Paläopathologie

Introduction

Archaeological finds indicate the presence of humans in the area of the Central Rhineland (Germany) from the Late Lower Palaeolithic onwards. One of the oldest traces of human occupation in the area are the archaeological artefacts from the site Miesenheim 1 that are associated with marine isotope stage (MIS) 15, i.e., date to about 600 ky BP (Turner 2000). The archaeological record also suggests that afterwards the presence of humans in the area was repeatedly interrupted (Baales 2005). Strata from glacial maxima – the most recent of which occurred about 25 ky BP – lack evidence of human presence in the region (Terberger 2013). The most severe impact on the biota of the region was probably the eruption of the Laacher See volcano which occurred around 12'920 calBP at the end of the Allerød-Interstadial (Greenland Interstadial [GI] 1a) (Jöris & Weninger 2000; Baales et al. 2002; Riede 2008; Riede et al. 2011; Sørensen 2010). Two major sites of the Magdalenian, corresponding to the cold period following the last glacial maximum (LGM) and dating to around 15'500 calBP, have been excavated in the Central Rhineland (Gönnersdorf and Andernach-Martinsberg; Street et al. 2012) and provide evidence for a rapid population growth subsequent to the LGM (Baales 2004). Archaeological and palaeontological sites from the subsequent part (Allerød) of the late glacial interstadial (middle to younger phase of the late glacial interstadial complex, GI 1 c-a) in the Central Rhineland are much more frequent. Up to now, five larger settlement areas attributed to the Final Palaeolithic *Federmessergruppen* and several smaller sites have been discovered directly below the widespread Laacher See eruption (LSE) tephra (Baales 2002, 2005, 2006; Gelhausen 2011a, b). A further *Federmessergruppen* site (Bad Breisig) was uncovered above the LSE tephra, dating to the final Allerød interstadial (GI 1a) (Baales & Jöris 2002).

There are only very few human skeletal remains assigned to the Late Upper and Final Palaeolithic of the Central Rhineland, and the dating of these few cases remains largely dubious. An isolated skull from Plaidt-Rauschermühle, found around 1912, was assumed to originate from a Magdalenian context. However, the skull was destroyed during the Second World War and the documentation of the find circumstances is insufficient for an unequivocal archaeological dating (Schröter 1998). Another find of unclear stratigraphic position was made in 1922 at Weißen-thurm. It was described as having originated from below an undisturbed layer of LSE tephra. However,

this find was also lost, and only a single photograph and a drawing of the stratigraphy of the site are preserved (Baales 2002). Based on the available information, therefore, the affiliation of the find to the Palaeolithic has been questioned (Flohr et al. 2004). It must thus be concluded that for the Central Rhineland at present no human skeletal remains are available that can with certainty be assigned to the Magdalenian or the *Federmessergruppen*.

Human skeletal remains of the period immediately before and within the late glacial interstadial complex (GI 1e-a) are generally scarce in Central Europe. There are only some (mostly undated) single finds recorded in relevant archaeological contexts (Street et al. 2006; Orschiedt 2000, 2013). The neonate burial from Wilczyce, Poland (Irish et al. 2008), the secondary burial of the Brillenhöhle on the Swabian Alb, Germany (Orschiedt 1999), the skeletal remains exhibiting cut marks from the Dietfurt cave at the upper Danube, Germany (Gietz 2001) and the double burial from Bonn-Oberkassel, Germany (Verworn et al. 1919), are some of the most important finds from this period in Central Europe.

The Bonn-Oberkassel double burial comprises a female and a male individual who died at an age of about 20 - 25 years and 50 - 60 years, respectively (Bonnet 1919). Skeletal remains of what is considered to be some of the earliest known domestic dogs (Benecke 1986; Thalmann et al. 2013; Janssens et al. 2018) are considered to be part of the burial. The remains were found in 1914 during mining activities at the basalt quarry "Am Stingenberg", east of Bonn-Oberkassel. The human remains had not been documented *in situ* and had already been removed by the workers. However, an excavation at the site two days after the initial discovery recovered several foot bones, and also some red ochre was found *in situ* (Verworn et al. 1919). Based on the observations of the workers, the site was regarded as a double burial (Verworn et al. 1919; Wüller 1999). Several radiocarbon dates assign the double burial of Bonn-Oberkassel to a transitional period from the Magdalenian to the *Federmessergruppen* or early Final Palaeolithic of around 14.2 ky calBP (Baales & Street 1998; Hedges et al. 1998).

Human remains from the Late Upper and Final Palaeolithic (Late Magdalenian, Late Epigravettian, Hamburgian, Azilien, *Federmessergruppen*, and Ahrensburgian) are also relatively rare in other parts of Europe. Thus far, 71 individuals from 17 sites dating between about 16 and 14 ky calBP have been described (Pettitt 2011). However, assignment of some of these 17 sites to the period under discussion is

uncertain since they lack a detailed documentation of the excavation, stratigraphic data, and/or direct radiocarbon dates. Especially in specimens that have not been documented *in situ* within a clear stratigraphic context, radiocarbon dating is indispensable for assignment to a specific time period (Street et al. 2006). For instance, radiocarbon dating of specimens from Germany originally assigned to the Palaeolithic demonstrated a much younger age for some cases (Street et al. 2006). In other cases in which the collagen content of the samples is too low for successful dating (Formicola et al. 2005), the chronological affiliation remains uncertain.

Among the more reliably dated sites from the Late Upper and Final Palaeolithic of Europe, single burials of adults (e.g. Riparo di Villabruna), adolescent individuals (e.g. Roc de Cave) or children and neonates (e.g. La Madeleine, Wilczyce), double burials of adults (e.g. Bonn-Oberkassel) and children (e.g. Grotta dei Fanciulli), and multiple isolated burials at a single site

are known. Italian sites with multiple burials, like Arene Candide (Liguria), Grotta Romanelli (Apulia), Grotta Polesini (Latium), and maybe also San Teodoro (Sicily), have been regarded as the earliest cemetery-like structures, occurring in the latest Palaeolithic around 12'900 to 11'500 calBP (Formicola et al. 2005; Pettitt 2011; Orschiedt 2013, 2016). In this context, also the site of Taforalt (Tafoughalt) in Morocco is worth mentioning, where 40 individuals from 28 graves were dated by the youngest burial to around 12'900 calBP (Mariotti et al. 2014).

Discovery and context of the Irlich remains

In 1957, a number of human bones, covered with red ochre, and some associated artefacts were discovered in a heap of sand that had been extracted from a pit near the village of Irlich for construction works. The Irlich site is situated about 40 km south of Bonn-Oberkassel in the Middle Rhine area (Fig. 1). Initially,

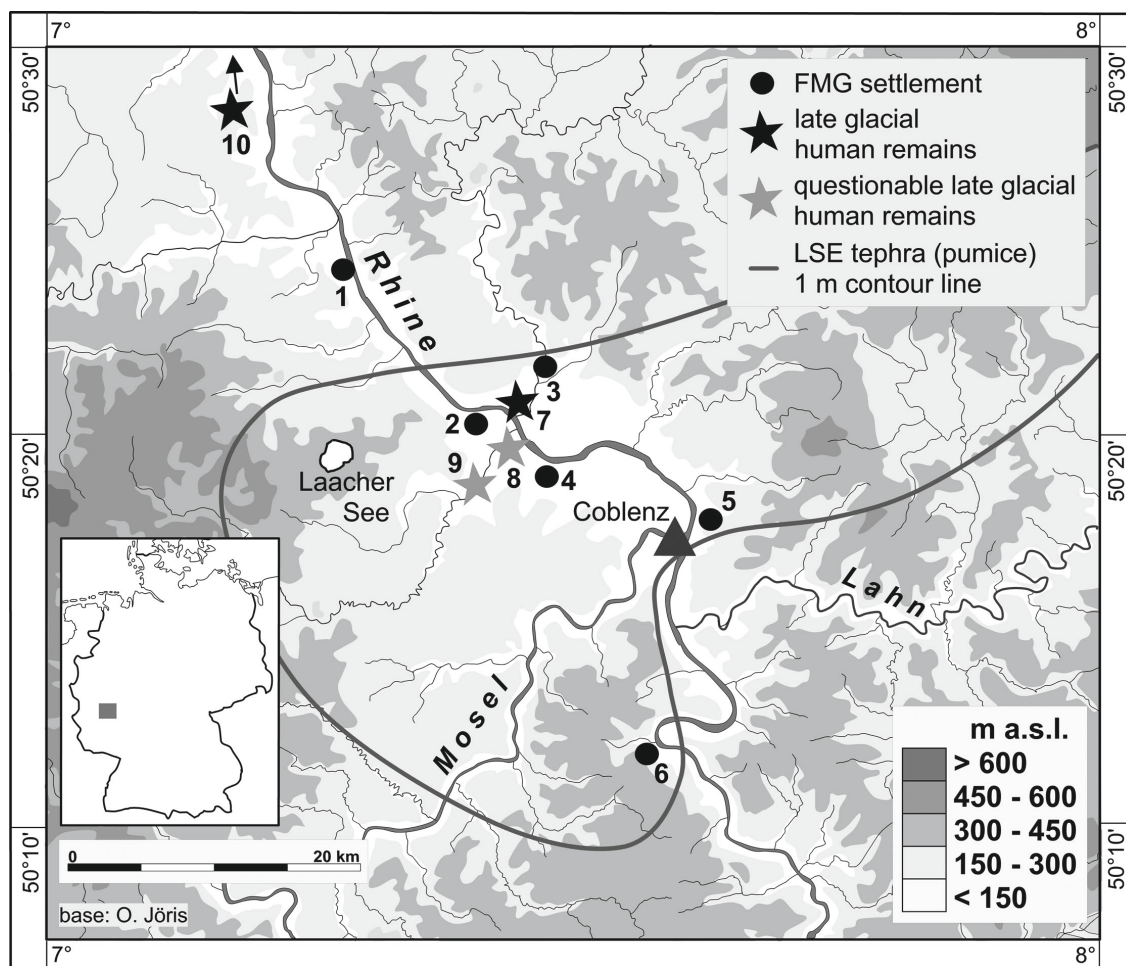


Fig. 1. Sketch map of the Central Rhineland with major Final Palaeolithic (*Federmessergruppen*, FMG) sites and find spots of questionable or dated late glacial human remains discussed in the text. 1 Bad Breisig. 2 Andernach-Martinsberg. 3 Niederbieber. 4 Kettig. 5 Urbar. 6 Boppard. 7 Irlich. 8 Weissenthurm. 9 Plaidt-Rauschermühle. 10 (to the north) Bonn-Oberkassel.

Abb. 1. Die Karte zeigt die wichtigsten endpaläolithischen (*Federmessergruppen*, FMG) Fundstellen, sowie die im Text erwähnten Fundorte späteiszeitlicher Funde menschlicher Skelettreste mit zuverlässigen, aber auch mit umstrittenen Datierungen. 1 Bad Breisig. 2 Andernach-Martinsberg. 3 Niederbieber. 4 Kettig. 5 Urbar. 6 Boppard. 7 Irlich. 8 Weissenthurm. 9 Plaidt-Rauschermühle. 10 (in nördlicher Richtung) Bonn-Oberkassel.

the finds received no further attention and were stored in the archive of a local museum (Kreismuseum Neuwed). A brief note that was written some years after the discovery was added to the finds and provides the only available information on the find circumstances. This note describes the finds as having "obviously originated underneath the pumice" and therefore representing "possibly pre-historic human bones" (translation from German by the authors). The mentioned pumice obviously refers to the tephra originating from the LSE which occurred only 15 km to the South-West of Irlich.

In the course of a re-evaluation project of all human remains assigned to the Palaeolithic of Germany (Orschiedt 2000; Street et al. 2006), the Irlich finds were re-discovered in 1998 (von Berg & Baales 2002). A first radiocarbon dating on an infant femur was performed at the AMS laboratory in Utrecht (UtC-9221) and revealed an age of $14'139 \pm 259$ calBP (Fig. 2). Four additional samples were extracted from other bones for AMS radiocarbon dating at the Oxford laboratory. The results confirmed the first age in three of the four samples, whereas the fourth sample revealed a much younger age of $2'792 \pm 32$ calBP (OxA-9876; Fig. 2). This result was not unexpected since the sample had been obtained from a bone fragment that differed in color and material properties from the other (older) ones. Thus, the younger bone was of a light brown color and brittle consistency, while the other bones showed a homogenous reddish color and a much more solid consistency. It is assumed that the younger bone fragment was accidentally intermingled with the other bones. This bone fragment was therefore excluded from the present study.

No excavation at the pit from which the sand containing the bones and artefacts had been removed could be performed since the pit had been extended markedly since the late 1950s and the exact site from which the finds were recovered is no longer known.

Archaeological findings

The artefacts that were associated with the bones consist of two flint artefacts (backed bladelet, burin spall), an antler point, and a red deer (*Cervus elaphus*) incisor (left I₁) with ten horizontally running grooves that are partly filled with red ochre and a perforation near the root tip (Fig. 3 & 4). The antler point - regarded as a projectile point - was sampled for AMS radiocarbon dating; however, insufficient collagen was obtained to facilitate measurement. The two lithic artefacts are typical for Upper to Final Palaeolithic contexts. The decorated red deer incisor in particular reveals similarities with a further red deer incisor showing several grooves on the root that was found within the Andernach *Federmessergruppen* horizon (Baales & Street 1996). The archaeological dating of the Irlich artefacts is consistent with the results of the radiocarbon dating of the Palaeolithic human remains. It is therefore plausible to assume that the artefacts and the human remains originate from the same context.

Description of the human remains

The macroscopic state of preservation of the human remains is generally good. The bones exhibit only minor erosion on their surface due to taphonomic processes. The assemblage consists of a number of elements from different regions of the body, with none of them articulating. Theoretically, therefore, the maximum number of individuals represented by the finds corresponds to the number of fragments. However, the elements differ clearly with respect to their stage of ontogenetic development, thereby suggesting that the assemblage comprises elements of four individuals who died at different ages. Consequently, we assign the elements to four individuals, designated Irlich 1 to 4. Pathological changes were observed only in the Irlich 1 individual.

Sample number	Description	$\delta^{13}\text{C}$	AMS date uncalibrated BP	AMS date calibrated BP ^f
OxA-9736	Rib fragment ^a	$\delta^{13}\text{C} = -19.4\text{‰}$	$12'310 \pm 120$	$14'482 \pm 380$
OxA-9847	Femur ^b	$\delta^{13}\text{C} = -19.2\text{‰}$	$11'910 \pm 70$	$13'815 \pm 160$
OxA-9848	Rib fragment ^c	$\delta^{13}\text{C} = -18.9\text{‰}$	$11'965 \pm 65$	$13'927 \pm 206$
OxA-9876	Fragment of the skull vault ^d	$\delta^{13}\text{C} = -18.8\text{‰}$	$2'660 \pm 40$	$2'792 \pm 32$
UtC-9221	Femur ^e	$\delta^{13}\text{C} = -23.9\text{‰}$	$12'110 \pm 90$	$14'139 \pm 259$

Fig. 2. Results of the AMS dating. a: belonging to an adult individual; b: belonging to Irlich 1; c: belonging to a younger, probably late infans II or juvenile individual; the date can therefore be assigned to Irlich 2; d: belonging to some skull fragments which are distinguished from the older fragments by their colour and material properties; e: probably belonging to Irlich 3; f: Calibration by CalPal Online v1.5. 2 Sigma range.

Abb. 2. Ergebnisse der AMS-Datierungen. a: Fragment gehört zu einem erwachsenen Individuum; b: Von Individuum Irlich 1; c: Fragment eines jüngeren Individuums, vermutlich spätes Infans II oder Juvenis; die Datierung kann somit vermutlich Irlich 2 zugewiesen werden; d: Von Schädelfragmenten, die sich hinsichtlich ihrer Farbe und dem Erhaltungszustand von den übrigen Knochen unterscheiden; e: Vermutlich zu Individuum Irlich 3 zugehörig; f: Kalibration mittels CalPal Online, Version 1.5 mit 2-Sigma Intervall.

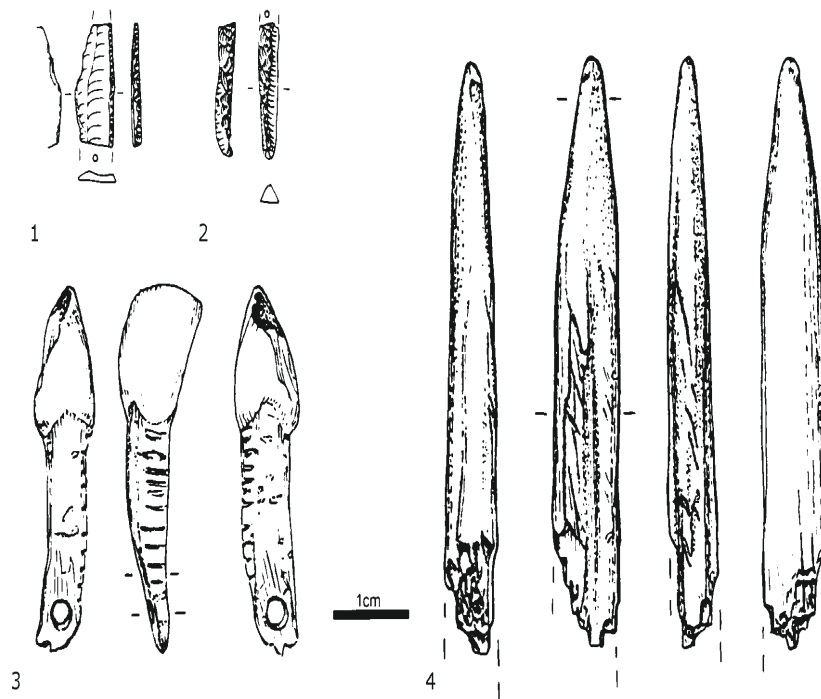


Fig. 3. Artefacts found with the human remains. 1 Backed bladelet. 2 Burin spall. 3 Perforated cervid tooth (incisor) pendant with engravings. 4 antler point.

Abb. 3. Mit den Menschenknochen assoziierten Artefakte. 1 Rückenmesser 2 Stichellamelle 3 durchbohrter Hirschzahn (Inzisivus) mit horizontalen Einkerbungen. 4 Geweihspitze.

Irlich 1

Six of the skeletal elements – a left femur, the distal third of a left ulna, a left trapezium, a lumbar vertebra, and two small skull fragments (a part of the left greater wing of the sphenoid, and a fragment of the left temporal squama) – share common features in that they are relatively gracile and might belong to a female individual that died in young adulthood. No abnormal

porosity was observed in the cranial fragments. Age assessment was based on the combination of the following traits: epiphyses fused, compact bone showing a high thickness and homogeneity, dense trabecular structures in the spongy bone, lack of signs of degeneration on the joint facets.

The Irlich 1 femur (Fig. 5) is gracile and slightly shorter than the femur of the female individual from



Fig. 4. Perforated cervid tooth (incisor) pendant. Bar indicates 1 cm.

Abb. 4. Durchbohrter Hirschzahn (Inzisivus). Balken entspricht 1 cm.



Fig. 5. The Irlich 1 femur in posterior (left) and anterior (right) view. Note the dorsal orientation of the lesser trochanter (arrowhead; for further details, see Flohr et al., 2017). Arrow: sampling site for radiocarbon dating. Bar indicates 10 cm.

Abb. 5. Das Femur des Individuums Irlich 1 in Ansicht von posterior (links) und anterior (rechts). Man beachte die dorsale Orientierung des Trochanter minor (Pfeilspitze; für weiterführende Informationen siehe auch Flohr et al., 2017). Pfeil: Materialentnahmestelle für die Radiokarbon-Datierung. Balken entspricht 10 cm.

Bonn-Oberkassel. Most of the measurements taken on the Irlich 1 femur are closer to the values for the female than those for the male individual from Bonn-Oberkassel (Fig. 6).

The remaining parts of the articular facets are well preserved and lack signs of degeneration. X-ray examination revealed remnants of the epiphyseal lines at the femoral head and the distal epiphysis. X-ray and conventional computed tomography (CT) images demonstrate a dense trabecular structure in the epiphyseal areas (Fig. 7) as well as a high relative cortical area (84.5 % CA) in the midshaft region (Fig. 8). All macroscopic features are indicative of a young adult age at death (approximately 20-35 years). A

histomorphometric age-at-death estimation was not possible due to poor collagen preservation. Applying the histomorphological method of Schultz (1986) on transverse ground sections of one half of the femoral midshaft likewise yielded a young adult age at death. With the exception of the attachment area of the *gastrocnemius* muscle, which shows some osteophyte-like proliferations, the Irlich 1 femur exhibits only weak muscle attachments.

The distal part of a left ulna (length 83 mm) also preserved (Fig. 9). As with the femur, the compact bone area relative to the total area of the cross section is high. The articular surface is well preserved and lacks signs of degenerative changes. Both features are

	Measurement (1. - 24. given in mm)	Irlich	Bonn-Oberkassel female	Bonn-Oberkassel male	
		left	right	right	left
1.	Maximum length	427	431	–	447
2.	Bicondylar length	424	430	–	444
4.	Trochanter length	402	–	–	436
6.	Sagittal midshaft diameter	30	25	–	35
7.	Transverse midshaft diameter	26	25	–	32
8.	Midshaft circumference	84	77	–	101
9.	Transverse diameter of the proximal shaft	33	32	43	40
10.	Sagittal diameter of the proximal shaft	25	25	30	31
15.	Vertical collum diameter	30	–	32	32
16.	Sagittal collum diameter	24	–	30	28
17.	Collum circumference	90	–	103	103
18.	Vertical head diameter	46	–	49	48
19.	Transverse head diameter	46	–	50	50
20.	Head circumference	144	–	155	155
21.	Epicondylar breadth	81	75	–	85
23.	Maximum length of the lateral condylus	59	–	–	65
24.	Maximum length of the medial condylus	63	–	–	67
	Pilastric index (6./7.)	115.38	100.00	–	109.38
	Platymeric index (10./9.)	75.76	78.13	69.77	77.50

Fig. 6. Measurements of the Irlich 1 femur and comparison with the femora from Bonn-Oberkassel. Measurement numbers in left column refer to the listing in Bräuer (1988), corresponding to the original measurements given by Martin (1928). Measurements of the Bonn-Oberkassel finds from Bonnet (1919).

Abb. 6. Messwerte des Irlich 1-Femur im Vergleich zu den korrespondierenden Werten der Femora der Bonn-Oberkassel Bestattungen. Die Nummerierungen der Maße in der linken Spalte entsprechen denen bei Bräuer (1988; in Anlehnung an Martin 1928). Maße der Femora von Bonn-Oberkassel aus Bonnet (1919).

indicative of a young adult age at death. The attachment for the *pronator quadratus* muscle is strongly developed and elevated. Due to the fragmentary nature of the ulna, other attachment sites could not be evaluated. As in the femur, histomorphological age estimation on a transverse ground section of the ulna indicated a young adult age at death.

As only few and partly fragmentary skeletal elements assigned to Irlich 1 are present, we do not attempt to draw conclusions on activity patterns based on enthesal features of this individual.

Irlich 2

The second individual is represented by a right ischium (Fig. 10). It represents an individual that died at a much younger age than the Irlich 1 individual, but at a higher age than the other individuals represented in the assemblage and is therefore assigned to a separate individual, Irlich 2. The stage of development of the ischium is consistent with an age at death of about 8 to 12 years (Scheuer & Black 2000). The face for articulation with the ilium is well preserved and shows no signs of initiation of fusion between these two bones. This fusion starts around 11 years of age in females and around 14 years in males and is completed by 15 years in females and 17 years in males (Scheuer & Black 2000).

Irlich 3

The third individual is represented by some small fragments of the cranial vault, mostly of the occipital squama, the crown of a deciduous left upper first molar, a number of rib fragments and a femur which clearly differ in their stage of development from the bones assigned to individuals Irlich 1 and 2. The skeletal fragments and the developmental stage of the deciduous first molar are consistent with a much younger age at death, most likely about 6 to 12 months (AlQahtani et al. 2010; Scheuer & Black 2000; Uberlaker 1978) (Fig. 11).

Irlich 4

A single fragment of a left (?) parietal bone represents a fourth individual. The fragment is a part of the postero-medial portion of a parietal bone with a segment of the lambdoid suture exhibiting three small sutural bones (Fig. 12). The fragment differs from the other cranial fragments (Irlich 3) present in the assemblage and is attributed to an individual (Irlich 4) that probably died at a younger age than Irlich 2 but at an older age than Irlich 3. The thickness of the cranial vault fragment of Irlich 4 and the stage of development of the *diploë* are indicative of an age at death between 4 and 8 years. However, since morphological



Fig. 7. X-ray image of the proximal part of the femur of Irlich 1. Note the dense trabecular structure indicative of a young adult age at death.

Abb. 7. Röntgenbild des proximalen Bereichs des linken Femur von Irlich 1. Die dichte Spongiosastruktur deutet auf ein jungerwachsenes Sterbealter hin.

variability in this anatomical region is high, it cannot be ruled out with certainty that this cranial fragment belongs to individual Irlich 2, although this is considered unlikely.

Paleopathological findings in the Irlich 1 specimen

The Irlich 1 femur exhibits patches of woven bone apposition in many areas of the midshaft (Fig. 13: a) and also in the proximal and distal shaft areas. In addition, a small area of woven bone apposition is present on the posterior aspect of the distal portion of the neck (Fig. 14). The original extension of the

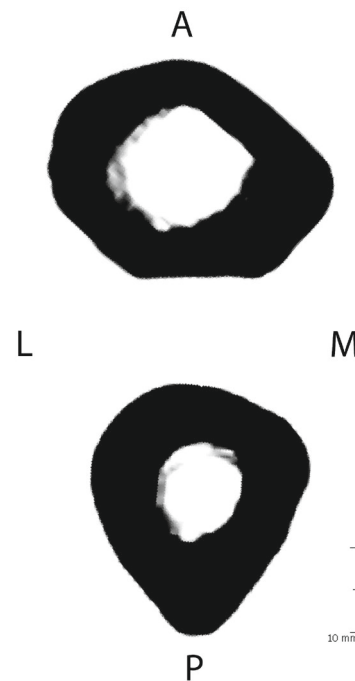


Fig. 8. Cross-sectional CT-images of the femur of Irlich 1 at 80 % (top) and 50 % (bottom) biomechanical length. A = anterior; L = lateral; M = medial; P = posterior.

Abb. 8. CT-Querschnittsaufnahmen des Femur von Irlich 1 auf den Höhen 80 % (oben) und 50 % (unten) der biomechanischen Länge. A = anterior; L = lateral; M = medial; P = posterior.

apposed bone on the femoral shaft must have been larger than in the present-day condition. This is indicated by the presence of sharp edges where parts of the apposed bone have flaked off, thereby exposing the underlying osseous structures that appear more lightly stained than the surrounding bone surface. Microscopic investigation of a transverse section through the femoral cortex revealed that initially a thin layer of woven bone was deposited on the original cortex. Numerous slender pedicles connect this thin bone layer to the peripheral portion of the woven bone (Fig. 13: b). The original cortical surface and the underlying compact bone show no indications of abnormal osteoclastic or osteoblastic activity. The morphological findings suggest a relatively fast formation mode of the apposed bone. The lack of signs of remodeling indicates that it was formed relatively shortly (presumably some weeks) before death.

Except for the attachment area of the *pronator quadratus* muscle, almost the complete surface of the ulnar fragment is covered by an up to 1 mm thick layer of subperiosteally formed woven bone (Fig. 9), similar to the situation in the Irlich 1 femur. Also in the ulna, the apposed bone layer has partly been flaked off postmortem. Again, it is evident that the periosteal new bone was laid down on top of the intact original bone surface. In both, femur and ulna, the compact bone tissue as well as the marrow spaces exhibit no pathological changes. Thus, the

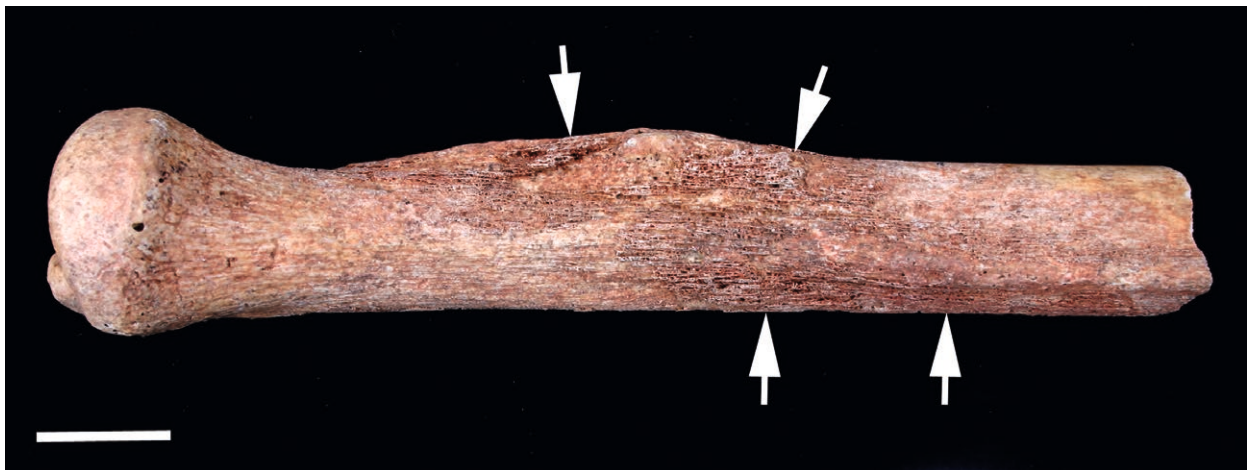


Fig. 9. Distal part of the left ulna of Irlich 1. Note woven bone apposition (arrows) present in large areas of the shaft. Bar indicates 1 cm.

Abb. 9. Distaler Bereich der linken Ulna von Irlich 1. Die Pfeile deuten auf Bereiche mit periostalen Knochenneubildungen am Schaft. Balken entspricht 1 cm.

periosteal reaction did not develop in the course of an osteomyelitis. Assuming that the bones assigned to Irlich 1 indeed belong to the same individual, the similar appearance and mode of the bone apposition suggests a systemic rather than a local (e.g. trauma) cause. The kind of bone formation seen in both skeletal elements has been associated with the occurrence of subperiosteal hemorrhagic processes (Schultz 2001, 2012). A chronic vitamin C deficiency (scurvy) might be a plausible reason for this. Bone

formation in the course of a periostitis (Schultz 2001) or a hypertrophic osteo(arthro)pathy (Masson et al. 2013; Flohr et al. in 2018) have to be considered as alternative diagnoses. However, the periosteal new bone is not of the shell-like appearance that is a characteristic feature of hypertrophic osteoarthropathy (Flohr et al. 2018).



Fig. 10. Right ischium of a juvenile individual designated as individual Irlich 2 (left: medial view; right: lateral view). Bar indicates 1 cm.

Abb. 10. Das rechte Os ischii des als Irlich 2 bestimmten Individuums (links: Ansicht von medial; rechts: Ansicht von lateral). Balken entspricht 1 cm.

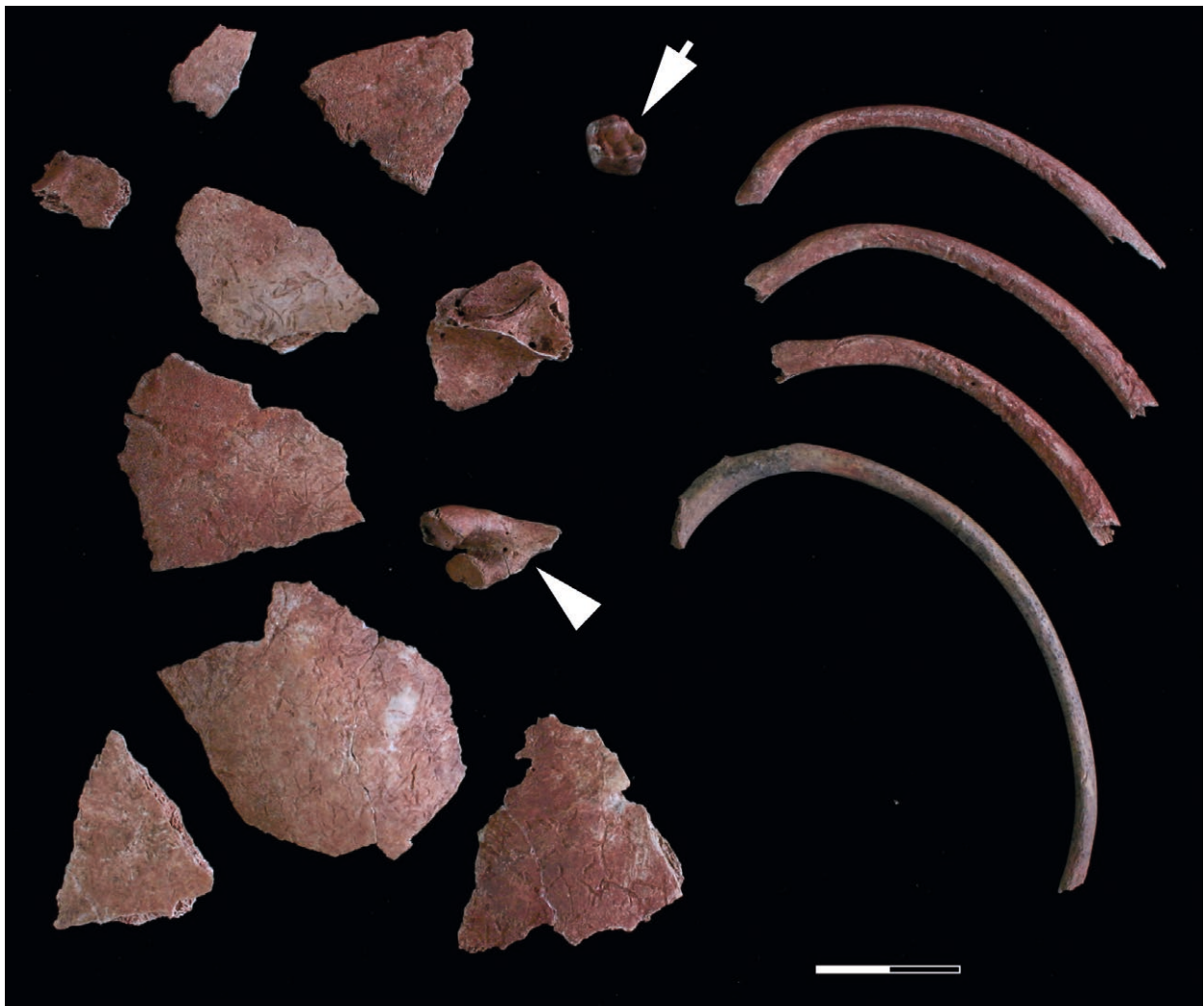


Fig. 11. Fragments of cranium and ribs designated as individual Irlich 3. Arrow: left upper first deciduous molar; arrowhead: fragment of the right lateral part of the occipital bone with the two limbs of the condyle unfused. Bar indicates 2 cm.

Abb. 11. Schädel- und Rippenfragmente des als Irlich 3 bestimmten Individuums. Der Pfeil deutet auf die Krone des linken oberen ersten Milchmolars; der Pfeilkopf weist auf ein Fragment der rechten Pars lateralis des Os occipitale. Die beiden Kondylen der Pars lateralis sind unfused. Balken entspricht 2 cm.

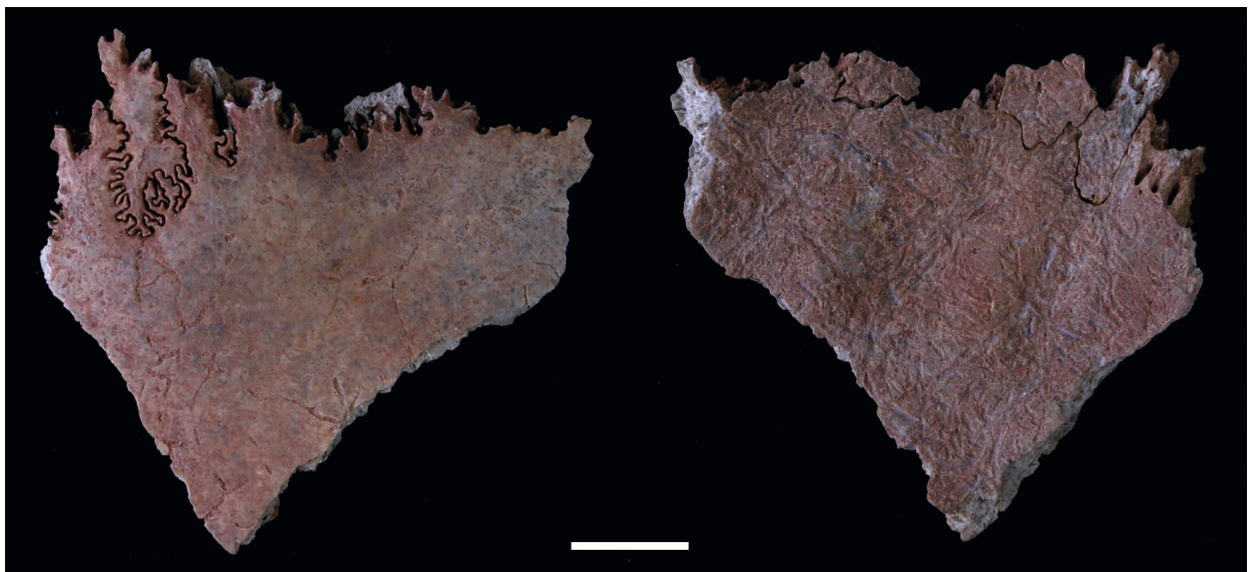


Fig. 12. Fragment of cranium designated as individual Irlich 4 in ectocranial (left) and endocranial (right) view. Bar indicates 1 cm.

Abb. 12. Schädelfragment des als Irlich 4 bestimmten Individuums in Ansicht von ektokranial (links) und endokranial (rechts). Balken entspricht 1 cm.

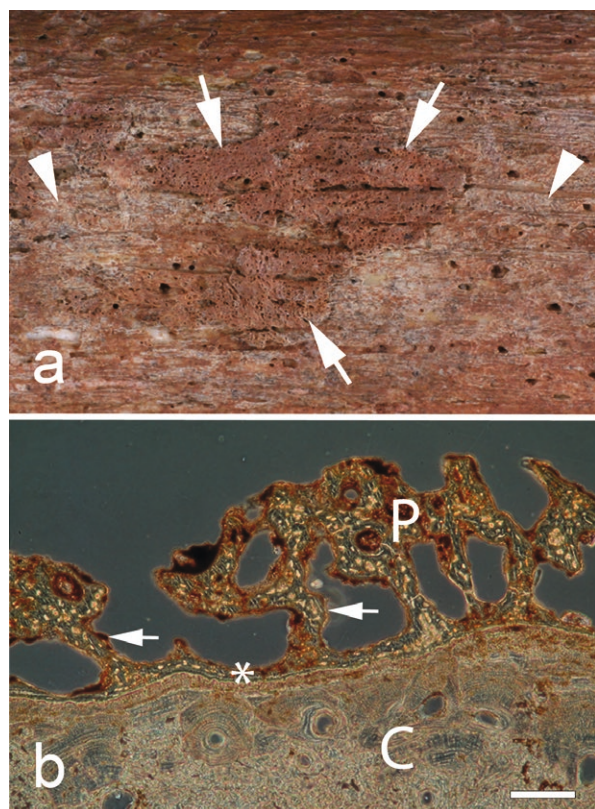


Fig. 13. Irlich 1: (a) Subperiosteally formed woven bone (arrows) deposited on the Irlich 1 femur. Arrowheads indicate areas where the woven bone has broken off *post mortem* exposing the underlying bone surface. (b) Dark field image of an unstained ground section showing the apposed bone and the underlying cortex (bar indicates 0.1 mm). Note a thin layer of bone (asterisk) deposited on the original cortex (C) and numerous osseous pedicles (arrows) connecting this layer to the peripheral portion of the new bone (P).

Abb. 13. Irlich 1: (a) subperiostale Knochenneubildung (Pfeile) am Femur Irlich 1. Die Pfeilköpfe markieren Bereiche, an denen die Knochenneubildung *post mortem* abgesplittert ist und den darunterliegenden Knochen zum Vorschein kommen lässt. (b) Mikroskopische Darstellung der Neubildung auf dem ursprünglichen Kortex im Dunkelfeldmodus am ungefärbten Dünnschliff. Balken entspricht 0,1 mm. Der neugebildete periphere Knochen (P) ist über stielartige Bälkchen (Pfeile) mit einer durchgängigen, initialen Knochenlage (Stern) verbunden, die dem originalen kortikalen Knochen (C) aufliegt.

Discussion

Beside the burials from Bonn-Oberkassel, the described skeletal specimens from Irlich are the only undisputable human remains from the late glacial interstadial context in Central Europe. However, a number of single, double, and multiple burials are known from other Late or Final Palaeolithic sites outside this region. Burials like those from Aven des Iboussières in southeast France (Gély & Morand 1998), which was equipped with shell and tooth ornaments as well as stone and bone artefacts (d'Errico & Vanhaeren 1998), as well as Arene Candide and other sites from the Epipalaeolithic and the earliest Mesolithic of Italy (Formicola et al. 2005) are regarded to represent the onset of the use of cemeteries (Pettitt 2011; Orschiedt 2016). They demonstrate a

variety of burial practices from western and southern Europe at the end of the Pleistocene. The rareness of recovered human remains dating to GI 1 of Central Europe, however, makes even poorly documented and fragmented remains like the Irlich finds a potentially important source of information for this period. The presence of red ochre on the human remains from Irlich, and the association with a perforated and decorated cervid tooth as well as flint and antler artefacts, which most likely represent grave goods or decorations, suggest that the Irlich individuals represent intentional burials. It is unclear whether the finds represent bones from individual burials, double burials, or a multiple burial.

In contrast to the finds from Bonn-Oberkassel, those from Irlich were previously unrecognized and re-discovered more than 40 years after their initial discovery in 1957. In the meantime, the sand pit from which the remains originated was extensively exploited, precluding the relocation of the exact location of the Irlich finds and a reconstruction of their archaeological context. As with the Bonn-Oberkassel finds, a possible relation between burial places and settlements can thus not be investigated with the Irlich finds. Generally, despite the existence of a number of Palaeolithic sites in the Central Rhineland area, thus far no burials have been found associated with settlements.

Pathological conditions other than trauma have been reported in a few individuals from the Upper Palaeolithic. Examples of congenital disorders include the acromesomelic dwarf from a double burial in Riparo del Romito in Calabria, Italy (Romito 2) (Frayer et al. 1988), and the Mladeč 5 individual showing a malformation of the inner ear (Holt & Formicola 2008). Abnormal bowing of long bones due to chondrodysplasia has been diagnosed in the Dolní Věstonice 15 specimen, Czech Republic (Formicola et al. 2001), and in the individual Sunghir 3 from Russia (Formicola & Buzhilova 2004). A probable case of X-linked hypophosphatemic rickets in an individual showing long bone bowing deformities, abnormal tendon and ligament calcifications, and ossification disturbances was described from the Late Epigravettian site of Arene Candide, Italy (Formicola 1995). Evidence for infectious diseases in the Upper Palaeolithic is rare. A case of *otitis media* was reported for the individual Dolní Věstonice 14 (Trinkaus et al. 2006). Pathological changes of unknown origin, including periosteal new bone formation, sclerotic changes in the marrow cavities, and osteoclastic resorption of cortical bone, were described in the individual Brno 2 (Oliva 2000; Schultz & Nováček 2005).

Linear enamel hypoplasia (LEH) as a non-specific stress indicator in childhood is infrequent and of low intensity in human skeletal remains from the Upper Palaeolithic (Trinkaus et al. 2006). However, there might be an increased frequency of LEH from the Early Upper Palaeolithic to the Late Upper Palaeolithic

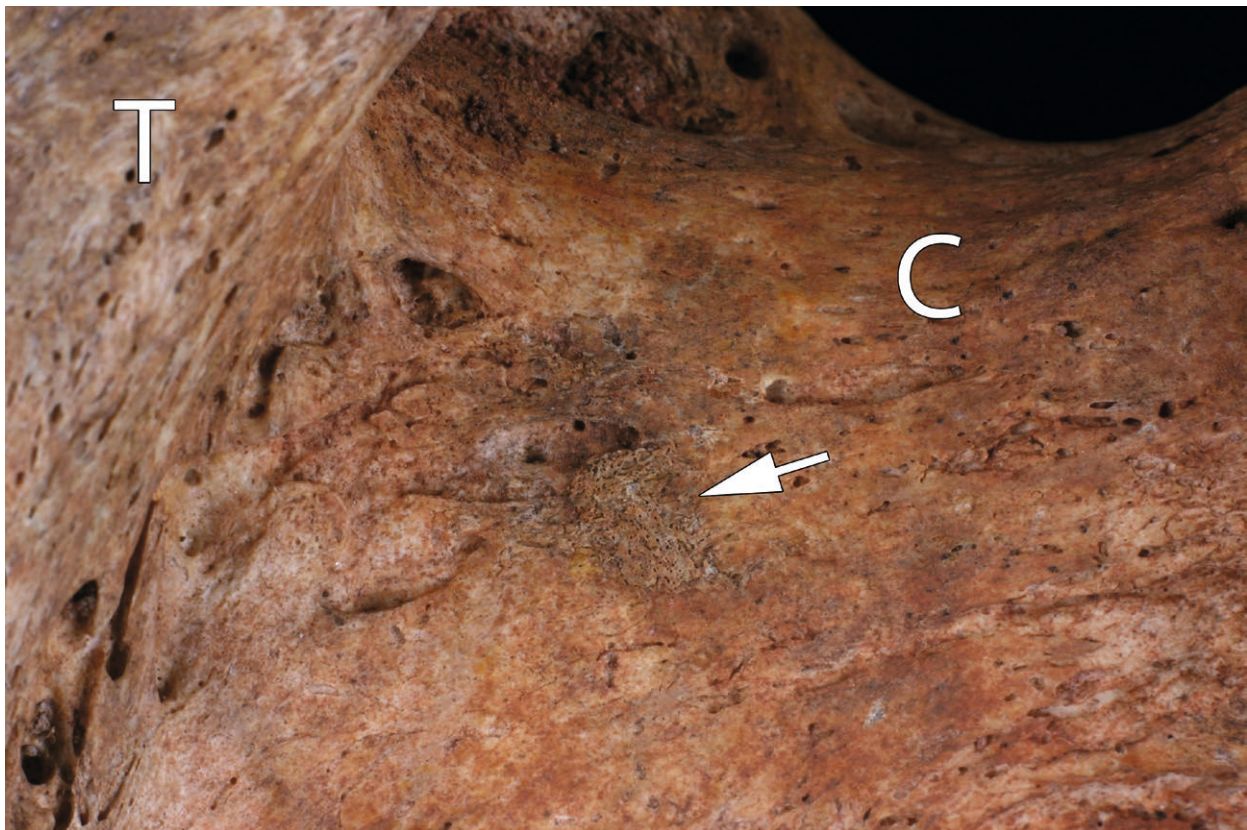


Fig. 14. Irlich 1: Small patch of subperiosteally formed bone (arrow) on the posterior aspect of the distal portion of the femoral neck. C = Collum femoris; T = Trochanter major.

Abb. 14. Irlich 1: Kleiner Bereich subperiostaler Knochenneubildung (Pfeil) im posterioren Bereich des distalen Oberschenkelhalses. C = Collum femoris; T = Trochanter major.

(Holt & Formicola 2008), indicative of deteriorating living conditions. This may have included an increase in the frequency of vitamin deficiencies during cold phases of the younger Dryas (Weber et al. 2011). Our finding of probable skeletal manifestations of scurvy in the Irlich 1 individual would be consistent with this assumption. However, given the limited evidence presently available, more research into the living conditions of the human population in Central Europe during the Late Pleistocene is certainly needed.

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