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EVERYTHING IS A QUESTION OF TIME – AGE OF IMPORTANT QUATERNARY PALAEONTOLOGICAL FINDS FROM WESTPHALIA

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Abstract: Accelerator mass spectrometry (AMS) was used to establish the age of three mammal specimens from the Quaternary of the Münsterland, North Rhine-Westphalia, Germany. The dated samples represent regionally important finds: The woolly mammoth from Ahlen with an age of 41 ka BP and the musk-ox from Herne with an age of 24 ka BP are typical representatives of the so-called mammoth steppe. The European Bison from Gladbeck with an age of 9.2 ka BP confirms the Early Holocene appearance of this species in Europe.

Key words: *Mammuthus*, *Ovibos*, *Bison*, AMS-dating, Quaternary, Germany

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Introduction

The Quaternary deposits in Westphalia are mainly characterized by sediments of the Saalian and Weichselian Glacial periods, as well as the Holocene (Speetzen 1986). During the Saalian Glacial Complex, and here at the Drenthe-Warthe stage (OIS 6), glaciers covered large parts of Westphalia, and reached the northern edge of the Rhenish Massif. Glacial sediments from this period are mainly basal tills and meltwater sands. In the following Eemian Interglacial period (OIS 5e), these sediments were partially eroded and redeposited, e.g. as river terraces. During the time of the Weichselian Glacial (OIS 5d–2), the region was a periglacial area. The southern glacier front was approximately 300 km to the North, along a line Flensburg-Hamburg-Berlin. The Weichselian sediments are mainly river deposits, such as gravel, sand and silt, as well as aeolian sediments like sand, sand-loess and loess. In the current Holocene Interglacial, rivers such as Lippe and Ems cut into the Weichselian deposits to build valleys and terraces.

Sampled specimens

As the starting point of a research programme dating Quaternary mammals of the Münsterland area in the lowland of North Rhine-Westphalia, Germany, a few iconic specimens well known in the regional literature have been selected. They are part of the collection of the Geomuseum of the Westfälische Wilhelms-Universität (Münster) (GMM), come from various localities (Text-fig. 1) and represent typical members of the coeval fauna.

Woolly mammoth from Ahlen

The Geomuseum of the WWU (Münster) houses a famous articulated skeleton of a woolly mammoth *Mammuthus primigenius* (Blumenbach, 1799), described in detail by Siegfried (1959), and featured by Müller (e.g. 1989) in various editions of his German palaeontology textbook. Approximately three-quarters of its bone mass are preserved (Text-fig. 2). It is a bull, judging by the pelvis, which died at the age of approximately 40–45 years. This age is deduced from the degree of wear on the sole preserved molar (Text-fig. 3), a third permanent tooth. There is some wear, but it is not intense. It has a size of 28 by 18 by10 cm. The skeleton is one of the only seven articulated individuals of this species ever found in Germany (von Koenigswald 2002). Two fairly complete specimens from Steinheim and Borna, respectively, were destroyed in WW II (Siegfried 1959), leaving the Ahlen specimen second only to the 1903 find of Gosda-Klinge, Brandenburg (Fischer 1996) in terms of completeness.

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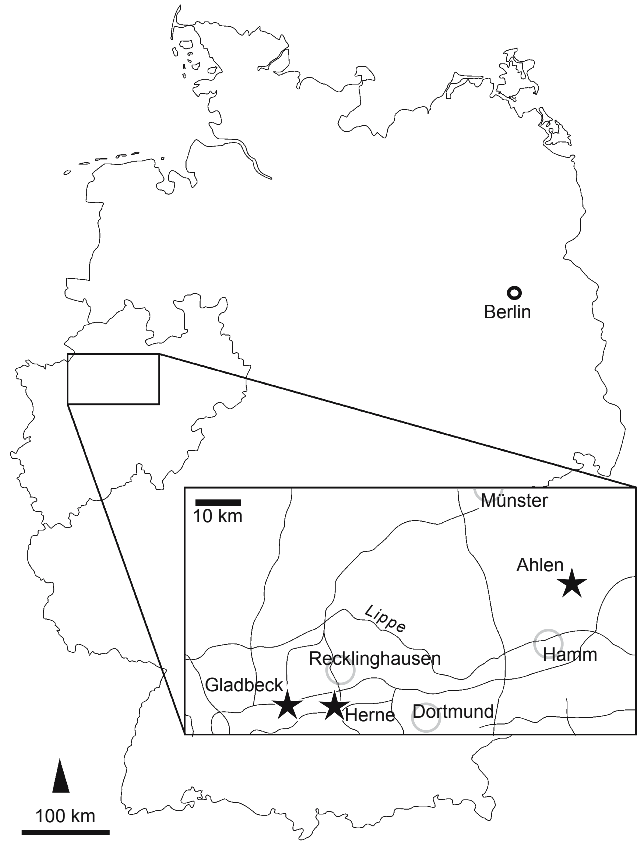
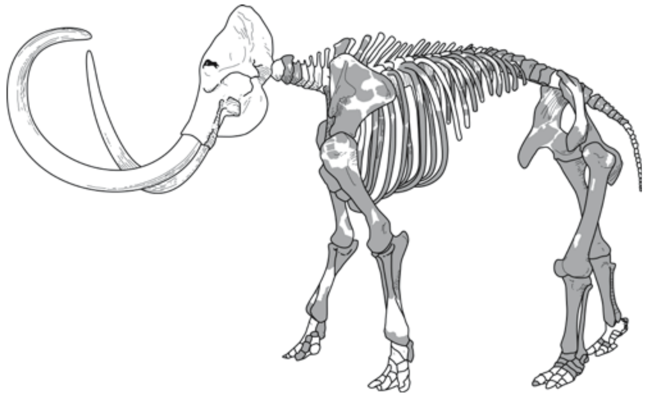


Text-fig. 1. Map of Germany with outline of North Rhine-Westphalia indicated; detailed map with sample locations (asterisks), motorways and major cities.

The skeleton was unearthed in the Seiler clay pit in Ahlen, Warendorf County, Westphalia, in 1910. In just five days, workers excavated the bones, and they were donated to the geological museum by the pit owner. Only one tusk and one molar were found, and many toes and fingers probably escaped discovery due to their relatively small size and the hasty excavation process performed by non-professionals. The tusk seems to have been lost later, whereas the innumerable fragments of the flattened skull were never recovered. The skeleton was prepared in the following 1.5 years, and it was on public display from late 1911 onwards (Wegner 1933). With Münster being a potential target of allied bombs, it was evacuated in 1941, before the museum was actually destroyed. Its building was one of the first university buildings to be reconstructed after the war, and the skeleton was put on display again in 1956 (Siegfried 1959). In 2006, the skeleton was dismantled for some anatomical corrections, in the course of a loan process preceding the temporary closure of the museum in 2007. Its posture was adjusted in all details during the reconstruction of the Geomuseum, and the animal in its new configuration (Text-fig. 4) will form a main attraction of the exhibition from 2018 onwards. All original bones are included in the mount, which may be partially dismantled; and additions of resin are clearly marked. The skeleton is 3.3 m high and 5.2 m long, with head and tusks as resin replicas from a Siberian specimen of comparable age; the single preserved molar is exhibited separately. The dated sample is from the skull, below the foramen magnum.



Text-fig. 2. Skeletal scheme of a woolly mammoth (Abel 1925) with preserved bone material of the Ahlen specimen shaded.

Text-fig. 3. Third definite molar of the Ahlen mammoth. GMM A5N.412. Scale bar 5 cm.

Musk-ox from Herne

Specimens of Pleistocene musk-ox *Ovibos moschatus* (Zimmermann, 1780) are rare in Germany; Andree (1933) only had 28 samples available for study. He redescribes and refigures (his tables 4 and 5, figures 7 to 10) a skull fragment with horn cones (Text-fig. 5), which is on display at the Geomuseum of the WWU (Münster). It is well preserved, with a size of 32 by 29 by 18 cm, corresponding to a mature male (Andree 1933). Kukuk (1913) was the first to publish this specimen, however, under the name "*Ovibos mackenzianus*", giving good photographs from all sides (his plates 19 and 20), as well as a detailed description. It was found in 1912 during excavation of the Rhein-Herne canal in Herne-Crange, Ruhr area, Westphalia, in the so-called "Knochenkiese" (= bone gravels), 10 m below the surface (Kukuk 1913). These fluvial sediments are rich in gravel layers, and have yielded a fauna ranging from the Saalian glaciation to the Eemian and Weichselian (Guenther 1994), resulting in some debate over age. The dated portion is from the posterioventral part of the cranium.

European bison from Gladbeck

The showroom in the Geomuseum of the WWU (Münster) exhibiting Holocene fossils features mounted skeletons of

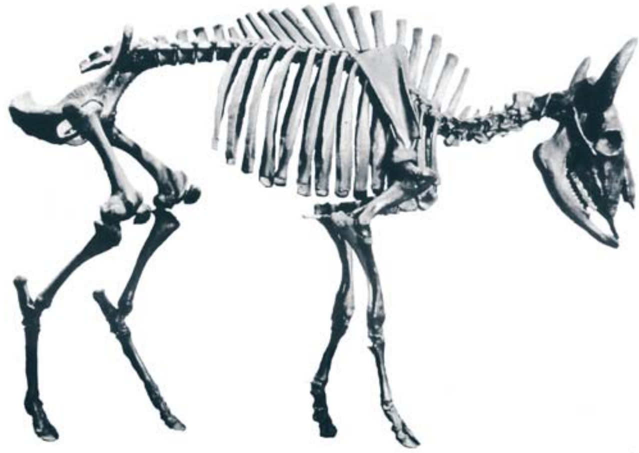
Text-fig. 4. The Ahlen mammoth in its new mount of 2016. GMM A5N.383 (photo: Oliver Kunze).

two bovids: the famous aurochs (*Bos primigenius* Bojanus, 1827) from Füchtorf (e.g., Müller 1989), recently dated to 3,300 BC (calibrated), and a European bison (*Bison bonasus* (Linnaeus, 1758)). This bull died at the age of approximately three to four years (Text-fig. 6).

The bison was found in late 1957 in Gladbeck-Brauk, Recklinghausen County, Westphalia, in an excavation for a major building (Siegfried 1961). Its matrix was fen peat, containing freshwater snails and a typical pollen suite, leading Siegfried (1961) to a Preboreal age estimation. The bones were registered as such by the workers, and reported to the local museum. As nobody at this institution was interested in them, they became part of the scree on a dump. Several months later the bones were accidentally discovered

Text-fig. 5. Fragment of the musk-ox skull from Herne-Crange. GMM A5.53. Scale bar 5 cm.

by Arno Heinrich, head of the Bottrop museum, who performed an intense search with pupils on the secondary deposit. This was rather successful, but most of the skull could not be found. The skeleton was handed over to the Geological Museum of the Westphalian Wilhelm University, predecessor of the Geomuseum, and it was prepared and mounted there during the following years. Missing parts have been cast with resin in 2016; the mount has a length of approximately 2.6 m and a height of 1.9 m. The sample was taken from a humerus.



Text-fig. 6. The skeletal remains of the European bison from Gladbeck as reconstruction and presentation in the anatomical position. GMM A5.K 517.

Techniques

The bone samples were radiocarbon-dated using an MICADAS Accelerator at the Curt Engelhorn Centre for Archaeometry (CEZA), with its subsidiary institute Klaus Tschira Archaeometry Centre. The development of accelerator mass spectrometry (AMS) not only significantly reduced the quantity of samples required, but also considerably increased measurement speed and accuracy.

Table 1. AMS dating of bone samples from three finds from Westphalia.

lab no.	sample	^{14}C (BP)	±	^{13}C [‰]	bone weight (mg)	coll.	coll. [%]
Hd-28901	mammoth	40,990	464	−21.6	1036.6	88.8	8.6
Hd-29185	musk-ox	24,280	119	−19.79	609.7	27.6	4.5
Hd-29017	European bison	9,256	27	−20.9	817.5	50.8	6.2

As contamination can occur during soil sedimentation, datable carbonaceous samples are freed from coarse impurities and foreign carbon that can distort age. Acid and alkali pre-treatment separates carbonates from humins. In the case of bone samples, the collagen – a structural protein – is extracted, ultra-filtered to remove molecules of chain length lower than 30 kDa (potentially younger proteins taken up by the bone from water), and freeze-dried. Bone was long considered to be unsuitable for ^{14}C dating because it is very porous, and the bone apatite is prone to exchange reactions with groundwater and surrounding material. Collagen, however, is not very prone to such exchanges. In the final step, organic samples are converted into carbon dioxide and subsequently reduced to graphite. Sample sizes in the mg range are suitable for measurement in an accelerator mass spectrometer. The graphite sample obtained is sputtered with caesium ions in order to obtain carbon ions. The ions of the carbon isotope are separated in the accelerator according to their different masses. The age of the samples may then be determined from the measured $^{14}C/^{12}C$ ratios. The measured ^{13}C percentage serves as the control for fractionation processes in nature or in the laboratory.

Radiocarbon data are by default reported as conventional ^{14}C age BP. This should not be taken as a calendar age. The origin of this convention lies in the fact that originally the data were converted to an age by using the radioactive decay for age determination assuming constant ^{14}C production, hence atmospheric ^{14}C level, in the past. Unfortunately, it turned out that this is incorrect (Baird 1997). Radiocarbon is produced in the atmosphere by extra-terrestrial irradiation, of which galactic cosmic rays provide the major component. Variable shielding by the geomagnetic field and the magnetic field of the protons in the solar wind lead to fluctuations in the atmospheric radiocarbon level. To cope with this, a calibration curve was established using independent dating methods such as dendrochronology (until approx. 10,000 BC), uranium-thorium dating of speleothems and corals, and varve counting of terrestrial and marine sediments. The limit of the method is due to the fact that after approximately 10 half-lives (half-live of 5,730 ± 40 years), less than 1 part per thousand of the original ^{14}C remains, hence no material older than 50,000 years can be dated reliably with this method (Olsson 2009, Reimer et al. 2013).

The ^{14}C age is normalized to $\delta^{13}C = -25$ ‰ (Stuiver and Pollach 1977). The $\delta^{13}C$ value stems from measurement of isotopic ratios in the accelerator; its error is reported as approximately 0.5 ‰. However, the value can be falsified by isotope separation during preparation, and in the ion source of the accelerator over the original value of the sample material, and can only be used to correct the fractionation effects. The value is therefore not comparable with measurements in a mass spectrometer for stable isotopes (IRMS), and should not be used for further data interpretation. Typically, the AMS-derived value is accurate within 2–3 ‰ compared to the original value.

Results

Results are shown in Table 1. The C/N ratio and carbon content of the collagen extracted are in the normal range (van Klinken 1999), and collagen preservation of the samples is good. Calibrated ages are usually quoted with a 1-sigma error range, corresponding to a confidence probability of 68.3%. It rises to 95.5% for 2-sigma. The calibration was here performed using the programmes INTCAL04 and CALIB5 (Reimer et al. 2004).

Discussion

With an age of 41 ka BP, the woolly mammoth from Ahlen is similar to the one from Siegsdorf, Traunstein County, Bavaria (Rosendahl et al. 2005), but no age information on the other German articulated skeletons is available. It seems to be older than many isolated mammoth bones dated in Europe so far (Stuart et al. 2004, Stuart and Lister 2007), including samples from famous caves such as Vogelherd and Geißenklösterle on the Swabian Alb, as well as reports from the German lowland, e.g. Lommersum or Gönnersdorf (Nogues-Bravo et al. 2008).

Meinsen et al. (2004) attribute the so-called "Knochenkiese" formation from the Rhein-Herne canal, where the musk-ox was found, to an outburst of a glacial lake in the southwestern Münsterland at the end of the late Saalian Drenthe glaciation. This would imply amalgamation with younger sediments of very similar lithology, as the musk-ox recovered from the beds has been dated to approximately 24 ka BP – clearly Weichselian in age. It corresponds to the earliest datings from the Taimyr region and the Ural (Raghavan et al. 2014); other datings from Europe are not available to us. The species obviously was rather rare in Central Europe and its surroundings throughout the Pleistocene; Soergel (1942) reports no more than approximately 60 cranial and 80 postcranial samples from Central Europe.

The European Bison from Gladbeck has been dated to 9.2 ka BP and thus lived in Preboreal times. Whereas both Pleistocene *Bison priscus* and Holocene *Bos primigenius* are rather frequent finds in Central Europe (e.g., Martin 1990), *Bison bonasus* is not. Siegfried (1961) pointed out the importance of this rare skeleton, especially for the identification of any bovid postcranial remains.

The woolly mammoth from Ahlen and the musk-ox from Herne are typical representatives of the so-called mammoth steppe (e.g., Kahlke 1994). The woolly mammoth went extinct in Europe about 12,000 years ago; only on Wrangel Island off the coast of Northeast Siberia it survived until 3500 years ago (Stuart et al. 2002). The musk-ox went extinct in Central Europe around 2,500 years ago (Campos et al. 2010) and nowadays is restricted to the Arctic, mainly Greenland, Canada and Alaska. Herds of this species were successfully resettled on Taimyr Peninsula, Wrangel Island and Spitzbergen (Grubb 1993); smaller populations exist in northern Norway and Sweden. The European bison is the third species of the genus in the European Quaternary, after *B. priscus* and *B. schoetensacki*. It originated in the latest Pleistocene somewhere between southern France and the Middle East, and occurred all over Europe around the Pleistocene/Holocene boundary (Massilani et al. 2016). Its habitats were and are mixed and deciduous forests with clearings, as well as subalpine mountain forests. In the wild, the species was extinguished through hunting in 1919, but from 1980 onwards, it was successfully resettled from relict populations in zoos (Pucek 1986).

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