Hunting horse at the Danube – A Late Pleistocene cannon bone with cut-marks from Vienna-Nussdorf and its (re)discovery

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Abstract

A main goal of the project "Gog & Magog – the Time of Mammoth Hunters in Vienna" was establishing a database for recording Pleistocene mammal bones from different public collections. Main attention was laid on anthropogenic manipulation signatures such as cut-marks or fire influence - with the goal to gather information concerning formerly unknown Palaeolithic sites. ^{14}C-dating of a horse metacarpal bone with skinning marks produced an age of roughly 38,700 - 36,500 cal BC. This is the first evidence for the presence of Early Upper Palaeolithic hunter-gatherers in Vienna.

Zusammenfassung

Im Rahmen des Projekts „Gog & Magog – Die Mammutjägerzeit in Wien" wurde eine Datenbank der in unterschiedlichen öffentlichen Sammlungen vorhandenen pleistozänen Tierknochen aus Wien erstellt. Ein Hauptaugenmerk wurde dabei auf anthropogene Manipulationsspuren wie Schnittmarken und Feuereinwirkung gelegt, um Hinweise auf bislang unbekannte paläolithische Fundstellen zu erlangen. Die ^{14}C-Datierung eines Pferde-Metacarpales mit Schnittspuren, wie sie bei der Fellablösung entstehen, ergab ein Alter von 38.700 - 36.500 cal BC. Dies ist der erste sichere Nachweis für die Anwesenheit von Wildbeutern des älteren Aurignacien auf dem Gebiet des heutigen Wien.

Key words: *Equus* sp., Late Pleistocene, cut marks, Early Upper Palaeolithic, Aurignacian, Vienna, ^{14}C-dating

1. Introduction

1.1 Basic situation

In terms of the archaeological evidence Vienna is mainly renowned for its rich Roman and Medieval heritage. Due to its geographic position, the city, however, has at all times attracted both large herbivores and humans. It is therefore not surprising that also rich prehistoric remains have been recorded. This is mainly due to the position at the east-west-transition along the Danube, as well as the prominent geomorphological situation with landmarks such as the Bisamberg and the Leopoldsberg hills in

the north or the Wienerberg and the Laaer Berg hills in the south.
As always the case at popular settlement locations, intensive construction works caused massive destruction of archaeological information early on. On the other hand, earthwork shed light on the earliest prehistoric period in our region, the Palaeolithic. Best known of all these finds is a mammoth bone, which was recovered during the construction of the north tower of St. Stephen`s cathedral (Stephansdom) in the late Middle Ages. It was exhibited on the outer church wall for a long time, labelled with "AEIOU" (the motto of emperor Friedrich III) and "1443", the year of its discovery. In those times, long before Pleistocene megafauna fossils became commonly known, mammoth bones were interpreted as remains of giants. Systematic research on human lifeways during the Ice Age was never conducted in Vienna until now. Only scattered artefacts from insecure archaeological context, which could only roughly be assigned to the Upper Palaeolithic, were known so far (see Schmitsberger & Neugebauer-Maresch 2016a, 2016b), and there is only one publication specifically dedicated to mammoths, the "giants of the ice age" (Vávra 2002).
In 2015-2016, the Cultural Administration Office of the City of Vienna (MA 7) funded the documentation of old finds from museums and other scientific collections, their interpretation and additional field surveys (Project "Gog & Magog – the Time of Mammoth Hunters in Vienna", 1.1.2015-31.8.2016, directed by C. Neugebauer-Maresch). The project, named after the biblical giants, was hosted at the Institute for Oriental and European Archaeology (OREA) of the Austrian Academy of Sciences (ÖAW). Its goal was the reconstruction of a Palaeolithic find landscape in the Vienna area with the additional objective to define relevant areas of high archaeological potential, and to officially protect these if necessary.
Palaeolithic research is commonly interdisciplinary because only the reconstruction of the environmental conditions and the available resources allow assessments concerning the way of life of Ice Age human societies. Accordingly, this work was conducted in cooperation with various specialists from different research fields. The archaeological part was carried out by O. Schmitsberger and the palaeontological work by K. Saliari, with the support of U. Göhlich and F. A. Fladerer. Additionally collaborations were established with M. Penz (Stadtarchäologie Vienna) and R. Hopkins (at that time affiliated at Oxford University), who was responsible for the dating of the bones in the framework of her dissertation. Furthermore, there was cooperation with the Federal Monuments Authority Austria (BDA, C. Blesl) and E. Pucher (1st Zoological Department, Archaeozoological Collection of the NHMW/Natural History Museum Vienna).

1.2 Projects aims and approach

Summarizing the state of the art in 2015 nearly no secured information resp. only very sparse hints for the presence of Palaeolithic people in Vienna existed. Given the geographical position at the east-west passage of the Danube valley and specifically the striking geomorphological bottleneck situation of the Vienna Gate (cut of the Danube river through the Northern Alpine – i.e. the Rheno-Danubian

- Flysch Zone) between the Bisamberg and the Leopoldsberg (Fig. 1), encampments of Palaeolithic hunter-gatherer groups definitely had to be assumed. Moreover, the presence of such groups had to be expected due to the spatial extent of the study area and the generally favourable environmental conditions.

Therefore, the primary goal of the project was the compilation of indicators for (Upper-) Palaeolithic sites in Vienna, their verification or falsification and the dating of insecure/problematic old assemblages, as well as field investigations. The project was structured in three main work-steps. The first comprised delimitation and definition of promising areas or hot spots based on old collections of archaeological and especially palaeontological/archaeozoological finds including topographic and geological information. This also included creating a database of Pleistocene faunal remains from Vienna with the main goal to document 1) find concentrations, and 2) processing traces on fossil animal bones, which would allow us to infer the presence of Palaeolithic hunter-gatherer-groups in this area. The second stage included field surveys. Lastly, core drillings (at two different locations) and the recording of a loess profile (at a third one) for the recognition of potential Palaeolithic cultural layers were conducted (Schmitsberger & Neugebauer-Maresch 2016a, 2016b).

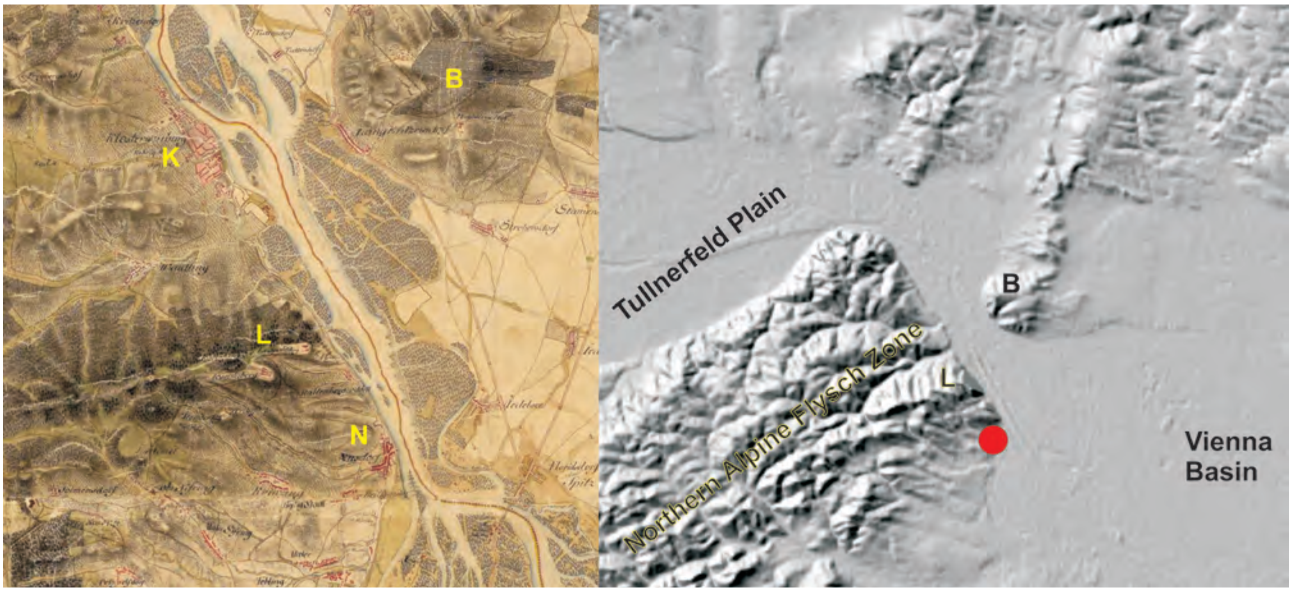

Fig. 1: Left: the Vienna Gate between Kahlenberg/Leopoldsberg (L) and Bisamberg (B) resp. Klosterneuburg (K) and Vienna-Nussdorf (N) (map: Josephinische Landesaufnahme 1763-1785). Right: Geomorphological situation of the region surrounding the Vienna Gate at smaller scale (Airborne Laser Scan © Amap Austrian Map/BEV), red dot marks Nussdorf.

Due to the notable concentration of Pleistocene mammal bones discovered at the loess covered Wienerwald foothills located close to the Danube in the 19th district of Vienna (especially at the localities Heiligenstadt, Nussdorf and Hohe Warte) (see 3.) it was assumed that they were, at least partially, accumulated by humans. Therefore, bone finds still available today were examined for possible manipulation marks. Many of these fossils were recovered in the 19th century. It is not surprising, that only eye-catching animal bones were collected and inconspicuous but supposedly present stone tools were ignored, as they were not recognized by the workers. One of the reasons is that prehistoric archaeology, especially the Palaeolithic, was at its very infancy at this time and the appearance (i.e. morphology) of stone artefacts – at least in Austria – largely not even known.

The survey of the animal bones primarily focused on the detection of manipulation marks like incisions or fire influence. Although some specimens could be classified as „potentially anthropogenically manipulated“ (see below), F. A. Fladerer was only able to verify cut marks on one horse metacarpal. All others were either not anthropogenic (e.g. bite marks), or so called excavation artefacts and therefore recent damages.

2. Recording the Pleistocene animal bones from Vienna in a database

2.1 Materials and methods of documentation

The faunal remains are almost exclusively accidental finds from construction sites and brickyards. Most of them were found in the 19th and the beginning of the 20th century. It cannot be excluded that Pleistocene bones were mixed with younger ones at some sites.

The material of the current study is housed in the following collections: Natural History Museum Vienna (NHMW), Wien Museum (Depot Himberg), University of Vienna (Department of Palaeontology), Geological Survey of Austria, and from the city district museums of Floridsdorf, Liesing, Hietzing, Döbling and Simmering. The individual collections differ significantly in terms of available information.

Altogether, approximately 810 datasets were recorded, comprising both individual bones and partial skeletons, the latter counting also only as one dataset. Additionally, the finds were mapped using a GIS-program.

The most important information recorded when documenting the bones were: a) Name of the actual collection and, if there had been a transfer, the name of the original collection; b) inventory number (and any information written on the bones); c) faunal information (species, skeletal elements, number of elements and fragments); d) site location; e) any kind of taphonomic observations; f) geological setting/type of sediment (loess, gravel); g) dating; h) references; i) additional observations.

The steps of documentation were 1) inventory creation, followed by 2) quantification and 3) determination. The quantification of the material is based on the number of bones and fragments. Unfortunately it was not possible to interpret the minimal numbers of individuals. Skeletons and partial skeletons were noted as well. Only a part of the bones had aready be determined. If possible, additional determinations were conducted in the course of the documentation work. The majority of the material consisted of bones which could not clearly be assigned to a species and had to be lumped together in groups: large mammals (in the size range of mammoth and rhinos), medium sized mammals

(approximately of Equidae size), and small mammals.
Similar to the classification of bones according to faunal size groups, the skeletal elements were grouped into the following categories: small bones, long bones, flat/tabular bones, skull fragments and indeterminable fragments.

2.2 Analysis on family level - the equids

In the investigated assemblage, Equids constitute the second most common family after Elephantidae. The majority of horse remains are teeth, metapodials and phalanges. Following the previous determinations, the most common species would be so-called "*Equus ferus fossilis*", however, also *Equus hydruntinus*, *Equus woldrichi*, and "*Equus abeli*" occur. Some fragments were only identified as "Equidae indet". It has to be noted that there were problems with some previous determinations such as "*Equus abeli*". According to Nobis (1971), the description of "*Equus abeli*" by Antonius (1913) is fundamentally wrong: Nobis (1971) reviewed the measurements of Equus abeli and observed that for the description of this "species" remains of different horse individuals were combined, partly even from medieval animals. "*Equus woldrichi*" is also problematic. There exist only very few fossils assigned to this species which are not described adequately and following the literature these remains are additionally of insecure date (Forsten & Dimitrijević, 2004).
The distribution of the equids differs from that of the mammoths – horses derive predominantly from Nussdorf/Heiligenstadt and the Laaerberg locality (Frank & Rabeder 1997a, 1997b).
Only for a little number of bones there is specific information regarding the geological setting; most of them had been preserved in a loess milieu and only very few derive from gravelly sediments.

2.3 Manipulation marks - proof of human activity

It was only possible in a few cases to clearly decide whether breakages on bones were recent or old. Another difficulty was the partly poor preservation of the fossils. Some surfaces were eroded to such an extent that potential manipulation marks could not be determined anymore. As mentioned above, some bones with questionable manipulation marks were detected in the course of the recording (e.g. a Phalanx 1 and a calcaneus of *Bison priscus* from Heiligenstadt). Only the marks on a horse metacarpal stood up to scrutiny and were verified to be actual anthropogenic cut-marks (Fig. 2).
Although the preservation of the animal remains depends on various factors, a dominating presence of specific bones can be observed (see above).
This observation could be of significance regarding natural or anthropogenic selection, however further interpretations are hampered by lacking context information.
With the exception of the Titlgasse site in the 13th district/Hietzing (Schmitsberger & Neugebauer Maresch, 2016b), no cultural layers or secure Palaeolithic stone tools have been recorded in Vienna to date. A possible explanation could be that many of the bones were found in the 19th century and possible associated artefacts were not recognised (see 1.2).

Fig. 2: Equus sp., metacarpal. a medial view, b dorsal view, c palmar view, d lateral view, e proximal view (with borehole from ^{14}C-sampling), f distal view, g: detail of cranial view with incision marks (all photos by A. Schumacher, NHMW).

2.4 Geographical distribution of Pleistocene animal bone finds in Vienna

Pleistocene animal bones are not uniformly distributed throughout Vienna, but show clear find concentrations, especially in Nussdorf/Heiligenstadt (Figs. 3 & 4) and at the Laaerberg hill. The find distribution pattern is governed by several factors. One of the more important aspects is the location of brickyards in 19th century Vienna.

Many of the finds stem from the clay pits of these brickyards, and it is therefore not surprising that especially the above mentioned localities are proportionally richer in animal bones than other areas since many large clay pits were located there.

There are not only geographical deviations in the distribution and number of bone finds, but also regarding the composition of the faunal remains.

To interpret this, a more detailed palaeontological investigation would be necessary. Here, only the find areas of Nussdorf and Heiligenstadt will be adressed.

A wide range of different families and species is represented in the faunal material from Heiligenstadt/Nussdorf.

Fig. 3: Mapping of Pleistocene animal bones in the north-western part of Vienna with a concentration in the Heiligenstadt-Nussdorf area (yellow: with exact location, violet: with approximate location; GIS-graph by K. Saliari).

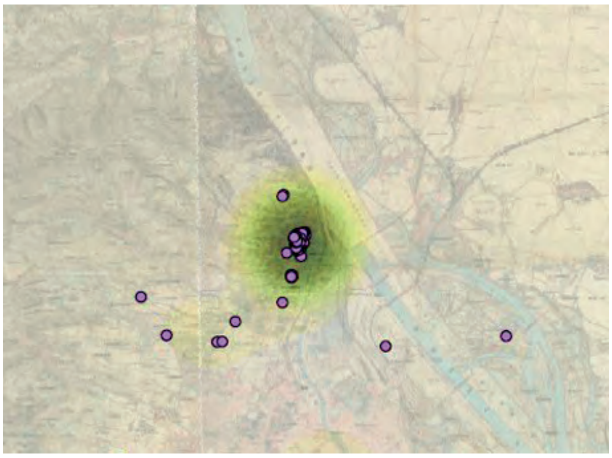

Fig. 4: Kernel Density for bones without exact location shows a clear centre (of altogether two in Vienna) in Nussdorf/Heiligenstadt (GIS-graph by K. Saliari).

It has to be emphasized, that most of these determinations refer to the already existing labels and have not been reviewed in the course of the documentation work, and therefore need not necessarily to be correct in each single case. Determined animal remains belong to Elephantidae (*Mammuthus primigenius, Mammuthus meridionalis*), Equidae (*Equus ferus, Equus hydruntinus*), Bovidae (*Bos primigenius*, *Bison priscus*), Cervidae (*Rangifer tarandus*, *Cervus elaphus*, *Megaloceros giganteus*, *Capreolus capreolus* and possibly *Alces alces*), Rhinocerotidae (*Coeleodonta antiquitatis*), Canidae (*Canis lupus*), Ursidae (*Ursus* sp.), Hyaenidae (*Crocuta spelaea*), Talpidae (*Talpa europaea*), Cricetidae (*Microtus* sp., *Arvicola* sp.), Leporidae (*Lepus europaeus*) and Soricidae (*Sorex* sp.).

According to Frank & Rabeder (1997b), the Nussdorf/Heiligenstadt fauna predominantly dates to the younger part of the Middle Pleistocene. This assessment is mainly based on the small mammals. The main subject of the current paper, the horse metacarpal, shows, that at least in Nussdorf there are Late Pleistocene faunal fossils too.

3. The horse metacarpal from Nussdorf in the palaeontological collection of the NHM Vienna

The fossil (Metacarpale III dext. of a horse *Equus* sp.) was originally located in the collection of the "Imperial & Royal Polytechnic Institute of Vienna" (founded in 1815), nowadays the Vienna Technical University. It is not known, when the specimen was incorporated to collection of the NHMW. The metacarpal was inventoried with the No. NHMW 2016/0111/0001 in the course of sampling for the ^{14}C-dating.

The caption on the historical label (Fig. 5) reads:

1870
Hinterer Metatarsus von
Equus fossilis (Equus adamiticus Schloth. [=Schlotheim])
Durchstich bei Nussdorf

Fig. 5: The historic label of the cannon bone (photo by U. Göhlich).

In the same box two more fragments of metapodials are kept, a distal half and a proximal half. The latter derives from a young animal, because it misses the proximal epiphysis. Both of them cannot securely be determined either as metacarpal or as metatarsal.

Equus adamiticus is not a valid species. Also, *Equus fossilis* most likely only indicates that it is a fossil (and not a recent) horse.

The term “Durchstich“ most likely refers to the inlet of the Danube channel. According to these indications, the bone does not seem to have originated from one of the Nussdorf brickyards, where most of the other fossil Nussdorf specimens were recovered.

4. Find location - attempt of reconstruction and geochronological assignment

4.1 Location

Although the label reads “Acquiriert (acquired) 1870“, the year 1870 is not necessarily also the year of the bone`s recovery. The Danube in present day Vienna comprises three (main) river branches; the so-called “Alte Donau”, the former main stream which is not an active branch anymore, the so-called “Neue Donau” (New Danube, the actual/regulated main stream) and the “Donaukanal” (Danube channel).

What is now the Danube channel, was originally a natural side stream of the Danube river, which branched off the old river bed which only existed until 1870 (Fig. 6; see also: Donaukanal, n.d.; For a detailed history of the Viennese Danube river and its streambed changes see Hohensinner et al., 2013a, 2013b, Haidvogl et al., 2013, Sonnlechner et al. , 2013).

The construction of the channel commenced as early as 1598 with an initial channel puncture in the “Wolfsau”. In 1832, an additional channel puncture was carried out at the present day Ostbahnbrücke.

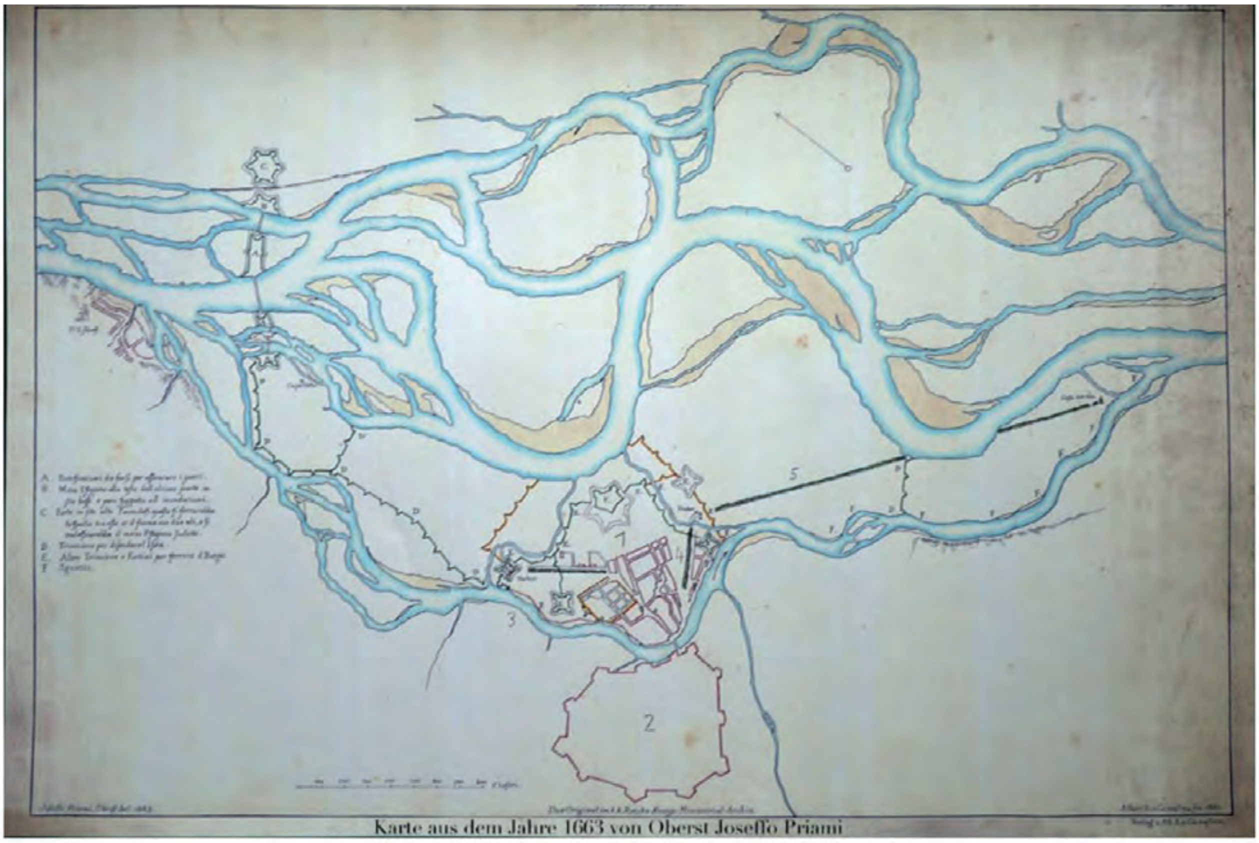

Fig. 6: Map of the Danube in Vienna from 1663 (Joseffo Priami, "Abriß zu Wien zu Versicherung der Brükhen", earliest detailed illustration of the Danube from Nussdorf to Simmering). The southernmost side stream represents the modern Danube channel; the presumable find spot is located where it branches off the main river (at the left edge, where the former Nussdorf village is also indicated on the map).

In the years 1894-1898 intensified construction activities took place in Nussdorf, which is clearly too late for our find.

Most likely the bone was found in the course of the general Danube river regulation 1870-1875 (see: DONAUREGULIERUNG, n.d.). The reason for the regulation of the Danube riverbed between Nussdorf and Albern (today Neue Donau/New Danube) was the frequent flooding of the area. In the course of the creation of the New Danube, the entire new stream bed, which is running between the flood embankments, was named "Wiener Durchstich". Hence, the find location indicated on the label, is not necessarily related to the Danube channel cutting, although this is very likely.
The modern Danube channel branches off the new main stream, commissioned in 1875, at Nussdorf shortly before the Nussdorf sluice complex (Figs. 7 & 8).
As already mentioned, the "Durchstich" (cutting/puncture) created in the course of the regulation of the Danube between 1868/1870 and 1875 does not predominantly refer to the Danube channel but rather to the New Danube, which now constitutes the main river bed.

Fig. 7: View from the eastern Nussberg foothill towards the Old Danube (left in the background) and the regulated Danube (in the centre). The branch in the foreground, immediately behind the houses of the Nussdorf village, is the Danube channel. The find spot is most likely located at the very left edge at the channel inlet. Drawing by Hugo Darnaut. Vorzeichnung zum „Kronprinzenwerk“ (Die österreichisch-ungarische Monarchie in Wort und Bild, Wien 1886-1902), Bd. „Wien“, 1886, 323; vor 1886. © ÖNB Bildarchiv und Grafiksammlung - http://data.onb.ac.at/rec/baa12956209

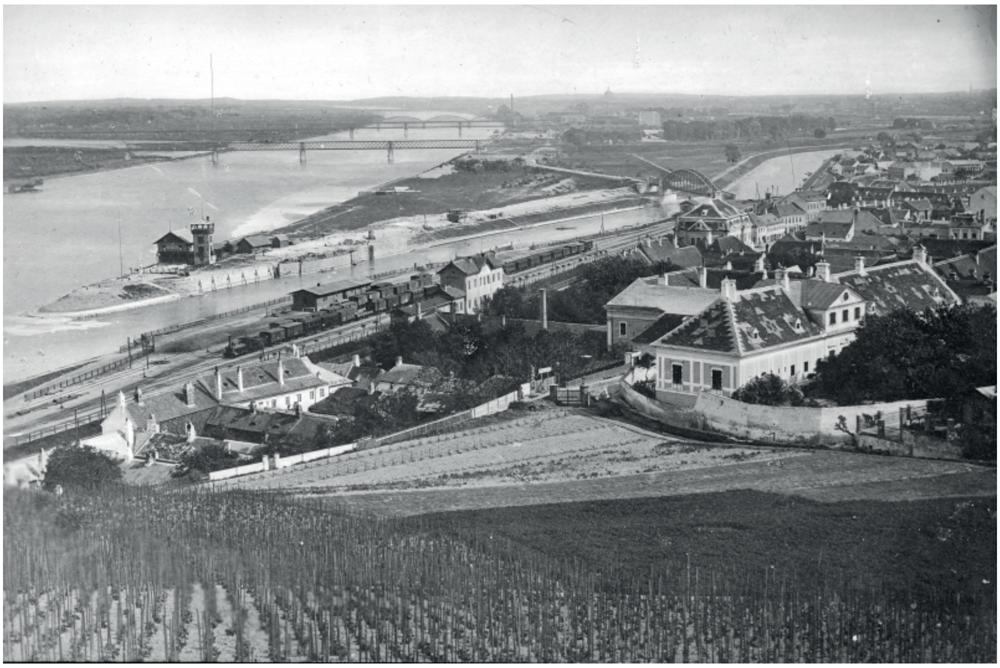

Fig. 8: View from the slope of the Nussberg hill towards the Nussdorf village, the “Brigittaspitz“ and the Danube bridges. The old Nussdorf sluice complex is located in the centre. Photo before 1894, the find spot is again in the foreground to the very left.
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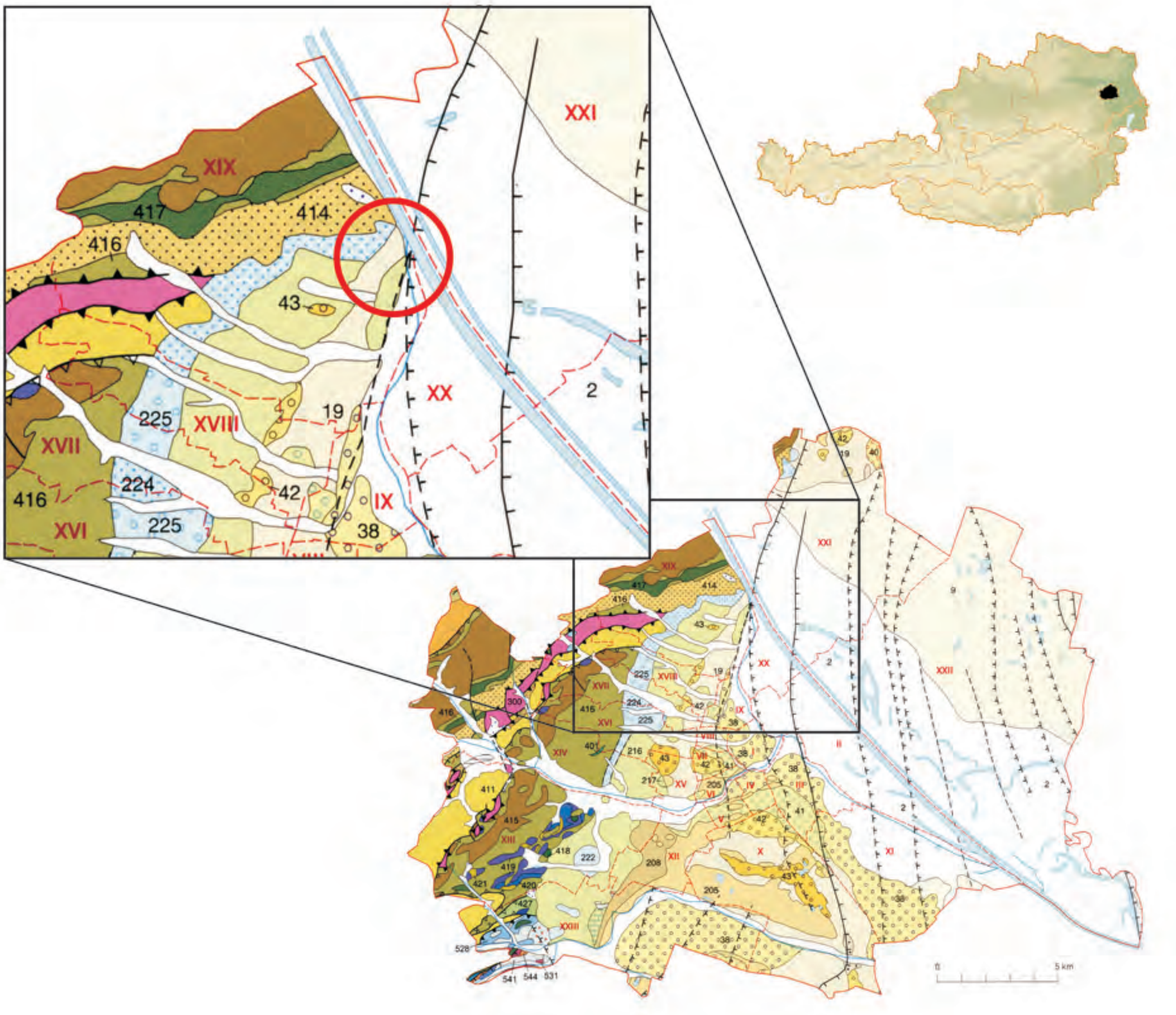

Fig. 9: Geological map of Vienna (modified after Summesberger, 2011, 63; based on Geological Map of Lower Austria 1:200.000, Schnabel et al, 2002). 19: loess; 38: Stadt terrace; 40-43: earlier Pleistocene Danube terraces; 2, 9: Prater terrace and Holocene gravels; light blue (especially 224) and light green (especially 216): Neogene sediments (Badenian and Sarmatian).

Therefore, due to the terminological confusion of the term “Durchstich” and its use for both the Danube channel as well as the New Danube, the meaning of this term on the label for the bone is insecure. In principle, the bone could therefore either have derived from the cutting of the New Danube, or from the channel inlet. In any case it was discovered at the eastern foothills of the Nussberg.However, in the course of the Danube regulation 1868-1875 the Danube channel was again expanded, especially the inlet construction at Nussdorf and also the outlet at Albern (Gaube, n.d.). This fits perfectly with the indications of “Durchstich bei Nussdorf“ (inlet) and “Acquiriert 1870“.

The loess cover only reaches the Danube in the very small area where the channel branches off the river. Since the bone (and the two additional specimens from this find post) must have been associated with loess and certainly not with gravel (state of preservation, no fluvial rounding, etc.), the find location can be reconstructed quite accurately: directly at the eastern foothills of the Nussberg at the inlet of the Danube channel, the only point in Vienna, where the loess cover reaches the Danube, immediately above its riparian zone. Hence it most likely derives from the lowest loess deposits above the river (Fig. 9). This situation corresponds to the entrance resp. exit of the geomorphological significant bottleneck of the Vienna Gate.

4.2 Geochronological assignment

The exact original site location is unknown, but we argue that it must have been located in/near the former Nussdorf village on the so called Stadt terrace of Rissian (resp. Saalian) age (Pfleiderer, 2008a, 114, Summesberger, 2011). This terrace, attested only through core drillings, represents the lowermost glacial terrace in this area, and is only partly preserved exposing underlying Neogene sediments (Pfleiderer, 2008a, Figs. 1 & 4). These geological units are covered by Wuermian (resp. Weichselian) loess deposits, which represent the find context of the bone.

The loess sediments can be roughly correlated with (or are somewhat older than) the gravels of the Wuermian Prater terrace, which is however not developed in this area, but only north of the pronounced meander zone of the Holocene Danube and maybe partially also beneath the gravels of the Holocene meander zone (Pfleiderer, 2008a, 2008b, Fig. 2). This youngest of the glacial terraces (Prater terrace) shows no more loess cover. For varying maps of the geological situation in this area see also Fuchs, 1873 Pl. XIX, Brix, 1972, and Fuchs, 1985.

5. Palaeontological and archaeozoological investigations and scenario reconstruction

5.1 Measurements and description

Equus ferus (NHMW Department of Geology & Palaeontology 2016/0111/0001)

Measurements (von den Driesch 1982)
Greatest length (GL): 245 mm
Lateral length on the outer side (Llat): 234 mm
Proximal width (Wp): 52.1 mm

Proximal (cranio-caudal) depth (Dp): 36.8 mm
Smallest diaphyseal width (SD): 39.9 mm
Distal width (Wd): 50.7 mm
Distal depth (Td): 27.9 mm

Fig. 10: Details of the cannon bone with marked incision groups A, B, C (photos A. Schumacher, NHMW).

The right metacarpal III, the cannon bone in popular vocabulary, is completely preserved. No epiphyseal scar is visible, hence the specimen represents an adult prime-aged individual. Slight damages are visible on the proximal end and on the dorsal as well as the palmar facies of the distal trochlea. Furthermore there are spallings and desiccation cracks on the shaft, as well as a narrow groove between the middle and the distal third of the diaphysis which can not be verified as a palaeolithic modification of the bone. The most striking and indicative taphonomic features are parallel cuts on the distomedial side of the shaft.

On the frontal or dorsal facies of the shaft, within the inner, the medial half, between 7 and 6 cm distant from the distal end, a group of three distinct more or less parallel cut-marks is situated, inclined to the longitudinal shaft axis by about 45°. The microscopic view shows a corrosion grade that is identical with the corrosion of the outer surface. This provides a taphonomic proof of the identical age of the bone and the modification: the lesion of the surface happened to the fresh bone.

The first proximal cut is 8.5 mm long (Fig. 10 Position A). About 1 cm downwards two merging cuts comprise a total length of 13.0 mm (Fig. 10 Position B).

The cuts display an asymmetrical profile or cross-section with more flattened distal cut faces (Fig. 11). The steep proximal face of the cut in position A shows chipped off micro-flakes causing a “ragged appearance” (sensu Binford, 1981, Fig. 2 Position A).

There are further parallel lineaments between the two positions (see Fig. 11 upper picture), as well as below, versus the trochlea (Fig. 10 Position C).

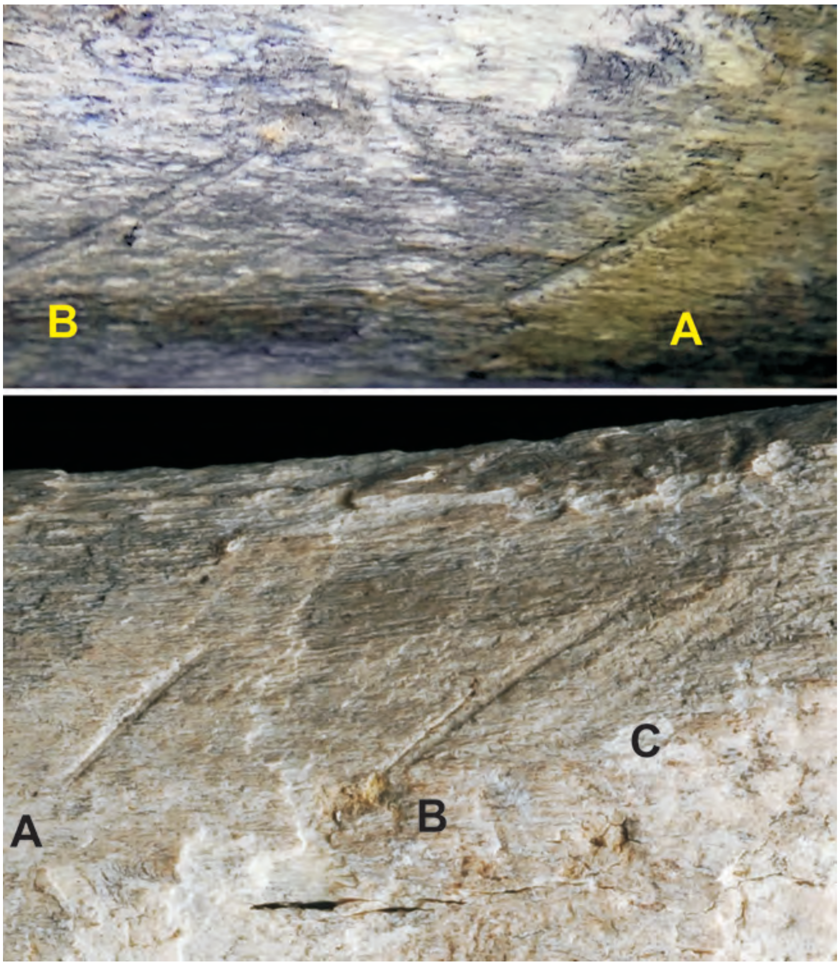

Fig. 11: Micro- (above) and Macro-photos (below) of the cut-marks from different views (photographs by F. A. Fladerer and A. Schumacher, NHMW).

They may derive from shallower cuts that did not completely penetrate the periosteum. On the posterior, palmar side of the metacarpal further lineaments can be observed, but an anthropogenic cause seems not very likely.

5.2 Discussion of bone dimension and species attribution

The greatest length measurement of the Vienna-Nussdorf specimen is 245 mm. An osteometric survey lists data of 123 Würmian horses, the means of greatest length is around 230 mm (Eisenmann, 1991b). Another study of the same author provides means of 222 mm calculated from 16 Late Pleistocene *E. germanicus*- and 215.5 mm from 36 recent *E. przewalskii*-specimens (Eisenmann, 1991a). Forsten & Ziegler (1995) report greatest length means of 239+-0.1 from 34 *E. germanicus*-metacarpals, and proximal width means of 56 mm. The distal width of the Nussdorf specimen of 50.7 mm obviously exceeds the range of the Przewalski-horses (x = 44.2, n = 88; Eisenmann, 2016). Compared to these data the Nussdorf horse is identified as a large individual.

Interpolated to a more recent survey of Late Pleistocene horses (Kagaan, 2000, Fig. 5.13) the metacarpal from Nussdorf again is grouped among the largest specimens of the studied sample from continental Ice-age Europe fossils. Three horse metacarpals from the camp site Alberndorf 1 (for chronol-

ogy see 6.3) yield measurements of 226, 234 and 269 mm, proving a rather broad intraspecific variability within only one assemblage (Fladerer,1996) and similar to data sets of domestic horse types. Nevertheless, available data suggest an at least coarse conclusion: the Vienna-Nussdorf individual is within the range of moderate large Late Pleistocene horses, and it was definitely not stout, but rather slender. According to the Kiesewalter-method (WH = lateral length of the metacarpal III * 6.41; e.g. Cramer, 2002) the withers height of the Nussdorf horse can be rated as 150 cm. Using the factor 5.77, specific for Przewalski horses, the calculated withers height amounts to 141 cm (Eisenmann, 2009).
Concerning the species attribution as *E. ferus*, caballine (caballoid) horses from West to Central European Late Pleistocene assemblages often are addressed as *E. germanicus* (compare Forsten & Ziegler, 1995), *E. gallicus*, *E. remagensis*, *E. solutreensis* or on subspecies-level as *E. caballus* (the guidelines of the International Commission on Zoological Nomenclature - ICZN 2003 state that the species name *E. caballus* should only be used for domesticated animals). Therefore a more reliable denomination might be *E. ferus* (e.g. *E. ferus ‘solutreensis’*, e.g. Rabeder, 1996). A general decrease of size from the Middle Pleistocene towards the last Glacial Maximum is observed (e.g. Forsten, 1991) and ecomorphologic size and stoutness variation triggered by glacial vs. more humid conditions are taken into account (e.g van Asperen, 2010, van Asperen & Stefaniak, 2011).

5.3 Archaeozoological interpretation

The cannon bone (German: Röhrbein) is the third longest front-limb element. It is positioned in the autopodium between the carpals and the first phalanx, the long pastern bone. There are strong joints connecting the element, proximally the carpal, and distally the metacarpo-phalangeal joint. The cannon bone contains in its medullary cavity a relative high amount of marrow, holding the fifth position behind femur, tibia, radius and humerus (e.g. Outram & Rowley-Conwy, 1998). The complete status of the bone proofs that the marrow had not been exploited, yet anthropogenic manipulation proven by a series of parallel cut-marks on the dorsomedial side of the diaphysis indicates result-oriented human behaviour. This position marks the cutaneous plane of the metacarpal, where the shaft of the bone is only covered by hide. The distinct asymmetric profile of the cut-marks, with the flat distal faces and micro-flaking of the steep proximal face indicates cutting from a distal position.
Cut-marks derive from various stages during processing an animal carcass - or its separated parts -, following an experienced sequence, between the kill of the animal and final acts within residential camps.
Considering the anatomical features of equine autopodials we suggest an interpretation of the cut-mark series as consequence of skin removal.
The medial part of its dorsal facies is the only position of the metacarpal where the hide is not separated from the bone by other structures like sinews or ligaments and cutting will therefore harm the bony surface very easily.

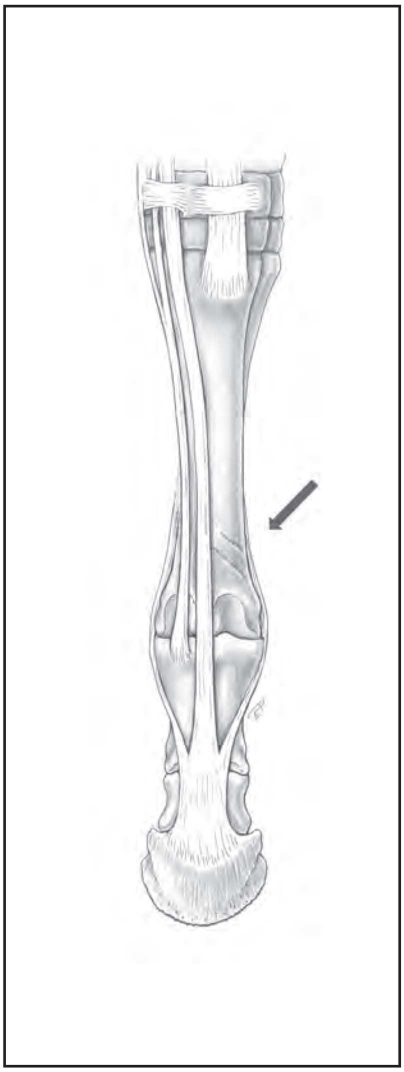

Fig. 12: Anatomical position of the cannon bone and adjoining tendons (Drawing by E. Polsterer).

The position of the cut-marks in their anatomical context is depicted in figure 12. Potentially, but not proven by indicative cut-marks, the metapodial has been cut out and the phalanges remained attached to the hide, as this helps to transport the hide and butchered meat by using the distal bones as handles. This behaviour might also be responsible for the under-representation of distal phalanges in kill site assemblages (compare Fladerer, 1996) while metapodials of horses are frequently observed in archaeological assemblages, at hunting or kill-sites as well as at residential sites (e.g. Niven, 2007, Soulier, 2014) and they often bear cut-marks (e.g. Niven, 2007, Brasser, 2012). At an Early Upper Palaeolithic site in Southern France (Soulier, 2014), rather isochronous to Vienna-Nussdorf, frequent oblique cut-marks are interpreted as caused during detachment of the skin and they are present over the entire length of the metapodial diaphysis. Additionally, short and transverse cut-marks are thought to indicate the removal of the strong tendon of the extensor muscle, as tendons are valued by indigenous people for their usefulness for cordage and also hafting (e.g. Binford, 1981).

5.4. A possible kill site/butchering site?

There are arguments for a “real“ archaeological site at this locality: two additional horse bones, presumably (but not certainly) from the same site, are kept in the same box. They represent animals of different age and therefore at least two individuals. According to one of the authors (U. Göhlich) the three bones do not belong to the same find complex. This assumption is based on a slightly differing preservation which could indicate a deposition in different sediments. This however does not exclude the possibility of the same find location, which in such a case could have been a seasonally used kill site at the banks of the Danube River. Because long bones of horses - compared to those of other large herbivores - contain very little marrow, they were often left behind at kill sites (West, 1996). The location at a geomorphological bottleneck situation (narrow section of the Danube valley) would have been predestined for a hunting spot. Since at the time of discovery only bones were kept for the natural scientific collections, potential stone tools would not have been noticed (see chapter 1.2).

Removing the skin from the carcass of large-sized ungulates like equids is part of the most initial butchery tasks. The bodies must be partly dismembered at the kill-site or a nearby butchering site (see, e.g., SIVERTSEN, 1980), at least within a Palaeolithic spatial organisation. Selected parts are then transported to residential camps. The unbroken shaft of the Nussdorf-specimen testifies that the marrow cavity has not been opened by the hunters. Actually, the bone-marrow is one of the most attractive substances because of its nutritional value, containing high quantities (up to 70%) of unsaturated fatty acids. These are known to be highest between late summer and early winter, while being rather depleted from late winter on (compare e.g. OUTRAM & ROWLEY-CONWY, 1998). Compared to reindeer or bison, horse bones contain much smaller marrow quantities (BLUMENSHINE & MADRIGAL, 1993), but the butchery and marrow exploitations patterns seem rather consistent (NIVEN, 2007). In the highly seasonal Pleniglacial annual climate course, and hence the hunter-gatherer`s subsistence cycles, we would expect marrow exploitation between late summer and mid-winter when marrow quality is best. Complete horse metapodials seem by far under-represented or even absent in Early to Mid Upper Palaeolithic residential sites, but there is clear evidence of broken specimens, very probably for marrow exploitation (NIVEN, 2007) which is similar to younger evidence from the Middle Danube Region (WEST, 1996). A large river system and the vicinity of low mountain ranges is surely a preffered landscape for Early Aurignacian spatial behaviour (HUSSAIN & FLOSS, 2016). We suggest a scenario where the Vienna-Nussdorf horse specimen derives from a hunting a,nd primary butchery episode of a local or regional population, probably carried out close to the Danube banks and maybe between mid-winter and early summer.

6. Radiocarbon dating and chrono-stratigraphic placement

6.1 Method

The specimen was sampled at the Natural History Museum in Vienna. Although documentation of restoration or preservation work is not available, visual inspection indicated that it had been heavily treated in the past. The cannon bone seemed to be coated with a thick layer of glue, omitting a smell reminiscent of acetone.

To prevent contamination of the radiocarbon sample, a circular surface area of ca. 1 cm^2 was cleaned with a drill before sampling. Bone powder for radiocarbon dating was obtained using key-hole drilling, a minimal invasive sampling technique collecting material from the interior of the specimens, while keeping the exterior largely intact (Fig. 2e).

The bone powder sample (696.92 mg) was treated and radiocarbon dated at the Oxford Radiocarbon Accelerator Unit (ORAU). First, a solvent wash protocol was applied to remove possible contamination deriving from conservation and restoration materials: 30 min in acetone, 30 min in methanol (both in a heating block at 40°C), 30 min in chloroform at RT. The sample was centrifuged and decanted between each step, and finally left to dry overnight in a heating bloc at 40°C.

Subsequently, the dried sample was pre-treated using the standard ORAU protocol for bone using acid-base-acid steps followed by gelatinisation and the use of Ezee-filters™ (Brock et al., 2010). A freeze-drying step was added after Ezee-filtering to assess whether collagen preservation is sufficient for ultrafiltration. The sample yield was adequate, and the unpurified collagen thus hydrolysed with 10 mL Milli-Q™ water and ultra-filtered. All remaining steps, graphitisation and AMS measurement, followed standard lab procedures as described by Brock et al. (2010) and Bronk Ramsey et al. (2004).

6.2 Result

The specimen was successfully dated to 34,550 ± 600 BP (Ox-A 34405). Collagen preservation was very good (Tab. 1), resulting in a collagen yield after ultrafiltration (AF*) of 9.19 wt%. The C:N ratio of 3.2 is consistent with collagen. All quality control measurements suggest a reliable radiocarbon age.

Sample-no	Site	Species	Treat	Yield (mg)	Yield (%)	Lab/P-no	$F^{14}C$	^{14}C age	%C	C:N	$\delta^{15}N$	$\delta^{13}C$
2016/0111/0001	Wien-Nussdorf	*Equus*	AF*	64.03	9.19	OxA- 34405 / P41690	0.01354 ± 0.00102	34550 ± 600	43	3.2	6.6	-22.1

Tab. 1: Radiocarbon result for specimen Inv.-nr. 2016/0111/0001, pre-treatment applied (* stands for solvent wash, AF for treatment with ultrafiltration; for ORAU codes see Brock et al. 2010), listing collagen yield after pre-treatment, Lab-code, radiocarbon measurement in fraction modern (F14C) with 1σ error and conventional radiocarbon date in BP, %C on combustion, carbon to nitrogen ratio and stable nitrogen and carbon isotope ratios.

Using the IntCal13 calibration curve the radiocarbon age calibrates to 40,600-37,700 cal BP at a confidence interval of 95.4% (Fig. 13).

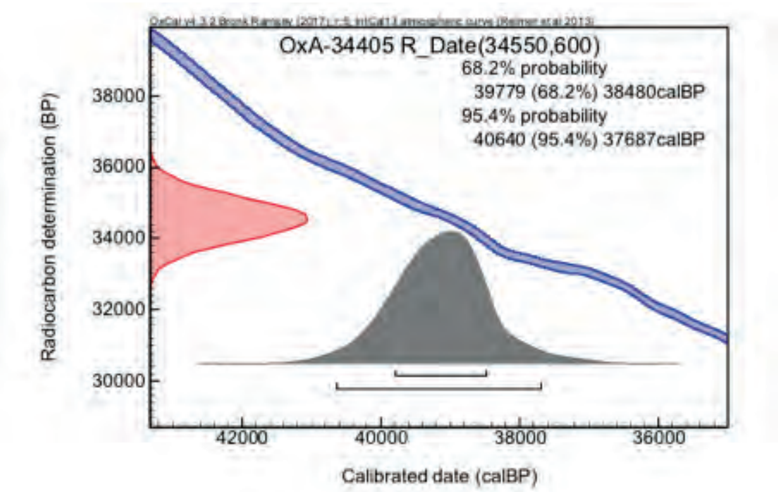

Fig. 13: Calibrated radiocarbon age obtained from the horse Metacarpale III dext. with anthropogenic marks using OxCal 4.3 (Bronk Ramsey, 2009). Red: conventional radiocarbon age for OxA-34405 (1σ). Blue: IntCal13 calibration curve (Reimer et al. , 2013). Black: calibrated radiocarbon age with both the 68.2% and 95.4% confidence interval marked.

6.3 Discussion and chrono-stratigraphic placement

Since no archaeological context was recorded for the anthropogenically modified horse Metacarpale III dext specimen of Vienna-Nussdorf (Inv.-nr. 2016/0111/0001), the obtained radiocarbon age is – beside the geographic location – of utmost importance for the reconstruction of a cultural and chrono-stratigraphic framework. In a broader sense, the radiocarbon age of 34,550 ± 600 BP for the Vienna horse specimen is in agreement with prevalent chronological assessment and hypotheses regarding the dispersal of early anatomically modern humans (AMH) into Europe (Conard & Bolus, 2003, Jöris et al., 2010, Chu, 2018, Hopkins, 2019). It can therefore be assumed that the anthropogenic modification of the bone, and thus also hunting, processing, and consumption of the horse was carried out by anatomically modern humans. The age of 40,600-37,700 cal BP (IntCal13) resp. 41,700-37,800 cal BP (CalPal-2007-Hulu) – both ranges given for the 95.4% confidence interval – corresponds to ages obtained for the regional early Aurignacian assessed at the northeast Austrian open-air sites Willendorf II, Senftenberg, and Krems-Hundssteig. The ages presented here (Tab. 2, Fig. 14) only include dates produced for unambiguous Aurignacian complexes, or – in some cases – only ages that clearly fall within the Aurignacian range.

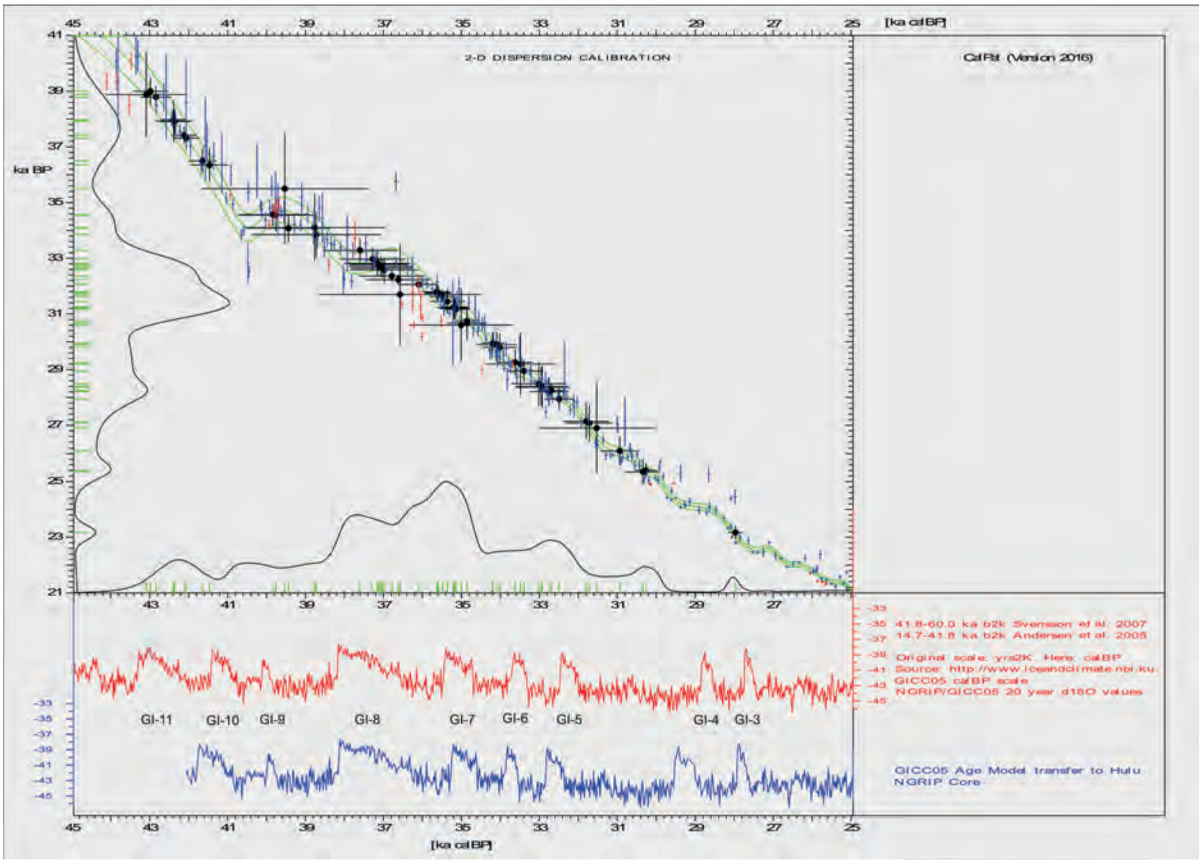

Fig. 14: Graphic representation of the data presented in Table 2 with the exception of samples VRI-1373, OxA-8511, and OxA-4595. Calibration was carried out with CalPal-Beyond the Ghost, Version 2016.2, http://monrepos rgzm.de/forschung/ausstattung.html#calpal (Weninger & Jöris, 2008). The Calpal-2007-Hulu calibration curve is given in green together with the underlying reference data. Beneath, the GICC05 timescale (Greenland Ice Core Chronology 2005, 15 - 42 ka; 20 yr δ 18O, http://www.iceandclimate.nbi.ku.dk, as well as a version of the GICC05 timescale adapted to the Hulu data) is provided as climate reference.

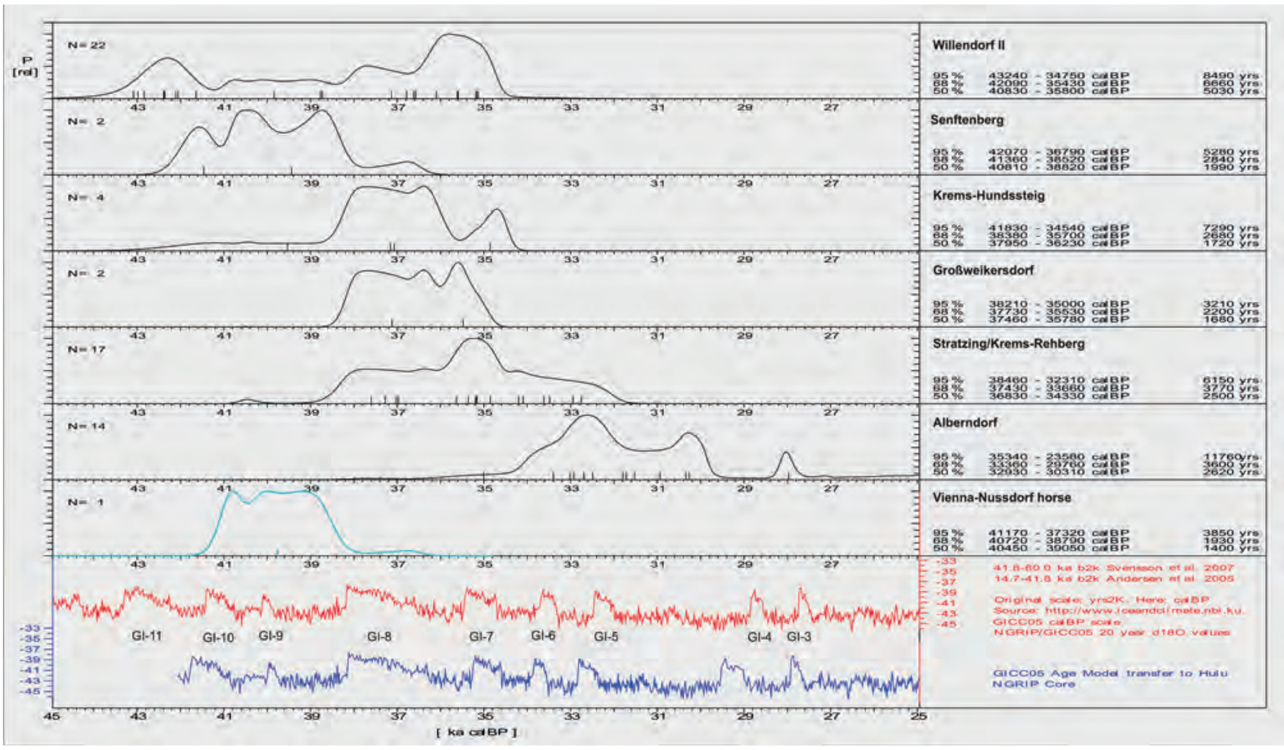

Fig. 15: Multigroup graph with sum plots of probability distributions of calibrated 14C dates (calBP) of Aurignacian contexts of northeast Austria produced with CalPal-Beyond the Ghost, Version 2016.2, http://monrepos-rgzm.de/forschung/ausstattung.html#calpal (Weninger & Jöris, 2008). The dates have been grouped according to sites. Beneath, the GICC05 timescale (Greenland Ice Core Chronology 2005, 15 - 42 ka; 20 yr δ 18O, http://www.iceandclimate.nbi.ku.dk, as well as a version of the GICC05 timescale adapted to the Hulu data) is provided as climate reference. Chronologically, the Vienna-Nussdorf specimen is clearly attributable to the earlier, i.e. pre Greenland Interstadial 8 phase of the Aurignacian.

Therefore, regarding Willendorf II, archaeological horizons 3 and 4, but not lithostratigraphic complex D, are considered here (Haesaerts et al., 1996, Haesaerts & Teyssandier, 2003, Nigst et al., 2014, Teyssandier & Zilhão, 2018).

This does not imply that we categorically reject considerably earlier dates for a Proto-Aurignacian, but we see no necessity to extend our discussion in this direction.

The ages presented for Krems-Hundssteig are not sensu stricto connected to stratified Aurignacian artefacts but rather represent dates from stratigraphically plausible positions at a site with evidenced Aurignacian industry (Hahn, 1977, Neugebauer-Maresch, 2008, Händel, 2017). The other radiocarbon-dated Aurignacian open-air sites in northeast Austria, namely Großweikersdorf, Stratzing/Krems-Rehberg, and Alberndorf, postdate the Vienna-Nussdorf horse. Sample ETH-6026 from Stratzing/Krems-Rehberg is included in the model although it derives from layer 3 since the age it provides clearly falls within the Aurignacian range.

Whereas Stratzing/Krems-Rehberg and Großweikersdorf overlap with the younger Aurignacian strata of Willendorf II and Krems-Hundssteig and represent well-dated contexts of the later regional Aurignacian, the majority of the (considerably younger) ages obtained for Alberndorf, provoked discussions regarding a prolonged duration of the regional Aurignacian. More recently produced dates, however, show chronological congruency with the later part of Stratzing/Krems-Rehberg's age range (Trnka, 2005, Jöris et al., 2010, Davies et al., 2015).

Radiocarbon ages are grouped by site (Fig. 15) and graphed with CalPal-Beyond the Ghost, Version 2016.2. The GICC05 timescale (Greenland Ice Core Chronology 2005, 15 - 42 ka; 20 yr δ 18O, http://www.iceandclimate.nbi.ku.dk; given in cal BP; as well as a version of the GICC05 timescale adapted to the Hulu data) was added to the multiple group graph to reference climate data (Andersen et al., 2006, Svensson et al., 2008). Assuming a temporal succession from the Aurignacian to the Gravettian, we must at least reject all ages postdating Greenland Interstadial GI-6 as too young when taking the well-dated, stratigraphically controlled, as well as artefact- and finding-supported Early Gravettian sequence of the Krems sites into account (Händel, 2017).

A third model (Fig. 16) considers only ages produced for horse remains. As there are currently only four directly radiocarbon-dated horse specimens for Austria in the time span of interest (namely from Krems-Hundssteig, Stratzing/Krems-Rehberg, Senftenberg, and of course the Vienna-Nussdorf specimen presented here), the model also includes ages produced for horses from Germany (Hohle Fels, Geissenklösterle and Vogelherd). Two dates from Germany were excluded from the model but are listed in Table 2: OxA-4595 produced on a femur provided a very early date, and OxA-8511 produced on a pelvis from Breitenbach B (too young, possibly due to poorly understood diagenesis).

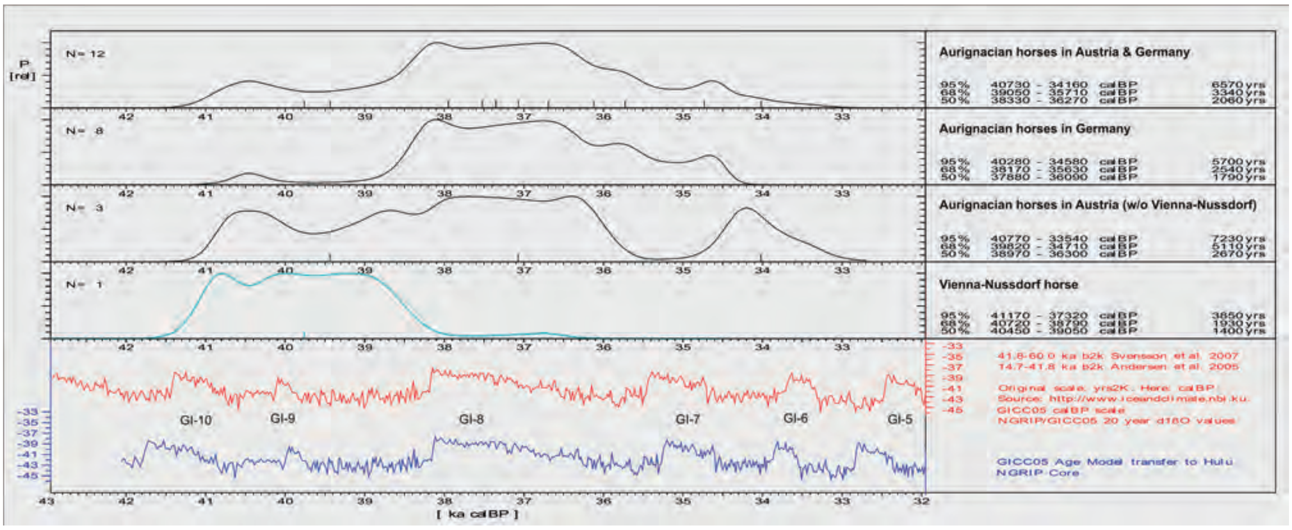

Fig. 16: Multigroup graph with sum plots of probability distributions of calibrated 14C dates (calBP) of Aurignacian horses of Austria and Germany (exceptions see text) produced with CalPal-Beyond the Ghost, Version 2016.2, http://monrepos-rgzm.de/forschung/ausstattung.html#calpal (Weninger & Jöris, 2008). Beneath, the GICC05 timescale (Greenland Ice Core Chronology 2005, 15 - 42 ka; 20 yr δ 18O, http://www.iceandclimate.nbi.ku.dk, as well as a version of the GICC05 timescale adapted to the Hulu data) is provided as climate reference.

It should also be noted that two potential horse specimens from Alberndorf are not considered in Figure 16 (but listed in Table 2). For both, species determination seems uncertain (Jöris et al., 2010). The sample with lab code VRI-1373 only provided a minimal age while sample ETH-13041 produced an

age that is clearly too young (see discussion on Alberndorf above).
Noticeably, in this group, the Vienna-Nussdorf specimen provided – together with the horse from Senftenberg – the earliest dates. Chrono-stratigraphically, these fall into the range of GI-10 to GI-9, and include GS-9 (Andersen et al., 2006). Referring to the refined INTIMATE event stratigraphy by Rasmussen et al. (2014), the 41,700-37,800 cal BP (CalPal-2007-Hulu) range given for the Vienna-Nussdorf specimen starts with the onset of GI-10 and ends before the start of GI-8b. Focussing on the 68.2% confidence interval (40,700-39,000 cal BP) reduces the range to between the start of GS-10 and the end of GS-9. Transition from GS-10 to GI-9 is considered atypical because the onset of GI-9 is more gradual than in neighbouring transitions. This could indicate that GI-9 and GI-10 can be considered parts of the same interstadial period (Rasmussen et al., 2014). In any case is the more distinct GS-9 – parallelized with Heinrich event 4 – included in the range so that placement of the Vienna-Nussdorf horse both in an interstadial and in a pronounced stadial context remains within the bounds of possibility.

7. Conclusive remarks

Clearly human-made incision marks on a horse metacarpal provide the first definite, unambiguous evidence for the presence of (anatomically modern) humans on the territory of present-day Vienna in the Early Upper Palaeolithic. ^{14}C-dating established a time range (68%) between 40,650 – 38,850 cal BP (CalPal) resp. 39,800 – 38,500 cal BP (OxCal) for which the presence of AMH is extensively attested for in the wider region, and which postdates any evidenced regional Neanderthal occurrence. From a geographic perspective, the presence of hunter-gatherer groups in this area was not unexpected due to the physiographic characteristics in the surroundings of the Vienna Gate and its location in the so-called Danube corridor. The results of this study securely establish such presence for the first time. When compared to the earliest dates claimed for the Upper Palaeolithic resp. AMH presence along the Danube, it seems, that the occupation represented by the Vienna-Nussdorf horse does not belong to this very earliest presence, but attests for a time very soon thereafter.

8. Acknowledgements

Marjolein Nigst-Bosch (University of Cambridge, McDonald Institute for Archaeological Research), Walpurga Antl-Weiser and Karina Grömer (Natural History Museum Vienna, Department of Prehistory) helped in using the Dino-Lite USB Mantis Elite eyepieceless stereo microscope for photography. Thanks to Erich Pucher (Natural History Museum Vienna) for especially the discussion of the cut marks and to Erich Draganits (University of Vienna, Department of Geodynamics and Sedimentology) for supporting the database and GIS work. Günther Karl Kunst (Vienna Institute for Archaeological Science) provided important references. Martin Penz (Stadtarchäologie Wien) gave support, Michael Brandl (OREA) helped with the translation and Leyla Seyfullah with the correction.

Lab-Nr	14C age	14C STD	Material	Species	Site	Techno-culture	Remark	cal BC	S p(68%)	cal BP p(95%)	Reference
VRI-1272	20500	1400	antler	reindeer	Alberndorf	Final Aurignacian?		22750	1740	28180 - 21220	Trnka 2005
VRI-1374	26900	1600	bone	mammoth	Alberndorf	Final Aurignacian?	long bone (compacta)	29580	1470	34470 - 28590	Trnka 2005
VRI-1536	25350	450	bone	mammoth	Alberndorf	Final Aurignacian?	Ulna	28390	450	31240 - 29440	Trnka 2005
VRI-1537	26100	500	bone	mammoth	Alberndorf	Final Aurignacian?	Tibia (same sample as VERA-0006)	28990	490	31920 - 29960	Trnka 2005
ETH-13040	25400	260	bone	reindeer?	Alberndorf	Final Aurignacian?	rib	28320	270	30810 - 29730	Trnka 2005
VERA-0006	28250	250	bone	mammoth	Alberndorf	Final Aurignacian?	Tibia (same sample as VRI-1537)	30740	320	33330 - 32050	Trnka 2005
GrA-5223	27140	650	charcoal	nd	Alberndorf	Final Aurignacian?		29850	580	32960 - 30640	Trnka 2005
GrA-5224	28360	760	charcoal	nd	Alberndorf	Final Aurignacian?		30980	690	34310 - 31550	Trnka 2005
GrA-5241	28490	780	charcoal	nd	Alberndorf	Final Aurignacian?		31060	710	34430 - 31590	Trnka 2005
GrA-5242	27080	650	charcoal	nd	Alberndorf	Final Aurignacian?		29770	590	32900 - 30540	Trnka 2005
OxA-X-2191-43	30600	1300	bone	reindeer	Alberndorf	Final Aurignacian?	reindeer antler "handle"	33060	1340	37690 - 32330	Davies et al. 2015
OxA-18523	28950	400	bone	reindeer	Alberndorf	Final Aurignacian?	reindeer antler "handle"	31450	450	34300 - 32500	Davies et al. 2015
OxA-X-2199-15	27940	390	bone	reindeer	Alberndorf	Final Aurignacian?	reindeer longbone fragment (modified?)	30540	380	33250 -31730	*W. Davies*
GrN-16263	32770	240	charcoal	nd	Grossweikersdorf	Aurignacian?	lower layer	35170	760	38640 -35600	Neugebauer-Maresch 1993
GrN-16244	31630	240	charcoal	nd	Grossweikersdorf	Aurignacian?	upper layer	33530	330	36140 -34820	Neugebauer-Maresch 1993
VERA-1616	30750	290	charcoal	nd	Krems-Hundssteig	Aurignacian?	HU2000-2002, ID 9003	32910	320	35500 - 34220	Neugebauer-Maresch 2008
VERA-2289	32810	450	charcoal	nd	Krems-Hundssteig	Aurignacian?	HU2000-2002, ID 232001	35210	850	38860 - 35460	Neugebauer-Maresch 2008
KN-654	35500	2000	charcoal	nd	Krems-Hundssteig	Aurignacian?	HU1895-1904	37580	2150	43830 - 35230	Hahn 1977
GrN-16887	36350	600	charcoal	nd	Senftenberg	Aurignacian		39510	490	42440 - 40480	Djindjian et al. 1999
ETH-6023	29950	370	charcoal	nd	Stratzing/Krems-Rehberg	Aurignacian	layer 2	32250	300	34800 - 33600	Neugebauer-Maresch 1996
ETH-6024	31450	440	charcoal	nd	Stratzing/Krems-Rehberg	Aurignacian	layer 2	33410	450	36260 - 34460	Neugebauer-Maresch 1996
ETH-6025	31230	430	charcoal	nd	Stratzing/Krems-Rehberg	Aurignacian	layer 2	33250	420	36040 -34360	Neugebauer-Maresch 1996
ETH-6026	32640	330	charcoal	nd	Stratzing/Krems-Rehberg	Aurignacian	layer 3	35070	810	38640 - 35400	Neugebauer-Maresch 1996
GrN-15641	30670	600	charcoal	nd	Stratzing/Krems-Rehberg	Aurignacian	layer 2 (moved)	32900	500	35850 - 33850	Neugebauer-Maresch 1996
GrN-15642	31190	390	charcoal	nd	Stratzing/Krems-Rehberg	Aurignacian	layer 2 (moved)	33220	390	35950 - 34390	Neugebauer-Maresch 1996
GrN-15643	29200	1100	charcoal	nd	Stratzing/Krems-Rehberg	Aurignacian	layer 2 (moved)	31530	920	35320 - 31640	Neugebauer-Maresch 1996
GrN-16135	31790	280	charcoal	nd	Stratzing/Krems-Rehberg	Aurignacian	layer 2	33690	350	36340 - 34940	Neugebauer-Maresch 1996
KN-3941	28400	700	charcoal	nd	Stratzing/Krems-Rehberg	Aurignacian	layer 2 (moved)	31000	660	34270 - 31630	Neugebauer-Maresch 1996
KN-3942	29900	600	charcoal	nd	Stratzing/Krems-Rehberg	Aurignacian	layer 2 (moved)	32140	520	35130 - 33050	Neugebauer-Maresch 1996
KN-4140	29260	460	charcoal	nd	Stratzing/Krems-Rehberg	Aurignacian	layer 1 (moved)	31670	450	34520 - 32720	Neugebauer-Maresch 1996
KN-4141	28210	500	charcoal	nd	Stratzing/Krems-Rehberg	Aurignacian	layer 1 (moved)	30800	500	33750 - 31750	Neugebauer-Maresch 1996
VERA 965	33285	440	charcoal	nd	Stratzing/Krems-Rehberg	Aurignacian	layer 1, G3	35650	950	39500 - 35700	Jöris et al. 2010
VERA 966	31200	300	charcoal	nd	Stratzing/Krems-Rehberg	Aurignacian	layer 2, G3	33210	350	35860 - 34460	Jöris et al. 2010
VERA 964	31210	340	charcoal	Pinus sp.	Stratzing/Krems-Rehberg	Aurignacian	layer 2, (partially moved) hearth F	33220	370	35910 - 34430	Jöris et al. 2010
VERA 963	32580	450	charcoal	Pinus sp.	Stratzing/Krems-Rehberg	Aurignacian	layer 2	35030	870	38720 - 35240	Jöris et al. 2010
VERA 961	32970	420	charcoal	Pinus sp.	Stratzing/Krems-Rehberg	Aurignacian	layer 2 (moved)	35330	830	38940 - 35620	Jöris et al. 2010
GrA-501	31210	260	charcoal	nd	Willendorf II	Aurignacian		33220	330	35830 - 34510	Damblon et al. 1996
GrA-896	37930	750	charcoal	Picea	Willendorf II	Aurignacian	layer C8-2 (sample ID A-166 a)	40430	490	43360 - 41400	Damblon et al. 1996
GrN-11192	34100	1200	charcoal	nd	Willendorf II	Aurignacian	layer C8-2 (sample ID PH 1990)	36820	1800	42370 - 35170	Damblon et al. 1996
GrN-1273	32060	250	charcoal	nd	Willendorf II	Aurignacian	AH 4	34150	490	37080 - 35120	Damblon et al. 1996
GrN-17805	38880	1530	charcoal	Picea	Willendorf II	Aurignacian	layer C8-2 (sample ID A-166 b)	41140	1050	45190 - 40990	Damblon et al. 1996
H-249-1276	31700	1800	charcoal	nd	Willendorf II	Aurignacian	AH 4	34620	2070	40710 - 32430	Damblon et al. 1996
GrA-35403	31250	230	charcoal	Picea/Larix	Willendorf II	Aurignacian	layer C4-1 (sample ID A-1905)	33240	320	35830 - 34550	Nigst et al. 2008
GrA-35404	31770	250	charcoal	Picea/Larix	Willendorf II	Aurignacian	layer C4-1 (sample ID A-1906)	33670	330	36280 - 34960	Nigst et al. 2008
GrA-35406	31170	230	charcoal	Picea/Larix	Willendorf II	Aurignacian	layer C4-2 (sample ID A-1912 a)	33190	310	35760 - 34520	Nigst et al. 2008
OxA-17396	32230	190	charcoal	Picea/Larix	Willendorf II	Aurignacian	layer C4-2 (sample ID A-1912 b)	34670	810	38240 - 35000	Nigst et al. 2014
GrA-45804	32360	210	charcoal	Pinus t. cembra	Willendorf II	Aurignacian	layer C4-2 (sample ID A-2421 a)	34840	840	38470 - 35110	Nigst et al. 2014
GrA-45011	32790	210	charcoal	Pinus t. cembra	Willendorf II	Aurignacian	layer C4-2 (sample ID A-2421 a)	35180	740	38610 - 35650	Nigst et al. 2014
OxA-22294	31750	260	charcoal	Pinus t. cembra	Willendorf II	Aurignacian	layer C4-2 (sample ID A-2421 b)	33640	340	36270 - 34910	Nigst et al. 2014
OxA-23562	33850	800	charcoal	Pinus t. cembra	Willendorf II	Aurignacian	layer C4-2 (sample ID A-2421 c)	36770	1660	42040 - 35400	Nigst et al. 2014
GrA-38250	34570	410	charcoal	Picea	Willendorf II	Aurignacian	layer C8-2 (sample ID A-2131)	37890	860	41560 - 38120	Nigst et al. 2014
GrA-35411	37320	390	charcoal	Picea	Willendorf II	Aurignacian	layer C8-2 (sample ID A-2039)	40110	340	42740 - 41380	Nigst et al. 2014
OxA-17397	37980	300	charcoal	Picea	Willendorf II	Aurignacian	layer C8-2 (sample ID A-1933)	40440	330	43050 - 41730	Nigst et al. 2014
GrA-44894	37420	300	charcoal	Picea/Larix	Willendorf II	Aurignacian	layer C8-2 (sample ID A-1935 a)	40160	330	42770 - 41450	Nigst et al. 2014
GrA-35409	37910	440	charcoal	Picea/Larix	Willendorf II	Aurignacian	layer C8-2 (sample ID A-1935 b)	40410	370	43100 - 41620	Nigst et al. 2014
OxA-22295	36500	450	charcoal	Picea/Larix	Willendorf II	Aurignacian	layer C8-2 (sample ID A-1935 c2)	39690	360	42360 - 40920	Nigst et al. 2014
GrA-45012	38790	400	charcoal	Picea/Larix	Willendorf II	Aurignacian	layer C8-2 (sample ID A-1935 c1)	40890	390	43620 - 42060	Nigst et al. 2014
OxA-23520	39000	500	charcoal	Picea/Larix	Willendorf II	Aurignacian	layer C8-2 (sample ID A-1935 c3)	41030	460	43900 - 42060	Nigst et al. 2014
VRI-1373	>16600		bone	horse?	Alberndorf	Final Aurignacian?	long bone				Trnka 2005
ETH-13041	23170	230	bone	horse?	Alberndorf	Final Aurignacian?	skull	26020	190	28350 - 27590	Trnka 2005
OxA-18527	32700	370	bone	horse	Krems-Hundssteig	Aurignacian	HU1895-1904, metapodial with spiral break	35120	810	38690 - 35450	*W. Davies*
VERA-3217	34080	500	tooth	horse	Senftenberg	Aurignacian	Molar (excavation Hampl 1949)	37490	1070	41580 - 37300	Hinterwallner 2007
OxA-18528	29800	500	bone	horse	Stratzing//Krems-Rehberg	Aurignacian	tibia diaphyseal fragment with helical break	32070	440	34900 - 33140	*W. Davies*
OxA-34405/P41690	**34550**	**600**	**bone**	**horse**	**Vienna-Nussdorf**	**Aurignacian?**	**Metacarpale III dext with cutmarks**	**37810**	**960**	**41680 - 37840**	
OxA-8511	27480	340	bone	horse	Breitenbach B	Aurignacian	pelvis	30170	270	32660 - 31580	Street & Terberger 2000
KIA-16035	33090	260	bone	horse	Hohle Fels	Aurignacian	femur	35400	770	38890 - 35810	Conard & Bolus 2003
KIA-16036	33290	270	bone	horse	Hohle Fels	Aurignacian	femur (retoucher)	35580	830	39190 - 35870	Conard & Bolus 2003
KIA-16040	30640	190	bone	horse	Hohle Fels	Aurignacian	pelvis (cutmarks and impact)	32780	240	35210 - 34250	Conard & Bolus 2003
KIA-8958	31870	260	bone	horse	Geissenklösterle	Aurignacian	humerus (impact)	33780	330	36390 - 35070	Bocquet-Appel & Demars 2000
OxA-4595	40200	1600	bone	horse	Geissenklösterle	EUP	femur	42090	1210	46460 - 41620	Conard & Bolus 2003
OxA-5707	33200	800	bone	horse	Geissenklösterle	Aurignacian	scapula (impact and cutmarks)	36000	1490	40930 - 34970	Conard & Bolus 2003
OxA-6369	31750	650	bone	horse	Geissenklösterle	Aurignacian		34170	1040	38200 - 34040	Stevens & Hedges 2004
KIA-8970	33080	320	bone	horse	Vogelherd	Aurignacian	long bone fragment (impact)	35400	790	38930 - 35770	Conard & Bolus 2003
PL0001339A	32180	960	bone	horse	Vogelherd	Aurignacian	tibia (cutmarks and green break)	34740	1300	39290 - 34090	Conard & Bolus 2003

Tab. 2: Radiocarbon data produced for Aurignacian contexts of open-air sites in northeast Austria, as well as data obtained for Aurignacian horses from Austrian and German sites. Calibrated ages are produced with CalPal-Beyond the Ghost, Version 2016.2, http://monrepos rgzm.de/forschung/ausstattung.html#calpal using the Calpal-2007-Hulu calibration curve (Weninger & Jöris, 2008), and given as cal BC p (68.2%) and cal BP with 2 Sigma ranges.

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