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^{14}C DATING OF THE UPPER PALEOLITHIC SITE AT KREMS-HUNDSSTEIG IN LOWER AUSTRIA

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ABSTRACT. The open-air archaeological site at Krems-Hundssteig is a well-known Upper Paleolithic site located in Lower Austria. The site was discovered in the late 19th/early 20th centuries when a large number of archaeological remains were collected during the course of loess quarrying. Although no systematic excavation has ever been performed, Krems-Hundssteig has been described since its discovery as typical of the Aurignacian period in this region based on the numerous archaeological finds; accordingly, the culture has been named *Kremsien* by some authors. Surprisingly, the artifacts found in a recent excavation adjacent to this location showed solely Gravettian features, calling into question the original assignment to the Aurignacian. Although the earlier assignment was supported by a radiocarbon date of ~35 kyr BP (Hahn 1977), new accelerator mass spectrometry (AMS) ^{14}C dates proved that the recently excavated cultural layer originates from the Gravettian period. Older paleosols were also detected by sondage drillings at some depth below it.

The new results indicate that a large Aurignacian level and a substantial complex of Gravettian layers are present in this area. Therefore, it must be assumed that more than 1 cultural level was affected and destroyed by the historic loess quarrying, and that the assemblage of Krems-Hundssteig artifacts, traditionally ascribed to the Aurignacian, might be interspersed with Gravettian pieces.

INTRODUCTION

Krems-Hundssteig is one of the numerous Paleolithic open-air sites in the loess region of Lower Austria (see Figure 1a), which have been well-known for a long time (Neugebauer-Maresch 1999). The site is located on a southward slope called Wachtberg, a promontory where the River Krems flows into the Danube (Figure 1b).

Rigorous loess quarrying was undertaken at this site between 1893 and 1904 for the embankment of the Danube. During this period, a large number of artifacts (~70,000 stone implements) and animal remains were discovered and collected for the local museum. In 1909, Strobl described the destruction of several cultural find spots and Obermaier attributed all archaeological artifacts to a single massive cultural layer (Strobl and Obermaier 1909). All subsequent articles and monographs (e.g. Broglio and Laplace 1966; Hahn 1977) referred to this paper, and as a result the findings from Krems-Hundssteig were interpreted as the remains of a single cultural phase. According to the numerous artifacts (i.e. various stone tools such as Dufour bladelets, Krems points, etc.) and perforated sea shells (Figure 2a), the site has been described as one of the representative sites of the Early Aurignacian ("Kremsien") in central Europe (see Hahn 1977; Teyssandier 2003). A radiocarbon age of 35,500 ± 2000 yr BP (KN-654) cited by Hahn (1977) supported this assumption. The only indication that younger cultural remains from the Gravettian period may be present at the Hundssteig area can be found in a small find complex of lithic artifacts supposedly collected together with human bones during excavation of a cellar in the narrow pass in the loess and published by Hahn (1972) and Jungwirth and Strouhal (1972). Later investigations showed that the human remains originate not from the Paleolithic but from the Middle Bronze Age, about 1500 BC (Trinkaus and Pettitt 2000).

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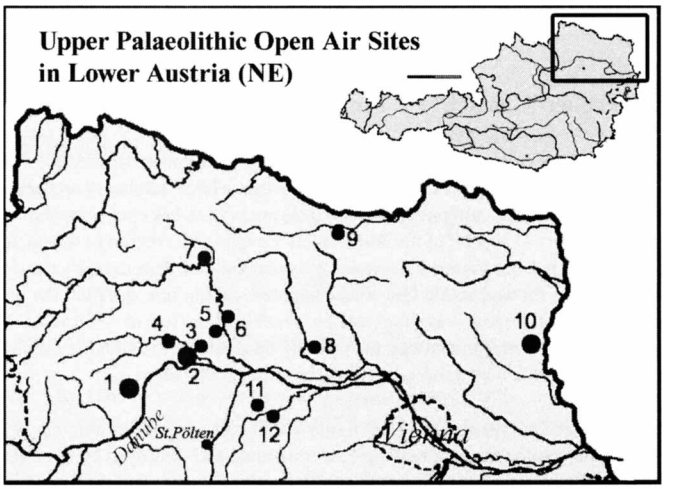

Selection of Upper Palaeolithic Open Air Sites in Lower Austria:
1- Willendorf/Wachau, 2-Krems-Hundssteig, Krems-Wachtberg,
3- Stratzing/Krems-Rehberg, 4- Senftenberg, 5- Langenlois,
6- Kammern-Grubgraben, 7- Rosenburg, 8- Großweikersdorf,
9- Alberndorf, 10- Stillfried-Wallanlage, Grub-Kranatwetberg,
11- Langmannersdorf/Perschling, 12- Saladorf/Perschling

Figure 1a Overview of the Upper Paleolithic open-air sites located in the loess region of Lower Austria. The Krems-Hundssteig site is indicated by #2 (graphic courtesy of the Prehistoric Commission of the Austrian Academy of Sciences [PK OEAW]).

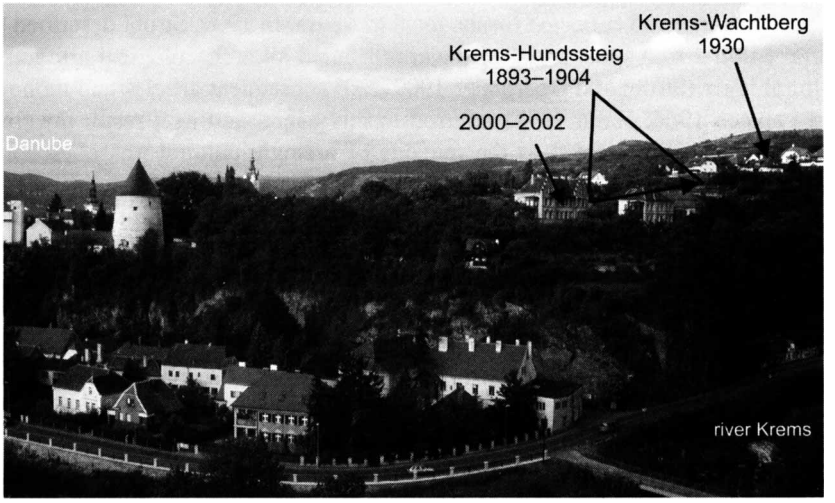

Figure 1b Panoramic view of Wachtberg with the archaeological sites of Krems-Hundssteig and Krems-Wachtberg indicated (photo courtesy of the Prehistoric Commission of the Austrian Academy of Sciences [PK OEAW]).

Recently, comparisons of the profiles described by Strobl and Obermaier (1909) with other contemporary descriptions of the various phases of the loess quarrying cast doubt on the single-layer theory and led to the suggestion that at least 2 layers must have been destroyed during the extensive mining period (Neugebauer-Maresch 2003). During the compilation of a new inventory of the archaeologi-

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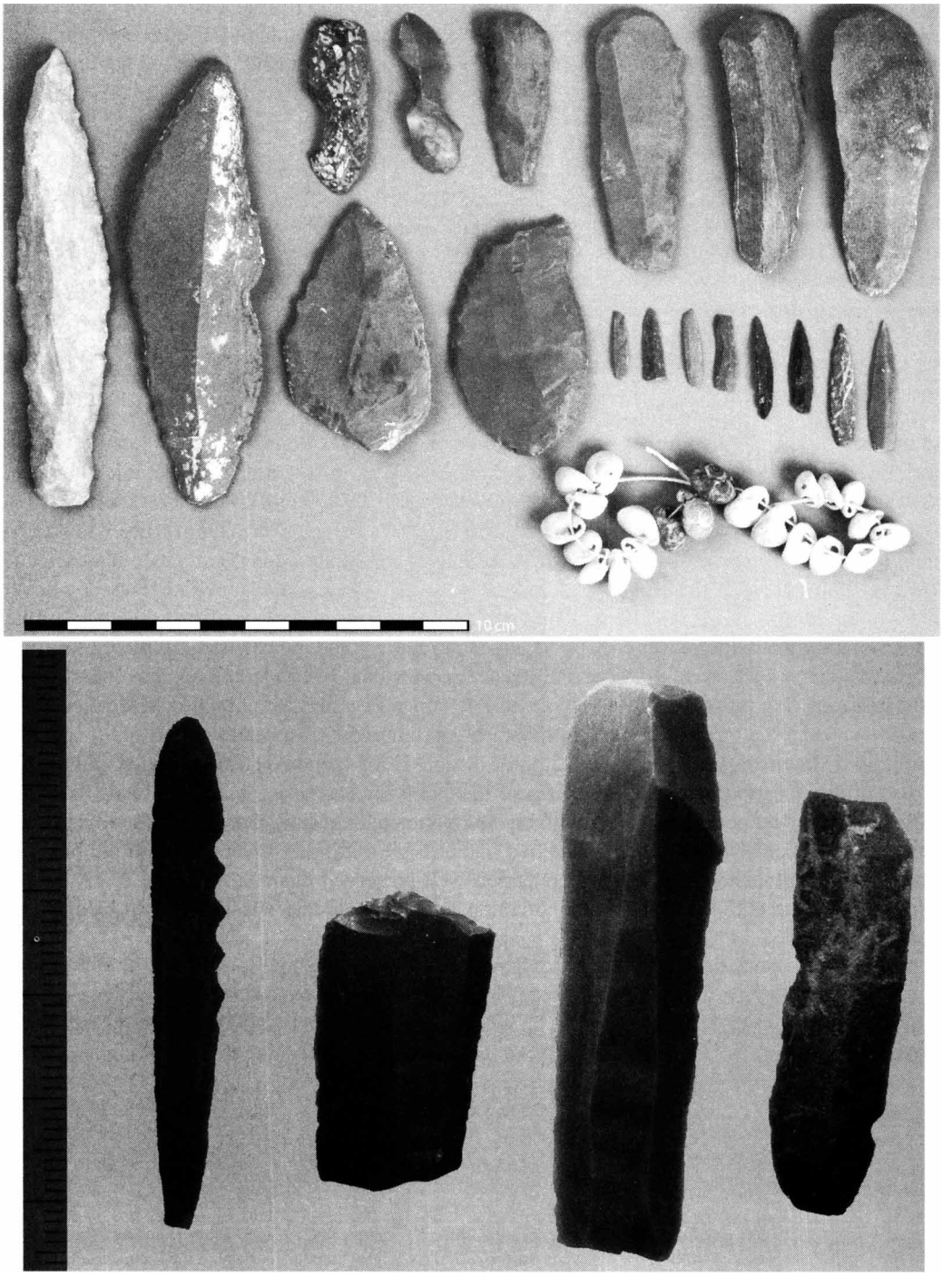

Figure 2 a) Artifacts and perforated shells with Aurignacian features collected during the loess mining period and stored at the Weinstadt Museum Krems, Lower Austria (photo courtesy A Schumacher). b) Gravettian stone artifacts (denticulated blade and scrapers) from the 2000–2002 excavation displayed alongside a centimeter scale (photo courtesy of the Prehistoric Commission of the Austrian Academy of Sciences [PK OEAW]).

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cal collection of the Weinstadt Museum Krems, a charcoal sample from the 1893–1904 Hundssteig assemblage without any stratigraphic information was taken for ^{14}C dating. Surprisingly, this sample yielded a ^{14}C age of 27,000 ± 150 yr BP (VERA-670), which further increased doubts about a single Aurignacian provenance and may be an indication that Gravettian cultural remains could also be present at the Hundssteig site.

RECENT EXCAVATIONS

In 1999, a large construction project was proposed directly adjacent to the south of the historical Krems-Hundssteig site, and hence new excavations were undertaken between 2000 and 2002. An initial test excavation in September 2000 exhibited a ~1.5-m-thick layer of cultural debris, which started—in agreement with the vertical run of the archaeological horizon described by Strobl and Obermaier (1909)—at the present-day street level. An initial ^{14}C date of 27,940 +220/–210 yr BP (VERA-1615) indicated that the truncated layer identified by Strobl and Obermaier (1909), and attributed by them to the Aurignacian, may be considerably younger than previously thought.

An area of 280 m^2 divided into 4 sub-areas was subsequently explored during 12 months of fieldwork (Figure 3). As expected from the test profile, these excavations uncovered the thick layer containing cultural debris. Systematic investigations showed that it originated from at least 2 distinct cultural periods (Gravettian and Aurignacian). Up to 8 archaeological horizons (AH 3,1 to AH 3,8) could be distinguished within the Gravettian complex (AH 3). In the horizon's identification code given in Tables 1 and 2, the second digit indicates the sub-areas 1 to 4 from east to west, e.g. subarea 1 in the case of AH 3,51. The sequence of the archaeological horizons (including the fireplace AH 3,51) is shown in the profile S-X41 displayed in Figure 4 and indicated in Figure 3. Indications of human activity such as cut marks and traces of fire were detected on faunal remains found in most of the horizons. The presence of both numerous anatomically connected animal skeleton parts (some of which showed the influence of large predators, e.g. bite marks, especially at AH 3,24) and a few briefly used fireplaces (AH 3,21; AH 3,22; AH 3,51; AH 3,54; and AH 3,64) provide evidence for the use of this location as a peripheral area of the camp for butchering hunted animals like mammoth, reindeer, wild horses, etc. Nearly all layers contained diagnostic Gravettian (Pavlovian) lithic artifacts, in particular a unique large toothed blade (Figure 2b) and several microlithic bladelets, some of them retouched. All hearths contained well-preserved charcoals (Figure 5). A detailed description of the entire archaeological situation at the Hundssteig site is given in Neugebauer-Maresch (2008).

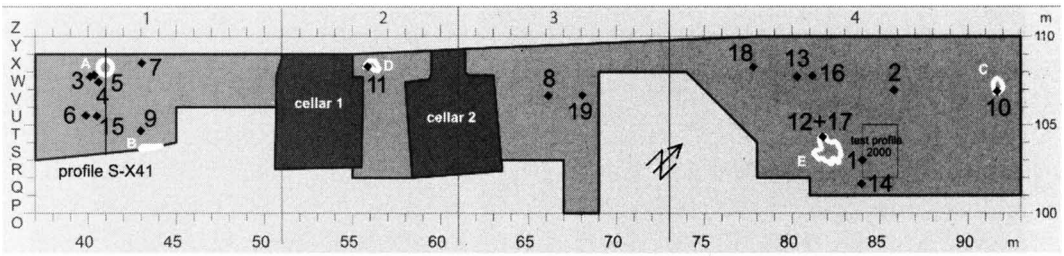

Figure 3 Excavation area (medium gray) with the location of the ^{14}C samples (#1–19, see Table 1) and hearths (A to D) and fire structure E indicated (axes show distances from an arbitrary origin; graphic courtesy of the Prehistoric Commission of the Austrian Academy of Sciences [PK OEAW]).

Test sondages and drillings up to ~3 m below the cultural package detected further paleosols at deeper levels in some areas within the excavation site. Due to the small excavation section, while some charcoal pieces could be recovered, archaeological artifacts rarely were (Figure 4).

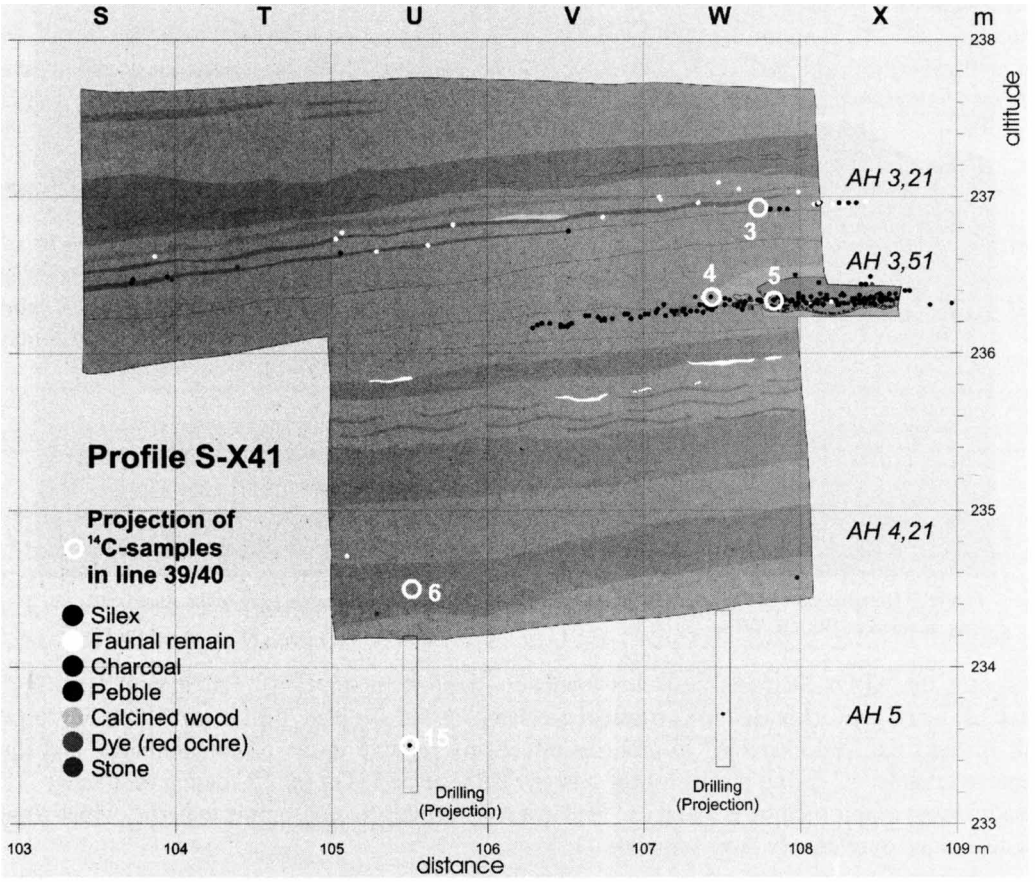

Figure 4 Profile of the site (coordinates S-X41) displaying the sediment stratigraphy AH 3,21 to AH 5,11; the hearth A; and the location of the ^{14}C samples (graphic courtesy of the Prehistoric Commission of the Austrian Academy of Sciences [PK OEAW]).

RADIOCARBON DATING

As described above, several apparently well-preserved charcoals have been found in the sediment during the recent excavations at Krems-Hundssteig (Figure 4). In order to verify the archaeological assessment of the cultural periods present in the profile, a total of 19 charcoal samples originating from hearths and other archaeological contexts in the cultural layers were accelerator mass spectrometry (AMS) ^{14}C dated at VERA.

The samples were pretreated with the standard ABA (acid-base-acid) method used at VERA. This method comprises a treatment with 1M HCl for 1 hr at 60 °C, followed by repeated treatments with 0.1M NaOH at 60 °C until the NaOH solution remains colorless, and a final 1M HCl step. Between each step of the chemical procedure, the samples were washed with bidistilled H_2O to near-neutral pH. Sample VERA-3283 completely dissolved during the NaOH step; therefore, the humic acids were precipitated by acidification of the alkaline solution and were used for dating. The pretreated samples were combusted as described in Wild et al. (1998), but with an extended combustion time of 6 hr. After combustion, the CO_2 of the samples was converted to solid graphite with the method adapted by Vogel et al. (1984) for the production of ^{14}C AMS targets. The ^{14}C determination of the sample targets was performed following the routine measurement protocol used for archaeological samples at VERA (Steier et al. 2004).

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Figure 5 Detailed view of the hearth A (photo courtesy of the Prehistoric Commission of the Austrian Academy of Sciences [PK OEAW]).

Recently, the ABOx-SC (acid-base–wet oxidation–stepped-combustion) pretreatment method for charcoal became of increased importance, especially for old samples. Bird et al. (1999) developed this method for "old charcoal" in order to effectively remove traces of contaminants, and thus achieve reliable ^{14}C dating results for the >40 kyr BP time period of the ^{14}C dating time range. The disadvantage of this method is that it can lead to a considerable loss of sample material, which limits the technique to relatively large samples.

Although the ABOx-SC method is mainly applied only to charcoals expected to yield ages >40 kyr BP, it was considered advisable in view of the discrepancies in the chronological assessment of the Hundssteig site to verify the ABA-treated dates in comparison to results obtained by the ABOx-SC method.

Therefore, 2 subsamples of the charcoals from the archaeological horizons AH 3,21 (sample #7; VERA-3280) and AH 3,54 (sample #10; VERA-3282) were dated at the Oxford Radiocarbon Accelerator Unit (ORAU) using both the ABOx-SC and the standard ABA pretreatments.

The standard ABA method at ORAU comprises treatment with 1M HCl for 20 min, followed by 0.2M NaOH for 20 min, and finally 1M HCl for a further 60 min. All treatments are carried out at 80 °C, and the sample is washed 3 times with ultrapure (MilliQ™) water between each step. The NaOH was replaced with fresh solution after 10 min for sample OxA-16031 due to the high levels of humics present.

The ABOx-SC method involves treating each sample with 6M HCl for 1 hr, followed by 1M NaOH for 30 min. As for the ABA treatment, the NaOH was replaced with fresh solution after 15 min for OxA-15988. The samples are washed 3 times with ultrapure water after each treatment, and then treated with 0.1M $K_2Cr_2O_7$ in 2M H_2SO_4 in a sealed tube at 60 °C for 20 hr. The samples were then precombusted at 630 °C for 2 hr in the presence of copper oxide wire. Prior to this precombustion, the loaded sample tubes were evacuated and sealed.

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Both ABA- and ABOx-SC-treated samples were then combusted at 1000 °C using a Europa Scientific ANCA-MS with a 20-20 IR mass spectrometer interfaced to a Roboprep CHN sample converter unit operating in continuous-flow mode with He carrier gas. CO_2 was collected and converted to graphite via reduction over an iron catalyst in an excess H_2 atmosphere at 560 °C prior to AMS ^{14}C measurement (Bronk Ramsey and Hedges 1999; Dee and Bronk Ramsey 2000).

RESULTS AND DISCUSSION

The uncalibrated ^{14}C ages and the $\delta^{13}C$ values determined at VERA for the charcoal samples from the Krems-Hundssteig site are given in Table 1, together with their location in the archaeological horizons of the sediment. Sample numbers refer to sample positions indicated in the map of the excavation area (Figure 3) and in the profile S-X41 displayed in Figure 4.

Table 1 ^{14}C data determined for charcoal samples excavated between 2000 and 2002 and 1 result from an "historic" sample stored in the museum of Krems.

Lab # (VERA-)	Archaeo. horizon[a]	Sample origin	Sample nr[b] in excavation area map	$\delta^{13}C$[c,d] (‰)	^{14}C age[c] (BP)
2291	AH 3,21	Cultural layer	**3**	–26.9 ± 0.7	27,200 + 240/–230
3280	AH 3,21	Charred wood	7	–23.4 ± 1.3	27,640 ± 260
3281	AH 3,21	Hearth B	9	–23.0 ± 0.6	27,970 + 270/–260
3279	AH 3,22	Hearth D	11	–21.6 ± 1.5	27,800 ± 250
1615	AH 3,24	Cultural layer	2	–20.1 ± 1.7	27,940 + 220/–210
3513	AH 3,43	Charred wood	8	–28.1 ± 2.4	27,860 + 270/–260
3514	AH 3,44	Area with charcoal chunks	13	–22.8 ± 1.0	28,070 ± 240
3515	AH 3,44	Area with charcoal chunks	14	–27.7 ± 1.0	27,630 ± 230
2292	AH 3,51	Hearth A	**4**	–22.9 ± 0.6	28,780 + 270/–260
2293	AH 3,51	Hearth A	**5**	–26.2 ± 0.5	28,550 + 250/–240
3282	AH 3,54	Hearth C	10	–20.1 ± 0.9	28,250 + 280/–270
3283	AH 3,64	Fire structure E (destroyed hearth?)	12	–24.9 ± 0.6	28,360 + 280/–270
3912	AH 3,64	Fire structure E	17	–23.3 ± 0.8	28,110 + 270/–260
3944	AH 3,73	Charcoal piece in chalk layer	19	–23.2 ± 0.6	27,900 ± 230
3910	AH 3,74	Area with charcoal chunks	16	–21.9 ± 0.9	27,820 + 270/–260
3943	AH 3,74	Area with charcoal chunks	18	–23.7 ± 0.7	27,790 + 250/–240
1616	AH 4,14	Sondage	1	–20.8 ± 1.6	30,750 + 290/–280
2289	AH 4,21	Sondage	**6**	–26.7 ± 0.7	32,810 + 450/–430
3516	AH 5,11	Sondage drilling	**15**	–29.5 ± 1.8	41,000 + 1300/–1100
670	unknown	Unknown	charcoal museum Krems	24.4 ± 1.0	27,000 ± 150

[a]The first number after the comma indicates the horizon within the archaeological complex; the second number after the comma indicates the sub-area (1 to 4 from west to east).

[b]Sample numbers in bold indicate samples with positions shown in the profile in Figure 4.

[c]1-σ uncertainty.

[d]Determined by the AMS system.

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Although calibration curves for the time period >26 kyr BP have been created from individual terrestrial and marine archives, an internationally agreed calibration curve beyond IntCal04 has not yet been established (see e.g. Bard et al. 2004; van der Plicht et al. 2004; Balter 2006). Therefore, all ^{14}C data given and discussed here are uncalibrated dates. This means that after a proper calibration the time difference between the individual archaeological horizons within the cultural layer package as well as the time gap to the deeper paleosols may change considerably.

Table 2 lists the results of the interlaboratory cross-check between VERA and ORAU for the individual pretreatment methods. It is obvious that the data determined for the ABOx-SC-treated samples at ORAU agree very well with the corresponding results of the ABA-treated material at VERA. Thus, the interlaboratory cross-check confirms that the ABA sample pretreatment method selected at VERA for the preparation of the Hundssteig charcoals yields reliable dating results. For sample #7 from the archaeological horizon AH 3,21, an agreement of the ABA and the ABOx-SC method was found at the ORAU laboratory, whereas for sample #10, originating from hearth C in the archaeological horizon AH 3,54, a divergence between the ABOx-SC and the ABA result was found at ORAU, with the younger age yielded by the ABA-treated sample. This charcoal sample appeared rich in humic acids, and the younger ABA result may be explained by the incomplete removal of the humic acids from the sample during the NaOH step.

Table 2 Comparison of the pretreatment methods used at VERA and ORAU (lab code OxA-).

Lab #	Pretreatment method	^{14}C age[a] (BP)
Charcoal from hearth C, AH 3,54 (sample #10)		
VERA-3282	ABA	28,250 + 280/–270
OxA-16031	ABA	27,290 ± 160
OxA-15988	ABOx-SC	28,160 ± 150
Charred wood, AH 3,21 (sample #7)		
VERA-3280	ABA	27,640 ± 260
OxA-16029	ABA	27,360 ± 150
OxA-16030	ABOx-SC	27,590 ± 170

[a] 1-σ uncertainty.

All 16 samples originating from different horizons of the massive cultural layer complex (AH 3) yielded ^{14}C ages between ~27 and ~29 kyr BP. Charcoals sampled from the archaeological horizons AH 4,14 and AH 4,21—which are separated from the cultural layer package (AH 3) by sterile loess and are at a horizontal distance of 45 m apart from each other in the excavation area—were dated to ~31 kyr BP (east) and ~33 kyr BP (west). Another sample with a significantly older age of ~41 kyr BP originates from a core of a sondage drilling at a position of ~2 m (AH 5) below AH 3 (Figure 4).

The ^{14}C results support the archaeological evidence that the recently excavated massive cultural layer package (AH 3) at Krems-Hundssteig has to be attributed to the Gravettian. No large differences between the ^{14}C ages for samples originating from the different archaeological horizons in the cultural layer package (AH 3, see Table 1 and Figure 4) are evident. However, the scatter of the data is larger than allowed for the acceptance of the null hypothesis (H_0) that all samples from this cultural layer complex are coeval within the limits of error ($\chi^2 = 33.38$; limit for a 5% significance at 15 degrees of freedom: $\chi^2 = 25$). This may be explained either by an additional uncertainty component in the ^{14}C measurement of ±280 yr (added quadratically to the individual 1-σ values), which is not accounted for in Table 1. Alternatively, the samples are indeed not exactly coeval, but distributed over

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a ^{14}C age range of about ±280 yr. However, since we have demonstrated the validity of our uncertainty estimates in several international intercomparison exercises (Scott 2003), we favor the latter assumption. Ignoring the unlikely possibility of a large "plateau" in the (as yet unavailable for this time range) ^{14}C calibration curve, our ^{14}C results indicate that the cultural layer package was deposited in a relatively short time period. This assumption is corroborated by the results of investigations that showed that the sedimentation rate at this site was very high. The in situ position and excellent preservation of charcoal chunks in the hearths, especially in hearth A (AH 3,51; Figure 5), was enabled by rapid sedimentation conditions. Also, paleontological investigations show that several faunal remains were found in anatomically correct positions and without gnawing marks. This is also interpreted as evidence for a rapid embedding of the animal remains in the loess sediment.

The older ages of charcoals from the layers AH 4 and AH 5 (Table 1, Figure 4) indicate that older paleosols are situated at deeper positions in the stratigraphy. It can be speculated that these deeper layers may correspond to the adjacent area in the north, which was described by Strobl and Obermaier (1909). According to the historic description, the area with the highest density of Aurignacian findings was located approximately 50 m uphill from the recent excavation site.

CONCLUSION

The present study strongly contradicts the traditional assignment of the Krems-Hundssteig findings solely to the Aurignacian. Recent systematic excavations indicate that more than 1 cultural layer package has been affected by the rigorous loess quarrying that occurred around 1900. Therefore, it can be assumed that the Aurignacian assemblage of artifacts that was collected then (not via systematic excavations) might be interspersed with younger material. Our results justify the doubts regarding the single-layer theory of Strobl and Obermaier (1909). Moreover, the data seem to suggest that the site was frequently used by hunter-gatherer populations from at least ~33 to ~27 kyr BP. The question whether the site was used before this time period, which might be suggested by the ^{14}C age of ~41 kyr BP, must be left open. This age was determined for a charcoal sample originating from AH 5,11 in a sondage drilling, where no anthropogenic evidence could be detected. It should be noted that these dates may change considerably once a definite calibration curve has been established (e.g. Bard et al. 2004).

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