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Radiocarbon dating the late Middle Paleolithic and the Aurignacian of the Swabian Jura

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A B S T R A C T

Many lines of evidence point to the period between roughly 40 and 30 ka BP as the period in which modern humans arrived in Europe and displaced the indigenous Neandertal populations. At the same time, many innovations associated with the Upper Paleolithic – including new stone and organic technologies, use of personal ornaments, figurative art, and musical instruments – are first documented in the European archaeological record. Dating the events of this period is challenging for several reasons. In the period about six to seven radiocarbon half-lives ago, variable preservation, pre-treatment, and sample preparation can easily lead to a lack of reproducibility between samples and laboratories. A range of biological, cultural, and geological processes can lead to mixing of archaeological strata and their contents. Additionally, some data sets point to this period as a time of significant spikes in levels of atmospheric radiocarbon. This paper assesses these questions in the context of the well-excavated and intensively studied caves of Geißenklösterle and Hohle Fels in the Swabian Jura of southwestern Germany. We conclude that variable atmospheric radiocarbon production contributes to the problems of dating the late Middle Paleolithic and the early Upper Paleolithic. To help establish a reliable chronology for the Swabian Aurignacian, we are beginning to focus our dating program on short-lived, stratigraphically secure features to see if they yield reproducible results. This approach may help to test competing explanations for the noisy and often non-reproducible results that arise when trying to date the transition from the Middle to the Upper Paleolithic.

Introduction

Many studies of the terminal Middle Paleolithic and early Upper Paleolithic point to variable radiocarbon signals and periods of excess atmospheric radiocarbon. Factors affecting levels of atmospheric radiocarbon include variations in cosmic ray flux as a result of changes in the geomagnetic field, variable production via solar neutrons, and changing patterns of oceanic circulation, among others. Models for cosmogenic isotopic production and carbon exchange between the ocean and atmosphere indicate that changes in radiocarbon levels should not exceed a maximum of about 50% of a half-life, or roughly 3,000 years (Hughen et al., 2004, 2006; Fairbanks et al., 2005).

Recent work has produced data that suggest that these models may be incorrect, and that unusually high levels of radiocarbon production could perhaps lead to ages that are more than one half-life too young (Voelker et al., 2000; Beck et al., 2001; Conard and Bolus, 2003; Giaccio et al., 2006; Nadeau et al., 2006). Giaccio et al.'s data (2006) from sediment core CT85-5 in the Mediterranean Sea suggest that the Laschamp magnetic event may have led to a production peak as great as 15,000 years in foraminifera. If these data are correct, a disjunction currently exists between empirical data and models for the production and transport of radiocarbon. Regardless of where the source of this problem lies, researchers must solve it before it will be possible to establish reliable dates for the beginnings of the Upper Paleolithic, the arrival of modern humans in Europe, and the extinction of Neandertals. Such production peaks could make dates for late Neandertals appear younger than they are and create a "Coexistence Effect" with modern humans, thus making the apparent temporal overlap of both taxa greater than it actually was (Conard and Bolus, 2003).

The amplitudes of late Pleistocene production peaks remain highly controversial. The peaks in the speleothem data from the Bahamas have been reduced by new models for accounting for dead carbon and by using smoothing functions to reduce the amplitude of peaks and bring them in line with data from the Cariaco Basin and other marine archives (Hughen et al., 2006; Richards et al., 2006). The irregularities in the North Atlantic data of Voelker et al. (2000) have been largely dismissed as a result of stochastic noise inherent in measurements near the limits of the radiocarbon

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method. Giaccio et al.'s (2006) data from the Mediterranean are generally considered impossible, based on known production models, and still earlier peaks seen in data from the North Atlantic (Nadeau et al., 2006) are viewed as speculative since they lie beyond the limits of routine high precision measurements. Many archaeological data including those from the caves of the Swabian Jura (Conard and Bolus, 2003; Conard et al., 2003a) suggesting major production peaks have been discarded as being the result of taphonomic disturbances (Zilhão and d'Errico, 2003).

A preliminary consensus suggests that the radiocarbon variations in the Cariaco data may reflect the best available approximation of past levels of atmospheric radiocarbon (Hughen et al., 2004, 2006; Fairbanks et al., 2005). Records including speleothems from Socota Island off the coast of southern Arabia (Weyhenmeyer et al., 2003) and varves from Lake Suigetsu in Japan (Kitagawa and van der Plicht, 2000) document fluctuations in atmospheric radiocarbon that are more or less consistent with the Cariaco record (van der Plicht et al., 2004). Even these relatively constant records of atmospheric radiocarbon suggest excess radiocarbon equivalent to nearly one half-life in the crucial period between 30 and 40 ka and raise questions about existing models and data for atmospheric radiocarbon.

If researchers are to clarify the chronology of major events in human evolution, such as the beginning of the Upper Paleolithic and the displacement of Neandertals by modern humans, these issues related to past levels of atmospheric radiocarbon need to be clarified. In addition to the problems related to variations in levels of atmospheric radiocarbon, recent studies show that radiocarbon dates vary according to which methods of sample preparation are used (Jacobi et al., 2006; Brock et al., 2007; Hüls et al., 2007). There is an urgent need to determine which methods of sample preparation provide reliable results.

While a range of diverse geological archives provided relatively continuous records needed for such studies, the archaeological record is the only source of information on the timing and patterns of human evolution. Thus, archaeologists and paleoanthropologists must invest more time and energy in solving these problems on a case by case basis in connection with new fieldwork and new dating programs. This paper reports on the current dating program under way in the caves of the Swabian Jura and points to progress and continuing pitfalls that hamper research.

Data from the Ach Valley

Ongoing excavations in the caves of the Swabian Jura (Fig. 1) have provided a wealth of new information on the late Middle Paleolithic and the early Upper Paleolithic (see Conard and Bolus, 2006 and references therein). The Swabian Upper Paleolithic begins abruptly with the Aurignacian (Conard et al., 2006), which at Geißenklösterle is dated to ca. 40 ka BP using the thermoluminescence (TL) signal of burnt chert (Richter et al., 2000). The radiocarbon signature for the Aurignacian ranges between 40 and 29 ka ^{14}C BP with most dates falling between 30 and 35 ka ^{14}C BP (Conard and Bolus, 2003, 2006). Here we present all of the available dates for the Swabian Aurignacian and focus on the sites of Geißenklösterle and Hohle Fels in the Ach Valley, where recent excavations and a series of 35 new dates from the Aurignacian and Middle Paleolithic strata (Fig. 2) are helping to provide better chronological resolution for the archaeology of these periods. The dates for Geißenklösterle and Hohle Fels (Tables 1 and 2) are given with details on collagen yields in percent where available, while the dates for the other Ach Valley sites (Table 3) and the Lone Valley sites (Table 4), which are not the focus of the present paper and have mostly been published previously, are given for comparison. As we will see, this research is often at the limit of reliable application of the radiocarbon method. Thus, we are increasingly focusing our attention on specific short-lived features within a known stratigraphic sequence to try, step by step, to establish chronostratigraphic control of the late Middle Paleolithic and Aurignacian deposits.

Geißenklösterle

The last major report on radiocarbon dates from Geißenklösterle documented a noisy signal for the upper and lower Aurignacian deposits of Archaeological Horizon (AH) II and III with ages ranging between 29 and 40 ka ^{14}C BP (Conard and Bolus, 2003). The same report indicated that the stratigraphically deeper dates from beneath the lower Aurignacian provide ages between 32 and 34 ka ^{14}C BP, which were nearly 10,000 years younger than the ages expected on the basis of stratigraphic arguments and electron spin resonance (ESR) dates published by Richter et al. (2000). Since

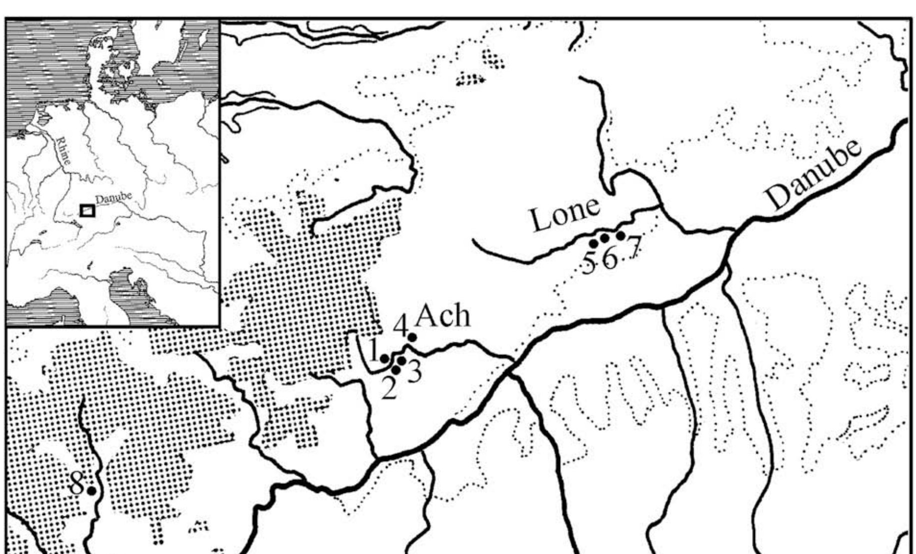

Fig. 1. Map of southwestern Germany with the principal Aurignacian sites. Ach Valley: 1 = Sirgenstein, 2 = Hohle Fels, 3 = Geißenklösterle, 4 = Brillenhöhle; Lone Valley: 5 = Bocksteinhöhle and Bockstein-Törle, 6 = Hohlenstein-Stadel and Hohlenstein-Bärenhöhle, 7 = Vogelherd; Lauchert Valley: 8 = Göpfelsteinhöhle. After Conard and Bolus (2006).

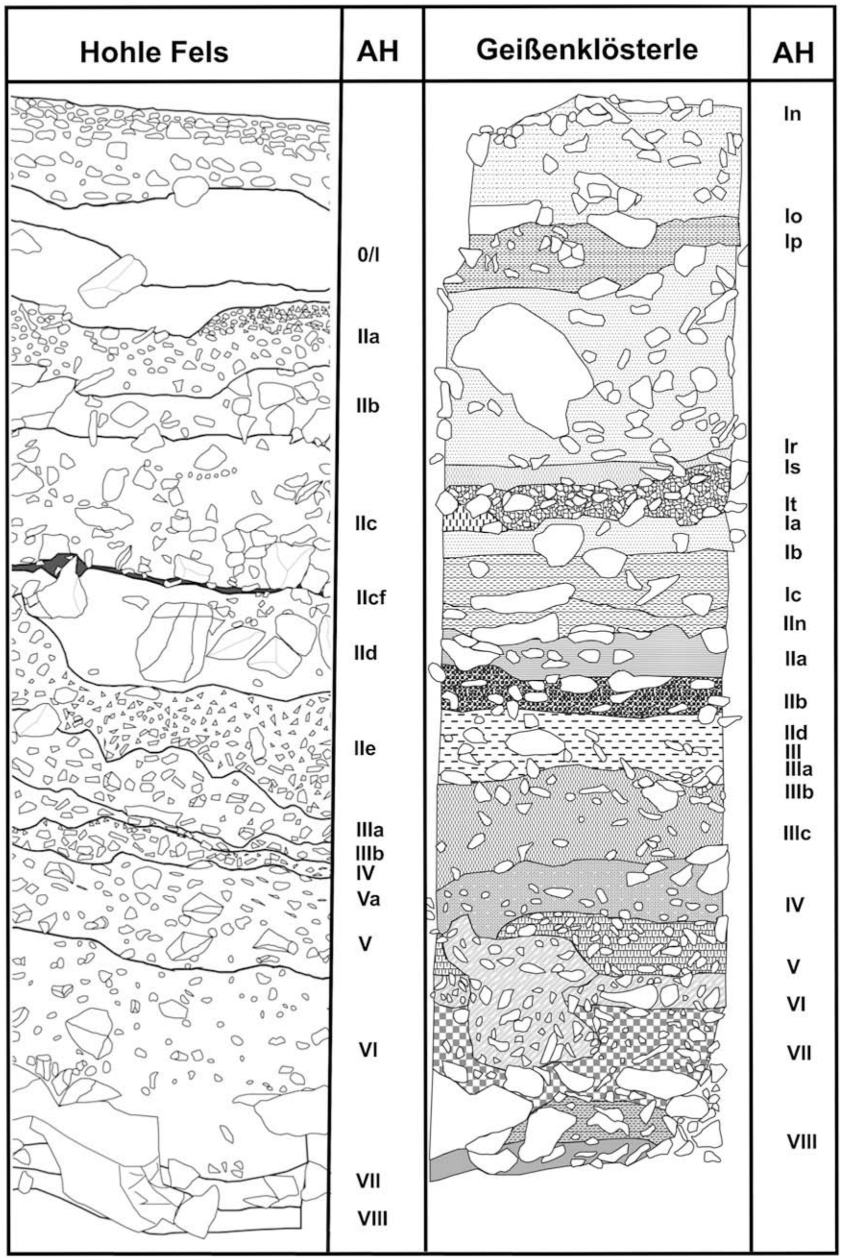

Fig. 2. Schematic stratigraphic profiles of Hohle Fels and Geißenklösterle indicating the locations of the Archaeological Horizons (AH).

micromorphological analysis by P. Goldberg, refitting studies, and other contextual data indicated that the deposits were not significantly mixed, we concluded that the most plausible explanation for these young ages was the presence of excess atmospheric radiocarbon (Conard, 2002; Conard and Bolus, 2003; Conard et al., 2003a). As we have argued and Zilhão and d'Errico (1999, 2003, 2004) have repeatedly stated, a degree of taphonomic mixing due to cultural, biological, and abiotic processes is likely. These taphonomic processes, however, while no doubt important, do not seem to be the main causes of the variable radiocarbon signal from Geißenklösterle.

The new dates from Geißenklösterle reinforce our arguments published in 2002 and 2003 (Fig. 3; Table 1). Additional dates from the lower Aurignacian of AH III tend to fall between 33 and 37 ka ^{14}C BP, while the 11 new dates for the underlying largely sterile layer Geological Horizon (GH) 17 (AH IIIc) and Middle Paleolithic horizons IV, VI, VII, and VIII fall between 31 and 42 ka ^{14}C BP. Again one observes that the age of the deposits does not necessarily increase with depth. If we assume that the dates, which were all made on well-preserved bones with high collagen yields at the Leibniz Laboratory in Kiel are reliable, there appears to be a structure to these data with no fewer than two major pulses of excess radiocarbon documented in the layers underlying the Aurignacian. As unexpected as the young dates from GH 17 immediately below the Aurignacian are, the dates of between 31 and 34 ka ^{14}C BP for the lower lying AH VII and VIII (GH 21 and 22) are even more remarkable. These dates could only be explained by massive reworking or high levels of contamination. Since chemistry blanks on ancient bones at Kiel typically date in the 50 ka ^{14}C BP range and our geological observations during the excavation and Goldberg's micromorphological analyses rule out large scale mixing (Goldberg and Conard, in press), it appears that the dates, while no doubt representing minimum ages, are meaningful. Again here it is necessary to stress that no diagnostic Aurignacian artifacts have

Table 1
Uncalibrated ^{14}C dates with 1σ uncertainties for Geißenklösterle[a]

Lab. number	Arch. horizon	Material	Modification	Collagen (%)	Date	Cultural group	First publication
Geißenklösterle							
OxA-5157	Ir	Hare pelvis			24,360 ± 380	G	Housley et al., 1997
OxA-5159	Ir	Lynx mandible			26,300 ± 500	G	Housley et al., 1997
Beta-143243	Ir	Cave bear incisor			26,740 ± 120	G	Conard and Moreau, 2004
OxA-4855	Ir	Reindeer phalange			27,000 ± 550	G	Housley et al., 1997
Beta-161019	Ir	Cave bear incisor			27,240 ± 200	G	Conard and Moreau, 2004
Beta-161018	Ir	Cave bear incisor			27,340 ± 180	G	Conard and Moreau, 2004
OxA-4857	Ir	Horse rib	Cutmarks		27,500 ± 550	G	Housley et al., 1997
Beta-161020	Ir	Cave bear incisor			27,870 ± 190	G	Conard and Moreau, 2004
OxA-4856	Ir	Horse radius			30,950 ± 800	G	Housley et al., 1997
Beta-143244	Is	Cave bear incisor			26,530 ± 120	G	Conard and Moreau, 2004
OxA-5227	Is	Horse femur			28,050 ± 550	G	Housley et al., 1997
OxA-5226	It	Reindeer tibia	Impact		26,540 ± 460	G	Housley et al., 1997
OxA-5229	It	Mammoth rib	Cutmarks		27,950 ± 550	G	Housley et al., 1997
OxA-5228	It	Mammoth rib			28,500 ± 550	G	Housley et al., 1997
OxA-4592	It	Reindeer phalange			29,200 ± 460	G	Hahn, 1995
OxA-4593	It	Bone			29,200 ± 500	G	Hahn, 1995
OxA-5706	Ia	Red deer antler			29,220 ± 500	G	Richter et al., 2000
OxA-5161	Ic	Reindeer metacarpal	Impact		30,300 ± 750	G	Housley et al., 1997
OxA-18718	Ic	Reindeer metacarpal (2nd measurement from sample OxA-5161)	Impact		33,380 ± 390	G	
Beta-156088	IIn	Cave bear incisor		22.8	29,390 ± 210	UA	Hofreiter et al., 2007
H 4147-3346	IIa	Mixed bone sample			30,625 ± 796	UA	Hahn, 1982
Beta-143245	IIa	Cave bear incisor		13.7	31,090 ± 200	UA	Hofreiter et al., 2007
H 4279-3534	IIa	Mixed bone sample			31,525 ± 770	UA	Hahn, 1982
OxA-18713	IIa	Horse scapula (2nd measurement from sample OxA 5707)	Impact + cutmarks		33,000 ± 240	UA	
OxA-5707	IIa	Horse scapula	Impact + cutmarks		33,200 ± 800	UA	Richter et al., 2000
OxA-5160	IIa	Hare tibia			33,700 ± 1,100	UA	Hahn, 1988
OxA-4594	IIa	Reindeer? humerus			36,800 ± 1,000	UA	Hahn, 1995
KIA 8960	IIb	Mammoth rib	Impact	1.6	29,800 ± 240	UA	Conard and Bolus, 2003
Pta-2361	IIb	Charred bone			31,070 ± 750	UA	Hahn, 1982
KIA 8958	IIb	Horse humerus	Impact + cutmark	15.6	31,870 + 260/-250	UA	Conard and Bolus, 2003
Pta-2270	IIb	Charred bone			31,870 ± 1,000	UA	Hahn, 1982
OxA-5708	IIb	Mammoth cranium			32,300 ± 700	UA	Richter et al., 2000
PtA-2116	IIb	Charred bone			32,680 ± 470	UA	Hahn, 1982
OxA-5162	IIb	Hare pelvis			33,200 ± 1,100	UA	Housley et al., 1997
Beta-156089	IIb	Cave bear incisor		11.0	33,350 ± 340	UA	Hofreiter et al., 2007
H 4751-4404	IIb	Mixed bone sample			33,700 ± 825	UA	Hahn, 1982
OxA-6256	III	Reindeer tibia	Impact		30,100 ± 550	LA	Conard and Bolus, 2003
KIA 8963	III	Long bone	Impact	15.2	31,180 + 270/−260	LA	Conard and Bolus, 2003
H 5118-4600	III	Mixed bone sample			34,140 ± 1,000	LA	Hahn, 1982
KIA 16031	III	Reindeer metatarsal	Fresh break	15.2	35,060 + 370/−350	LA	
OxA-18716	III	Reindeer tibia (2nd measurement from sample OxA-6256)	Impact		35,700 ± 550	LA	
H 5316-4909	III	Mixed bone sample			36,540 ± 1,570	LA	Hahn, 1982
OxA-5163	III	Ibex mandible			37,300 ± 1,800	LA	Housley et al., 1997
Beta-156090	III	Cave bear incisor		13.6	38,010 ± 520	LA	Hofreiter et al., 2007
OxA-4595	III	Horse femur			40,200 ± 1,600	LA	Hahn, 1995
OxA-6629	IIIa	Reindeer metatarsal			30,300 ± 550	LA	Conard and Bolus, 2003
OxA-6628	IIIa	Reindeer metatarsal			30,450 ± 550	LA	Conard and Bolus, 2003
ETH-8268	IIIa	Bone			33,100 ± 680	LA	Hahn, 1995
OxA-5705	IIIa	Reindeer metatarsal			33,150 ± 1,000	LA	Conard and Bolus, 2003
ETH-8269	IIIa	Bone			33,500 ± 640	LA	Hahn, 1995
OxA-6255	IIIa	Rhino humerus			32,900 ± 850	LA	Conard and Bolus, 2003
KIA 19555	IIIa	Reindeer radius	Impact	10.4	32,910 + 330/−320	LA	
KIA 13075	IIIa	Reindeer tibia	Impact	12.0	34,330 + 310/−300	LA	Conard and Bolus, 2003
KIA 16030	IIIa	Small ruminant longb.	Impact	18.2	34,770 + 310/−300	LA	
KIA 13074	IIIa	Reindeer tibia	Impact	6.4	34,800 + 290/−280	LA	Conard and Bolus, 2003
ETH-8267	IIIa	Bone			37,800 ± 1050	LA	Hahn, 1995
KIA 8962	IIIb	Rib	Impact	12.5	28,640 + 380/−360	LA	Conard and Bolus, 2003
KIA 16033	IIIb	Small ruminant metac.	Impact	11.2	32,670 ± 250	LA	
KIA 8961	IIIb	Reindeer humerus		14.6	33,210 + 300/−290	LA	Conard and Bolus, 2003
KIA 17302	IIIb	Reindeer metatarsal	Impact	12.3	33,900 + 280/−270	LA	
KIA 13076	IIIb	Reindeer tibia	Impact + cutmarks	8.4	34,080 + 300/−290	LA	Conard and Bolus, 2003
KIA 8959	IIIb	Femur		11.2	34,220 + 310/−300	LA	Conard and Bolus, 2003
KIA 17303	IIIb	Horse femur	Probable impact	11.4	36,490 + 350/−340	LA	
KIA 16032	IIIb	Roe deer metatarsal	Impact	11.4	36,560 + 410/−390	LA	Conard and Bolus, 2003
OxA-6077	IIIc	Ibex tibia			32,050 ± 600	n.s.	Conard and Bolus, 2003
OxA-6076	IIIc	Red deer tibia			33,600 ± 1,900	n.s.	Conard and Bolus, 2003
KIA 17305	IIIc	Reindeer metatarsal	Impact	14.3	38,220 + 430/−410	n.s.	
OxA-18715	IIIc	Ibex tibia (2nd measurement from sample OxA-6077)			39,150 ± 750	n.s.	

(*continued on next page*)

Table 1 (*continued*)

Lab. number	Arch. horizon	Material	Modification	Collagen (%)	Date	Cultural group	First publication
OxA-18714	IIIc	Red deer tibia (2nd measurement from sample OxA-6967)			39,750 ± 550	n.s.	
KIA 21280	IV	Horse radius (2nd measurement from sample KIA 17299)	Probable cutmark	9.7	33,200 + 520/−490	MP	
KIA 17304	IV	Small ruminant bone	Cutmark	12.0	35,010 + 380/−360	MP	
KIA 17299	IV	Horse radius	Probable cutmark	1.1	36,700 + 450/−430	MP	
KIA 17300	IV	Small ruminant mand.	Cutmark	1.1	36,820 + 400/−380	MP	
KIA 19556	IV	Cave bear femur	Impact	13.6	37,780 + 520/−490	MP	
KIA 21278	IV	Small ruminant mand. (2nd measurement from sample KIA 17300)	Cutmark	9.4	38,240 + 780/−710	MP	
KIA 17301	IV	Chamois tibia	Impact	13.9	38,490 + 460/−430	MP	
KIA 19559	VI	Longbone fragment	Probable cutmark	13.7	38,450 + 550/−520	MP	
KIA 19557	VII	Small ruminant femur	Cutmark	11.7	31,629 + 391/−373	MP	
KIA 19558	VIII	Cave bear rib	Possible cutmark	10.8	33,430 + 480/−450	MP	
KIA 19561	VIII	Wolf tibia	Impact + cutmark	13.0	40,090 + 640/−600	MP	
KIA 19560	VIII	Longbone fragment	Probable cutmark	14.6	41,410 + 1,500/−1,260	MP	

[a] The dates from Heidelberg (H) and Pretoria (Pta) are conventional radiocarbon dates, those from Kiel (KIA), Miami (Beta), Oxford (OxA), and Zurich (ETH) are AMS dates. G = Gravettian, UA = upper Aurignacian, LA = lower Aurignacian, MP = Middle Paleolithic, n.s. = nearly sterile.

Table 2
Uncalibrated ^{14}C dates with 1σ uncertainties for Hohle Fels[a]

Lab. number	Arch. horizon	Material	Modification	Collagen (%)	Date	Cultural group	First Publication
Hohle Fels							
Beta-161023	IIb	Cave bear incisor			28,170 ± 180	G	Hofreiter et al., 2007
Beta-156092	IIb	Cave bear incisor			28,350 ± 220	G	Hofreiter et al., 2007
OxA-4598	IIc	Bear femur			26,000 ± 360	G	Hahn, 1995
Beta-161022	IIc	Cave bear incisor			27,840 ± 190	G	Conard and Moreau, 2004
Beta-156093	IIc	Cave bear incisor			28,170 ± 220	G	Hofreiter et al., 2007
OxA-4599	IIc	Reindeer antler	Tool (decor. adze)		28,920 ± 440	G	Hahn, 1995
OxA-5007	IIc	Reindeer antler	Tool (decor. adze) same object as OxA-4599		29,550 ± 650	G	Housley et al., 1997
KIA 3503	IIcf	Horse rib		3.6	27,030 + 250/−240	G	Conard, 2003
KIA 17742	IIcf	Horse tibia	Impact + cutmarks	20.1	27,690 ± 140	G	Conard, 2003
KIA 17744	IIcf	Rib rhino-mammoth	Tool (point)	12.9	27,780 ± 150	G	Conard, 2003
KIA 17743	IIcf	Cave bear vertebra	With chert point	17.5	27,830 + 150/−140	G	Conard, 2003
KIA 17741	IIcf	Reindeer antler		13.1	27,970 ± 140	G	Conard, 2003
Beta-156094	IId	Cave bear incisor			28,060 ± 170	A/G	Conard and Moreau, 2004
KIA 8964	IId (base)	Rib rhino-mammoth		9.2	29,560 + 240/−230	A/G	Conard and Bolus, 2003
KIA 8965	IId (base)	Reindeer antler		10.0	30,010 ± 220	A/G	Conard and Bolus, 2003
KIA 16040	IIe	Horse pelvis	Impact + cutmarks	15.9	30,640 ± 190	A/G	Conard and Bolus, 2003
OxA-4979	III	*Salix* charcoal			27,600 ± 800	A?	Housley et al., 1997
KIA 32056	IIIa Feature 1	Reindeer metatarsal	Impact	8.0	29,710 + 210/−200	A	
KIA 32055	IIIa Feature 1	Cave bear rib	Cutmark	6.6	30,340 + 290/−280	A	
KIA 16038	IIIa	Reindeer femur	Impact + cutmarks	14.4	29,840 ± 210	A	Conard and Bolus, 2003
KIA 18877	IIIa	*Pinus* charcoal			30,170 + 250/−240	A	Conard, 2003
OxA-4601	IIIa	Bone			30,550 ± 550	A	Hahn, 1995
KIA 18876	IIIa	*Pinus* charcoal			31,010 + 600/−560	A	Conard, 2003
KIA 16039	IIIa	Ungulate tibia	Impact	15.7	31,140 + 250/−240	A	Conard and Bolus, 2003
KIA 18878	IIIb	*Pinus* charcoal			29,780 + 330/−310	A	Conard, 2003
KIA 3505	IIIb	Bone rhino-mamm.	Impact		29,990 + 340/−330	A	
KIA 32060	IV Feature 6	Longbone fragment		6.6	30,110 + 220/−210	A	
KIA 32058	IV Feature 6	Horse mandible		3.7	30,420 ± 220	A	
KIA 32059	IV Feature 6	Rib fragment		7.1	30,460 + 250/−240	A	
OxA-4980	IV	*Salix* + Betula charc.			28,750 ± 750	A	Housley et al., 1997
KIA 32057	IV	Reindeer radius/ulna		9.5	30,040 ± 210	A	
OxA-4600	IV	Reindeer metapodial			31,100 ± 600	A	Hahn, 1995
KIA 18879	IV	Unidentif. charcoal			31,160 + 1,530/−1,280	A	Conard, 2003
KIA 16037	IV	Reind./cham. hume.	Impact + cutmark	14.4	32,470 + 290/−280	A	
KIA 16036	IV	Horse femur	Tool (retoucher)	15.5	33,090 + 260/−250	A	Conard and Bolus, 2003
KIA 35464	Va	Horse tibia/radius	Tool (retoucher)	9.2	31,750 ± 260	A	
KIA 35463	Va	Horse rib	Cutmark	14.2	32,030 + 280/−270	A	
KIA 35462	Va	Reindeer vertebra	Cutmark	9.5	32,090 + 350/−340	A	
KIA 35460	Va	Mammoth vertebra		6.4	32,370 + 280/−270	A	
KIA 35459	Va	Horse radius	Tool (retoucher)	10.3	32,550 + 300/−290	A	
KIA 16035	Va	Horse bone	Impact	17.8	33,290 ± 270	A	Conard, 2003
KIA 18880	Va	*Pinus* charcoal			34,190 + 340/−330	A	Conard, 2003
KIA 16034	Va	Ungulate humerus	Impact + cutmarks	18.6	35,710 + 360/−340	A	Conard, 2003
KIA 19564	VI	Red deer metacarpal	Impact + cutmarks	16.0	35,760 + 660/−610	MP	
KIA 19562	VI	Cave bear metapod.	Possible cutmark	17.7	36,380 + 380/−360	MP	
KIA 19563	VII	Ibex/reindeer bone	Impact	12.8	36,350 + 540/−510	MP	
KIA 32054	VII	Cave bear rib	Possible cutmark	6.8	37,940 + 530/−500	MP	
KIA 32052	VIII	Reindeer tibia	Probable cutmark	2.9	39,580 + 600/−560	MP	
KIA 32053	IX	Bone	Impact	4.7	38,560 + 530/−500	MP	

G = Gravettian, A = Aurignacian, MP = Middle Paleolithic.
[a] All dates are AMS dates from the laboratories in Kiel (KIA), Miami (Beta), and Oxford (OxA).

Table 3
Uncalibrated ^{14}C dates with 1σ uncertainties for other Ach Valley sites [a]

Lab. number	Arch. horizon	Material	Modification	Collagen (%)	Date	Cultural group	First publication
Ach Valley							
Sirgenstein							
OxA-12013	I	Cave bear molar			25,560 + 130	G	Hofreiter et al., 2007
OxA-12014	I	Cave bear molar			26,980 + 130	G	Hofreiter et al., 2007
OxA-11412	I	Mammoth rib			33,800 + 450	A	
OxA-12015	I	Cave bear molar			35,770 + 330	A	Hofreiter et al., 2007
KIA 13079	II	Bone	Tool (point)	4.9	27,250 + 180/-170	G	Conard and Bolus, 2003
KIA 13080	III	Bone	Tool (burnisher)	4.3	30,210 ± 220	A/G	Conard and Bolus, 2003
KIA 13081	IV	Mammoth rib	Tool (burnisher)	7.4	28,400 ± 200	A	Conard and Bolus, 2003
KIA 13082	V	Antler?	Tool (point)	10.2	26,730 + 170/−160	A	Conard and Bolus, 2003
KIA 13083	VI	Bone	Tool (awl)	14.0	30,360 + 230/−220	A	Conard and Bolus, 2003
Brillenhöhle							
B-492	VII	Charred bone			>25,000	G	Riek, 1973
KIA 19553	VII	Mammoth/rhino rib	Tool (point)	12.6	25,870 ± 230	G	Conard and Moreau, 2004
KIA 19549	VII	Mammoth/rhino rib		10.9	27,030 + 180/−170	G	Conard and Moreau, 2004
B-491	VIII	Charred bone			>29,000	?	Riek, 1973
KIA 19550	XIV	Reindeer? antler	Tool (point)	9.9	30,400 + 240/−230 (C in collagen) 32,110 + 480/−450 (residual C)	A	Bolus and Conard, 2006
KIA 19551	XIV	Reindeer? antler	Tool (point)	9.4	32,470 + 270/−260	A	Bolus and Conard, 2006

G = Gravettian, A = Aurignacian. Sirgenstein I has traditionally been classified as Magdalenian. The inverted dates presumably result from mixing.
[a] The dates from Bern (B) are conventional radiocarbon dates, those from Kiel (KIA) and Oxford (OXA) are AMS dates.

ever been recovered in the Middle Paleolithic deposits of Geißenklösterle (Fig. 4). This indicates that mixing between Aurignacian and Middle Paleolithic deposits is minimal, if present at all. Additionally, refitting studies and the structure of anthropogenic and geogenic features indicate that little if any mixing has occurred that could move younger materials down the stratigraphic column into the Middle Paleolithic deposits.

Clearly more work needs to be done on dating GH 17/AH IIIc and the underlying Middle Paleolithic deposits at Geißenklösterle, AH IV–VIII. Nonetheless, the available data document either major problems in measuring the ages of such old bones (Jacobi et al., 2006) or the existence of phases with significant amounts of excess radiocarbon. While we think that atmospheric radiocarbon peaks may contribute to these young dates, we do not wish to minimize the other potential sources of error. Currently, collaborative work is underway with multiple labs to test the validity of these results in the light of suggestions that ultra-filtration and other innovative laboratory techniques may help to push the reliable range of radiocarbon dating further back (e.g., Gravina et al., 2005; Higham et al., 2006; Pigati et al., 2007). Based on comparative tests using multiple forms of sample preparation at Kiel, including ultra-filtration and related techniques, colleagues in Kiel conclude that the ages younger than 40 ka ^{14}C BP reflect meaningful results well above the radiocarbon levels documented in chemistry blanks. This being said, it is surprising that the deepest archaeological deposits do not provide ages older then 42 ka ^{14}C BP. Equally surprising is that the ages of well-preserved Middle Paleolithic bones usually fall comfortably in the range of dates for the Aurignacian. This is all the more remarkable in the light of the observation that some of these samples are underlying the lower Aurignacian of AH III by as much as 1.5 meters (Fig. 3). These dates are also younger than the age estimate of ca. 43 ka BP_{ESR} for the upper portion of the Middle Paleolithic deposits that Richter et al. (2000) obtained using ESR dating. In all likelihood, the radiocarbon ages for the Middle Paleolithic archaeological horizons are much younger than their actual age. While other explanations, including problematic sample preparation, may help to explain these observations, major production peaks could be in part responsible for these data.

Hohle Fels

In contrast to Geißenklösterle, where important Aurignacian and Middle Paleolithic deposits were excavated between 1973 and 2002, at Hohle Fels excavations only recently reached Aurignacian and Middle Paleolithic deposits (Conard et al., 2003b). Thus, fewer dates have been published from Hohle Fels and no techniques other than radiocarbon have provided results. The research at Hohle Fels has been published in many reports. For an introduction to the site and for further references, readers can examine Conard and Bolus (2006). As at Geißenklösterle and other sites in Swabia, the uppermost Middle Paleolithic deposits at Hohle Fels are separated from the deepest Aurignacian horizons by an archaeological sterile deposit of ca. 50 cm (Fig. 5; Conard et al., 2006). When considering the plots and projections of finds and dated materials from Hohle Fels, it is important to realize that the deposits, unlike the relatively horizontal strata from Geißenklösterle, slope downward toward the northwest. This slope of roughly 15 degrees leads to the appearance of stratigraphic overlap between the archaeological horizons (Figs. 5 and 6). This, however, is not the case. The study of numerous features, refitting complexes, and geoarchaeological data suggests that, other than minor taphonomic factors and excavation errors, the stratigraphic sequence is reliable.

Although the subsistence bases of the Middle Paleolithic and Aurignacian inhabitants of the region were similar (Münzel and Conard, 2004), nearly all classes of artifacts show radical changes between the Middle Paleolithic and the Aurignacian. There is no evidence in Swabia for a gradual transition from the Middle Paleolithic to the Aurignacian. After the occupational hiatus documented in the caves of the region, the Aurignacian appears in a form that in every respect reflects a fully-developed Upper Paleolithic cultural group (Schmidt, 1912; Riek, 1934; Hahn, 1977, 1988; Conard and Bolus, 2003, 2006).

Prior to this paper, 18 radiocarbon dates from the Aurignacian and the transitional layers between Aurignacian and Gravettian have been published. With the exception of two dates on wood charcoal of 27.6 and 28.8 ka ^{14}C BP obtained by Housley et al. (1997), the other dates fall between 29.8 and 35.7 ka ^{14}C BP (Table 2). These dates fit well with the ages from other key Swabian Aurignacian sites including Geißenklösterle, Vogelherd, and Hohlenstein-Stadel (Tables 1 and 4). Only the lower archaeological horizons of AH IV and Va have produced ages in excess of 33 ka ^{14}C BP. Based on the radiocarbon results, most of the sequence from Hohle Fels appears to post-date the lower Aurignacian from Geißenklösterle. Most of the dates from Hohle Fels fall in the range of 30–31 ka ^{14}C BP. Prior to this report, no dates from the Middle Paleolithic deposits had been published.

Table 4
Uncalibrated ^{14}C dates with 1σ uncertainties for the Lone Valley sites[a]

Lab. number	Arch. horizon	Material	Modification	Collagen (%)	Date	Cultural group	First publication
Lone Valley							
Bockstein-Törle							
H 4058-3355	VI	Mixed bone sample			20,400 ± 220	A/G	Hahn, 1976
KIA 8956	VI	Bone		10.6	20,990 + 120/−110	A/G	Conard and Bolus, 2003
H 4058-3526	VI	Mixed bone sample			23,440 ± 290	A/G	Hahn, 1976
KIA 8953	VI	Reindeer radius-ulna	Fresh break	10.0	31,530 ± 230	A/G	Conard and Bolus, 2003
H 4059-3356	VII	Mixed bone sample			26,133 ± 376	A	Hahn, 1977
KIA 8952	VII	Reindeer metatarsal	Fresh break	16.6	30,130 + 260/−250	A	Conard and Bolus, 2003
H 4059-3527	VII	Mixed bone sample			31,965 ± 790	A	Hahn, 1983
KIA 8954	VII	Reindeer femur?	Fresh break	11.8	44,390 + 990/−880	A/MP?	Conard and Bolus, 2003
KIA 8955	VII	Horse metapodial	Fresh break	13.2	46,380 + 1,360/−1,170	A/MP?	Conard and Bolus, 2003
OxA-18552	VII	Horse metapodial (2nd measurement from sample KIA 8955)	Fresh break	7.7	51,600 ± 1,300	A/MP?	
Hohlenstein-Bärenhöhle							
KIA 8967	Brown loam	Bone	Fresh break	6.7	26,080 + 140/−130	A?	Conard and Bolus, 2003
Hohlenstein-Stadel							
KIA 8951	19 m, spit 6	Reindeer humerus	Impact	13.6	31,440 ± 250	A	Conard and Bolus, 2003
H 3800-3025	20 m, spit 6	Mixed bone sample			31,750 + 1,150/−650	A	Hahn, 1977
ETH-2877	20 m, spit 6	Reind. ulna + wolf astrag.			32,000 ± 550	A	Schmid, 1989
KIA 13077	20 m, spit 6	Reindeer radius	Fresh break	7.6	32,270 + 270/−260	A	Conard and Bolus, 2003
KIA 8949	19 m, spit 7	Reindeer? longbone	Fresh break	17.2	33,920 + 310/−300	A	Conard and Bolus, 2003
KIA 8950	19 m, spit 7	Elk metatarsal	Fresh break	8.1	36,910 + 490/−460	A	Conard and Bolus, 2003
KIA 8948	19 m, spit 8	Horse? longbone	Impact	9.1	41,710 + 570/−530	A?	Conard and Bolus, 2003
KIA 8947	19 m, spit 9	Horse longbone	Fresh break	10.2	42 410 + 670/−620	?	Conard and Bolus, 2003
OxA-18455	19 m, spit 9	Horse longbone (2nd measurement from sample KIA 8947)	Fresh break	10.2	47,100 ± 900	?	
KIA 8946	19 m, spit 10	Reindeer metapodial	Fresh break	15.4	39,970 + 490/−460	A?	Conard and Bolus, 2003
KIA 8945	19 m, spit 11	Longbone	Fresh break	11.0	40,220 + 550/−510	A?	Conard and Bolus, 2003
Vogelherd							
KIA 19542	?	Brown bear canine	Incised	4.2	29,620 ± 210	A?	Conard et al., 2003c
OxA-10196	III	Mammoth tooth dentin			25,780 ± 250	?	Conard et al., 2003c
OxA-10198	III	Giant deer tooth dentin			26,110 ± 310	?	Conard et al., 2003c
OxA-10195	III	Mammoth tooth dentin			31,680 ± 310	A	Conard et al., 2003c
OxA-10197	III	Rhino, tooth dentin			39,700 ± 650	?	Conard et al., 2003c
KIA 19537	IV (top)	Human cranium (Stetten 2)		3.0	3,980 ± 35	N	Conard et al., 2004
KIA 8966	IV	Bovid/horse femur	Cutmarks	19.6	13,015 ± 55	M	Conard et al., 2003c
KIA 8957	IV	Longbone	Cutmarks	5.9	26,160 ± 150	?	Conard and Bolus, 2003
H 4053-3211	IV	Mixed bone sample			30,730 ± 750	A	Hahn, 1977
OxA-18456	IV	Longbone (2nd measurement from sample KIA 8957)	Cutmarks	1.8	32,030 ± 280	A	
PL0001340A	IV/V	Reindeer metatarsal	Cutmarks		13,630 ± 410	M	Conard et al., 2003c
GrN-6583	IV/V	Mixed bone sample			23,860 ± 190	?	Hahn, 1977
GrN-6662	IV/V	Charred bone			27,630 ± 830	?	Hahn, 1977
PL0001339A	IV/V	Horse tibia	Cutmarks		32,180 ± 960	A	Conard and Bolus, 2003
PL0001342A	IV/V	Bovid-horse rib	Cutmarks		34,100 ± 1,100	A	Conard and Bolus, 2003
KIA 19538	V (base)	Human mandible (Stetten 1)		2.2	4,715 ± 35	N	Conard et al., 2004
KIA 19539	V (base)	Human vertebra (Stetten 4)			4,735 ± 30	N	Conard et al., 2004
KIA 20967	V (base)	Human cranium (Stetten 1)			4,910 ± 25	N	Conard et al., 2004
KIA 20969	V (base)	Human mandible (Stetten 1; 2nd sample)			4,985 ± 30	N	Conard et al., 2004
KIA 19540	V (base)	Human humerus (Stetten 3)		4.8	4,995 ± 35	N	Conard et al., 2004
H 4055-3209	V	Mixed bone sample			23,020 ± 400	?	Hahn, 1977
H 8498-8950	V	Mixed bone sample			25,900 ± 260	?	Hahn, 1993
H 8497-8930	V	Mixed bone sample			27,200 ± 400	?	Hahn, 1993
H 4054-3210	V	Mixed bone sample			30,162 ± 1,340	A	Hahn, 1977
H 8500-8992	V	Mixed bone sample			30,600 ± 1,700	A	Hahn, 1993
GrN-6661	V	Charred bone			30,650 ± 560	A	Hahn, 1977
H 8499-8991	V	Mixed bone sample			31,350 ± 1,120	A	Hahn, 1993
KIA 8968	V	Small artiodactyl tibia	Impact	13.1	31,790 ± 240	A	Conard and Bolus, 2003
H 4056-3208	V	Mixed bone sample			31,900 ± 1,100	A	Hahn, 1977
PL0001338A	V	Horse tibia	Cutmarks		32,400 ± 1,700	A	Conard and Bolus, 2003
KIA 8969	V	Reindeer longbone	Impact	13.6	32,500 + 260/−250	A	Conard and Bolus, 2003
KIA 8970	V	Horse longbone	Impact	11.4	33,080 + 320/−310	A	Conard and Bolus, 2003
PL0001337A	V	Bovid-horse longbone	Cutmarks		35,810 ± 710	A	Conard and Bolus, 2003
KIA 19541	VI	Antler	Tool (point)	4.9	31,310 + 240/−230	MP	Bolus and Conard, 2006

[a] The dates from Groningen (GrN) and Heidelberg (H) are conventional radiocarbon dates, those from Kiel (KIA), Oxford (OxA), Purdue (PL), and Zurich (ETH) are AMS dates. G = Gravettian, A = Aurignacian, M = Magdalenian. MP = Middle Paleolithic, N = Neolithic.

Here we report 21 new radiocarbon dates from the Leibniz Laboratory in Kiel (Fig. 6; Table 2). The bones used for dating were all well-preserved and generally produced high yields of collagen ranging between 3 and 20% of the weight of the sample, more than half of them being higher than 10%. Six of the new dates are from the Middle Paleolithic deposits of clayey silt with varying amounts of limestone rubble. The uncalibrated radiocarbon ages are 35.8 and 36.4 ka ^{14}C BP for AH VI, 36.4 and 37.9 ka ^{14}C BP for AH VII, 39.6 ka ^{14}C BP for AH VIII, and 38.6 ka ^{14}C BP for AH IX with standard deviations of 0.4–0.7 ka. These ages fall within the general

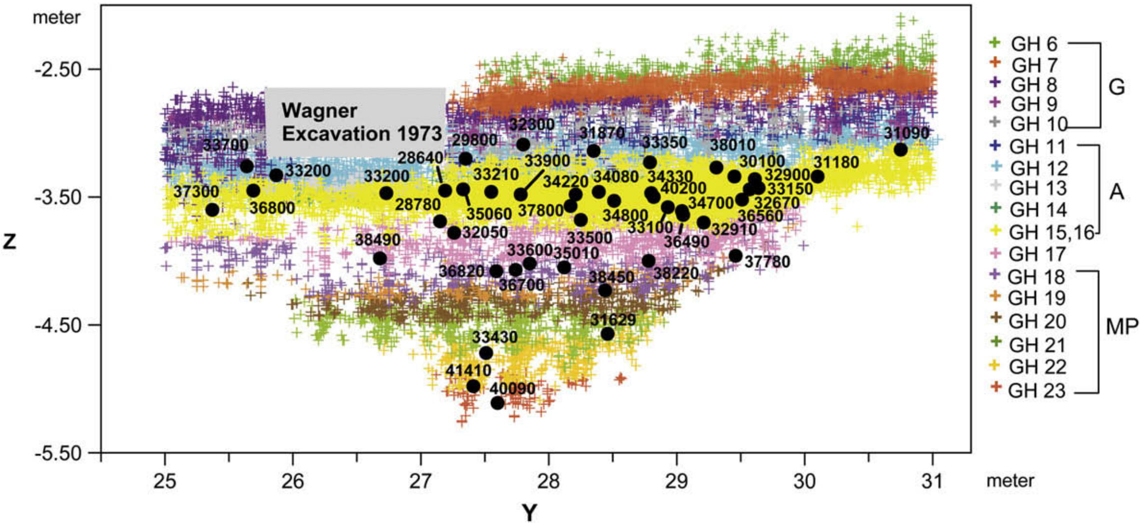

Fig. 3. Geißenklösterle. The stratigraphic position of the AMS radiocarbon samples from the Aurignacian and Middle Paleolithic deposits projected upon the north-south axis of the excavation. GH = Geological Horizon, G = Gravettian, A = Aurignacian, MP = Middle Paleolithic. The colored crosses reflect the location of piece-plotted finds.

range of Middle Paleolithic dates from Geißenklösterle and other sites in the region. As in the case of the other sites, these ages are probably underestimates of the actual ages of the deposits. D. Richter is currently working to establish a TL chronology for Hohle Fels, but no results are available at present.

Turning to the Aurignacian, we have learned from our experience dating sites including Geißenklösterle and have been working to obtain ages for well-defined, short-term features. These features are typically in situ combustion features or dumps from combustion features. They probably formed during a single occupation and should produce a very narrow range of radiocarbon dates. By systematically dating stratigraphically secure, short-lived features, it should be possible to establish better chronological resolution of the Aurignacian than has thus far been the case. This approach, combined with micromorphological studies, has been used successfully to document a dating inversion corresponding to the period between 27 and 28 ka ^{14}C BP in the Gravettian combustion feature of AH II cf (Schiegl et al., 2003; Conard and Moreau, 2004). Many dates above AH IIcf have yielded ages of ca. 29 ka ^{14}C BP. By focusing our dates on well-defined features, we hope to avoid many of the taphonomic uncertainties related to dating isolated finds scattered throughout multiple find horizons.

Excavations so far have identified eight anthropogenic features within the Aurignacian of Hohle Fels (Fig. 7; Table 5). Here we present dates for AH IIIa feature 1 and AH IV feature 6. The dates for AH IIIa feature 1 are 29.7 and 30.3 ka ^{14}C BP, and they seemingly provide a reliable uncalibrated radiocarbon age for this combustion feature. A new measurement for the underlying AH IV yielded an age of 30.0 ka ^{14}C BP, which is within the range of previous dates for the deposit. Three dates from AH IV feature 6 produced ages between 30.1 and 30.5 ka ^{14}C BP and are all statistically equivalent ages. This range appears to reflect a reliable uncalibrated radiocarbon age for this feature.

We have also obtained five dates (KIA 35459-35464) from a well-defined region of AH Va, which was excavated in 2007. These ages also cluster tightly and fall between 31.8 and 32.4 ka ^{14}C BP, thus giving consistent dates for this part of the lower Aurignacian. These new dates are not from the same stratigraphic setting of the previous dates from AH Va, which fell in the range between 33.3 and 35.7 ka ^{14}C BP.

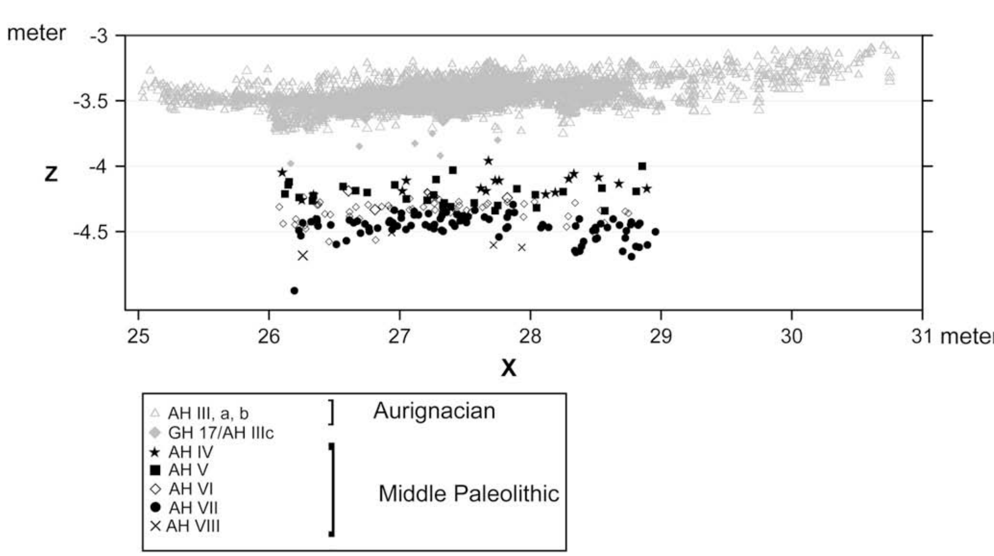

Fig. 4. Geißenklösterle. Vertical distribution of lithic and organic artifacts and piece-plotted burnt bones from the lower Aurignacian and Middle Paleolithic deposits. AH = Archaeological Horizon, GH = Geological Horizon.

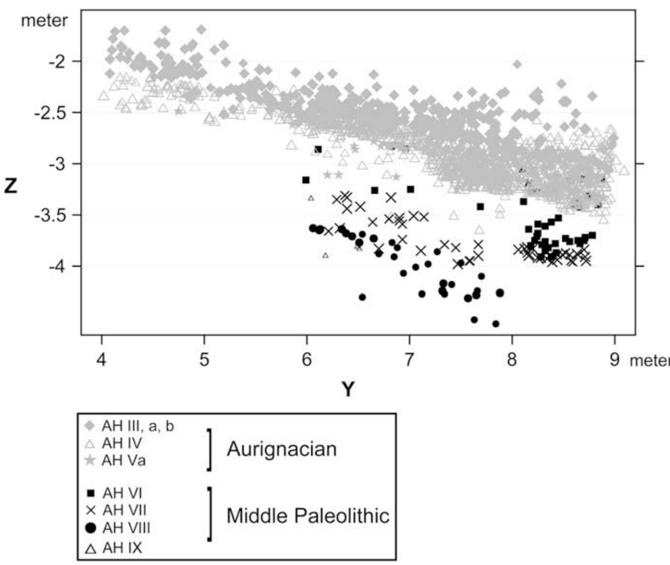

Fig. 5. Hohle Fels. Vertical distribution of lithic and organic artifacts and piece-plotted burnt bones from the Aurignacian and Middle Paleolithic deposits. Finds from both periods do not overlap stratigraphically. The apparent overlap results from projecting finds from sloping strata. AH = Archaeological Horizon.

In the coming years we plan to focus our dating program on more of the features of the Aurignacian at Hohle Fels. So far the dating results from Hohle Fels provide a fairly coherent picture with radiocarbon ages generally increasing with depth in line with our stratigraphic observations. At present we are not sure why the dates from Geißenklösterle provide a noisier signal than those from Hohle Fels. As larger areas of the lowest Aurignacian deposit of AH Va and of the Middle Paleolithic horizons VI–XII are excavated, we hope to gain a better understanding of the chronostratigraphic and cultural stratigraphic development at Hohle Fels.

Discussion

The ongoing research program of the University of Tübingen in several of the caves of the Swabian Jura has produced important new results on Middle Paleolithic and Aurignacian cultural developments (Bolus, 2003; Conard and Bolus, 2006; Conard et al., 2006). Our multidisciplinary approach to studying the sediments, taphonomy, paleoenvironments, and cultural stratigraphy of the sites is beginning to clarify the history of the use of these sites. The long-term research projects at the nearby sites of Geißenklösterle and Hohle Fels in the Ach Valley between Blaubeuren and Schelklingen form the cornerstones of current research.

Continuing work at Geißenklösterle has confirmed the irregularities in the radiocarbon record from the site. Both the upper and lower Aurignacian of AH II and III show a major overlap in uncalibrated radiocarbon ages. Most of the dates from AH II fall between 30 and 34 ka ^{14}C BP, while most of the dates from AH III also fall in this range, with several dates prior to 35 ka ^{14}C BP. Although the dates from AH III often predate those from AH II, this is by no means always the case. Other than the many dated bones of cave bear, the bones of other large mammals are of anthropogenic origin and reflect human hunting (Münzel, in press). This is the case even if they have not been published as bearing definite signs of anthropogenic modification, such as cutmarks and impact fractures. Cave bears were vegetarian (Bocherens et al., 1994, 1997; Bocherens and Drucker, 2006) and did not collect bones, and other agents that collect the bones of large and medium-sized mammals, most notably hyenas, are extremely rare at Geißenklösterle and Hohle Fels (Münzel and Conard, 2004; Münzel, in press).

Based on the abundant evidence that radiocarbon dates in the range between 30 and 40 ka ^{14}C BP systematically underestimate calendar ages, the radiocarbon measurements from Geißenklösterle are consistent with the thermoluminescence ages of ca. 40 and 37 ka BP_{TL}, respectively, for AH III and II (Richter et al., 2000). The most disturbing aspect of the radiocarbon record from Geißenklösterle is seen in the consistently young ages for the Middle Paleolithic horizons. Unless we invoke repeated errors in dating, and high levels of younger contaminants, or unjustified radical taphonomic alterations, a likely explanation is that some of the younger dates are effected by anomalously high levels of atmospheric radiocarbon production (Voelker et al., 2000; Beck et al., 2001; Conard and Bolus, 2003; Hughen et al., 2004; Giaccio et al., 2006). We, however, for the moment assume that the radiocarbon signal from Geißenklösterle also reflects a combination of other problems from the fieldwork and laboratory work that make dating beyond 30 ka ^{14}C BP difficult. At present we are using split samples and multiple laboratories to check if our dates are reproducible. Based on our reading of the data, production peaks in the general period of the late Middle Paleolithic and the Aurignacian must be taken seriously. We caution against uncritical use of radiocarbon ages. We prefer to rely primarily on our stratigraphic observations and taphonomic analyses, and only secondarily on chronometric dating until a higher level of reproducibility in radiocarbon dating can be obtained.

The results from Hohle Fels show similar, but less extreme trends. The dates from AH IId–Va fall mainly in the ca. 29–33 ka ^{14}C BP range. Only in the basal Aurignacian of AH Va do we see older radiocarbon dates of 33–36 ka ^{14}C BP. The radiocarbon ages of the underlying Middle Paleolithic deposits fall between 36 and 40 ka ^{14}C BP. Unlike at nearby Geißenklösterle, we have yet to observe evidence for dating inversions in the lower part of the sequence. The best well-documented dating inversion is in the basal Gravettian deposit of AH IIcf (Conard and Moreau, 2004).

As recently discussed by authors including d'Errico, Teyssandier, Zilhão, and ourselves, we do not yet have the chronological resolution to rigorously confirm or refute models for the origins of the Aurignacian (Conard and Bolus, 2003, 2006; Conard et al., 2003a; Zilhão and d'Errico, 2003; Teyssandier et al., 2006; Zilhão, 2006; Teyssandier, 2007). The answers to these questions will require high-resolution stratigraphic observations combined with intensive programs in radiometric dating and cultural stratigraphic studies at multiple scales. We are working on these problems to provide a strong database to allow researchers to place the Swabian Aurignacian in a meaningful regional and inter-regional context.

Our results from excavations in Swabia are consistent with models including the Danube Corridor and Population Vacuum models for the early migration of modern humans into the Upper Danube Basin around 40 ka BP. This migration presumably is associated with the major climatic fluctuations around the time of Heinrich Event 4 cooling (Conard, 2003; Conard and Bolus, 2003). Results from the excavations in the caves of Swabia are consistent with the Kulturpumpe hypotheses for important Aurignacian and Gravettian cultural innovations in the region. This, however, should not be misconstrued to mean all, or even most, elements of these macro-cultural groups developed in the Upper Danube region. On the contrary, as we have pointed out on many occasions, Swabia is one of, but by no means the only, key area of early Upper Paleolithic innovations. This status is also in part a reflection of the fact that the region has been a focus of intense Paleolithic research since the middle of the 19th century.

Finally, the new dates from the Middle Paleolithic and Aurignacian at Geißenklösterle suggest that dating inversions of the kind described as the "Coexistence Effect" (Conard, 2002; Conard

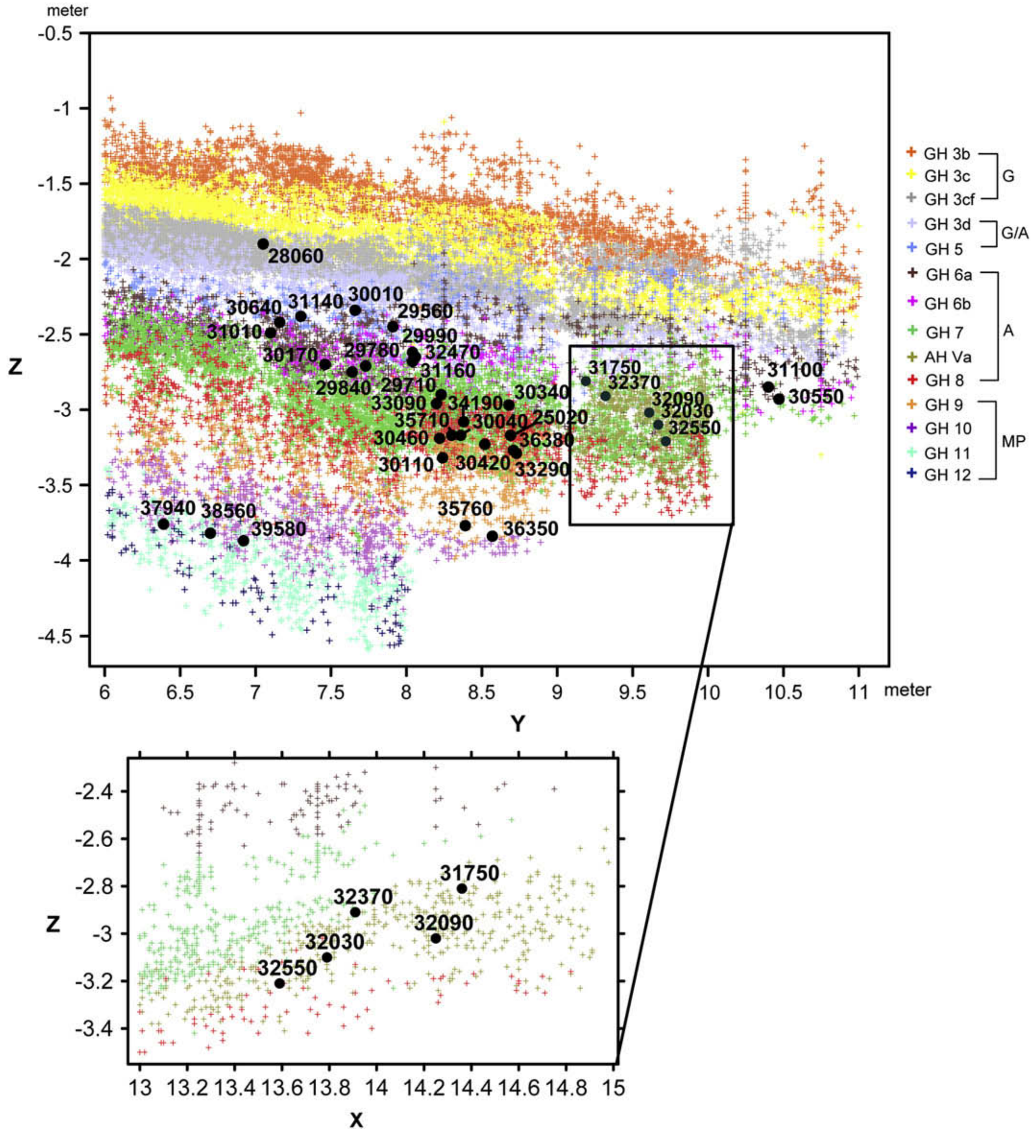

Fig. 6. Hohle Fels. The stratigraphic position of the AMS radiocarbon samples from the Aurignacian and Middle Paleolithic deposits projected upon the north-south axis of the excavation. The close-up shows the dates from part of AH Va projected on the east-west axis. Finds from the Aurignacian and Middle Paleolithic do not overlap stratigraphically. The apparent overlap results from projecting finds from sloping strata. GH = Geological Horizon, G = Gravettian, A = Aurignacian, MP = Middle Paleolithic. The colored crosses reflect the location of piece-plotted finds.

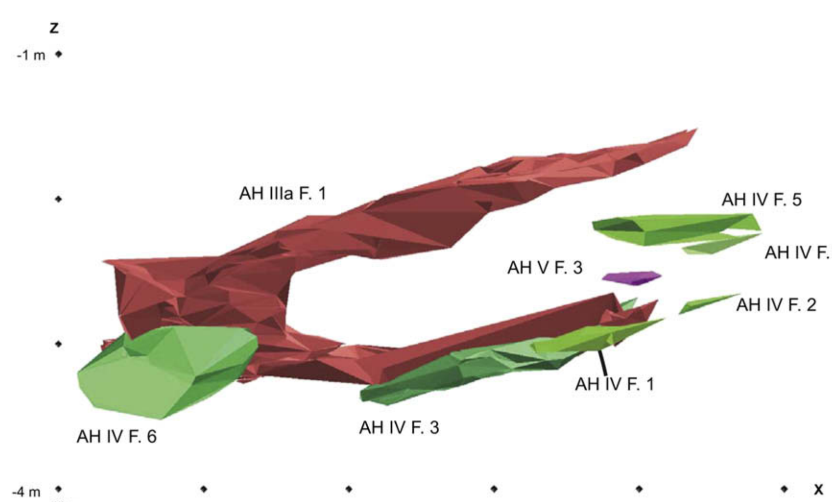

Fig. 7. Hohle Fels. Anthropogenic features within the Aurignacian deposits (for short descriptions see Table 5).

Table 5
Anthropogenic features within the Aurignacian deposits of Hohle Fels (see Fig. 7)

AH	Number	Description
IIIa	Feature 1	Sediment with abundant charcoal; dark-gray to black; only a few centimetres thick but widespread; many lithics and bones; for radiocarbon dates see Table 2.
IV	Feature 1	Small area of irregular gray-brown to black-brown sediment; color caused by charred bones and charcoal; also contains unburnt bones and limestone fragments; partially resting directly upon the underlying AH Va.
IV	Feature 2	Small area with ashy, gray colored sediment with many charcoal particles; resting directly upon the underlying AH Va.
IV	Feature 3	Dark gray-brown sediment; not richer in burnt material than AH IV in general, thus cause of color unclear; few finds.
IV	Feature 4	Small area with dark sediment including patches containing increased concentration of charcoal; some pieces of charcoal as large as 1.5 cm.
IV	Feature 5	Gray-brown to black-brown colored sediment; many pieces of charred bones, some of them >2 cm, some broken into small particles and heavily weathered; contains bones and burnt limestones.
IV	Feature 6	Gray-brown sediment with high amounts of charcoal and charred bones; pit-like form within AH IV; abundant lithics, mostly unburnt, bones, and ivory fragments; for radiocarbon dates see Table 2
Va	Feature 3	Small concentration of charred bones.

and Bolus, 2003) are real phenomena that continue to make dating the arrival of the earliest modern humans in Europe and the extinction of Neandertals difficult. While technical improvements such as ultra-filtration (Gravina et al., 2005; Higham et al., 2006; Jacobi et al., 2006) may improve matters, the problems associated with dating the Middle Paleolithic and Aurignacian will only be solved by using multiple lines of argument rather than radiocarbon dates alone. Until a high level of reproducibility can be established in radiocarbon dating beyond 30 ka ^{14}C BP, we recommend emphasizing the importance of high quality stratigraphic and contextual data in developing and testing archaeological models.

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