The Chronostratigraphy of the Upper Paleolithic Deposits at Vogelherd

Nicholas J. Conard
Laura B. Niven
Institut für Ur- und Frühgeschichte und Archäologie des Mittelalters
Abteilung Ältere Urgeschichte und Quartärökologie
Schloss Hohentübingen, 72070 Tübingen

Ken Mueller
Prime Lab
Purdue University West Lafayette, IN 47907, U.S.A.

Anthony J. Stuart
Department of Biology
University College London, UK

Abstract: *Over the past several years, 15 AMS radiocarbon dates on various archaeological and paleontological materials have been assembled for the site of Vogelherd, a key Paleolithic site in the Swabian Jura. These results along with existing conventional radiocarbon dates document the timing of the human use of the cave. These dates also provide a record for the presence of diverse mammalian species in the Lone Valley. This study does not consider the site's Middle Paleolithic horizons since they lie outside the range of reliable radiocarbon dating. As expected, these dates demonstrate a significant Aurignacian component at the site with numerous dates falling between 30 and 36 ka in uncalibrated radiocarbon years. The dates also document mixing between the archaeological units defined by Riek during the excavation in 1931. Although the archaeological data do not clearly demonstrate significant occupations of the site during the Gravettian, several dates between 28 and 23 ka bp suggest the use of the site during this period. A Magdalenian component dating to approximately 13 ka bp is also present at the site. Now that the general cultural stratigraphic framework for the site is in place, efforts should be made to date the important human skeletal remains and other unique organic artifacts from the site directly.*

Zusammenfassung: Der Vogelherd, etwa 1 km nordwestlich von Stetten am rechten Loneufer gelegen, ist einer der Schlüsselfundplätze für die Altsteinzeit der Schwäbischen Alb. Nachdem die Höhle 1930 entdeckt worden war, wurde sie von Gustav Riek 1931 in nur wenigen Wochen komplett ausgegraben. Riek unterschied in der Höhle und vor allem im Bereich der Eingänge elf geologische Einheiten, in denen er neun z.T. sehr fundreiche archäologische Fundschichten (I – IX) entdeckte. Die unterste dieser Fundschichten (IX) enthielt ein nicht weiter zu klassifizierendes Mittelpaläolithikum, Fundschicht VIII ein Mittelpaläolithikum mit beidflächig bearbeiteten Werkzeugen. Abgeschlossen wird die Folge aus der Zeit der Neandertaler durch zwei Fundschichten (VII und VI) des Moustérien. Es folgte ein bedeutendes Schichtpaket mit zwei Fundschichten aus dem Aurignacien (V und IV). Besonders hervorzuheben sind die Reste mehrerer menschlicher Individuen, die Riek zum größeren Teil an der Basis der Fundschicht V barg. Deutlich jünger als das Aurignacien sind zwei Fundschichten (III und II) aus dem Magdalénien, d.h. aus der Spätphase der letzten Eiszeit. Bereits in die Nacheiszeit gehört schließlich die jungsteinzeitliche Schicht I.

Wegen der Bedeutung der Funde aus dem Vogelherd kommt einer möglichst genauen Altersbestimmung der Fundschichten besonderes Interesse zu. So wurden in den vergangenen Jahren für die Höhle 15 AMS-Radiokohlenstoffdaten an verschiedenen archäologischen und paläontologischen Funden ermittelt. Zusammen mit bereits existierenden konventionellen ^{14}C-Daten kann so die zeitliche Abfolge der Nutzung dieser Höhle durch den Menschen nachgezeichnet werden. Leider ist es nicht möglich, für die Schichten

aus der Zeit des Neandertalers Radiokohlenstoffdaten zu ermitteln, da dieser Zeitabschnitt außerhalb der zuverlässlichen Datierbarkeit mit radioaktivem Kohlenstoff liegt. Zahlreiche Daten fallen in den Zeitraum zwischen 30.000 und 36.000 vor heute und dokumentieren so die erwartete und bereits von Riek hervorgehobene bedeutende Aurignacienkomponente an der Fundstelle. Auch diese Daten müssen allerdings mit einer gewissen Vorsicht betrachtet werden, da in den vergangenen Jahren gezeigt werden konnte, dass es gerade im Zeitraum zwischen 50.000 und 30.000 vor heute gewaltige Schwankungen in der Produktion radioaktiven Kohlenstoffs gegeben hat.

Bei einer genauen Betrachtung werden aber auch Vermischungen zwischen den archäologischen Einheiten, die Riek während seiner Ausgrabungen im Jahre 1931 definiert hatte, deutlich. Obwohl sich im archäologischen Fundmaterial intensive Begehungen während des auf das Aurignacien folgenden Gravettien nicht eindeutig nachweisen lassen, deuten verschiedene Daten zwischen 28.000 und 23.000 vor heute doch eine Nutzung der Höhle während dieser Periode an. Eine Magdalénienkomponente mit einem Alter von etwa 13.000 Jahren ist ebenfalls vorhanden.

Über die Aussagen, wann sich Menschen am Vogelherd aufgehalten haben, hinaus belegen die Daten die Anwesenheit verschiedener Säugetierarten im Lonetal. Auch hier wurden bedeutende Ergebnisse erzielt. Im Rahmen der wissenschaftlichen Bearbeitung der Säugetierreste aus dem Vogelherd wurde als wichtiger Fund der fast 30.000 Jahre alte Zahn eines Braunbären entdeckt, der tiefe Kerben um die Wurzel herum trägt und eindeutig als Schmuckobjekt getragen wurde. Sind Reste von Braunbären in eiszeitlichen Ablagerungen im Gegensatz zu solchen des Höhlenbären ohnehin schon eine Seltenheit, so stellt das Stück aus dem Vogelherd das einzige aus einem Braunbärenrest gefertigte Schmuckstück dar. Schließlich wurden einige der neuen Daten im Zusammenhang mit einem Forschungsprojekt ermittelt, welches zum Ziel hat, das letzte Auftreten der ausgestorbenen eiszeitlichen Tierarten festzustellen.

Nachdem der Rahmen für die allgemeine kulturelle Abfolge an der Fundstelle abgesteckt ist, sollte versucht werden, die bedeutenden menschlichen Skelettreste sowie einige der einzigartigen organischen Artefakte aus der Höhle direkt zu datieren. Diese Daten können eine neue Diskussionsgrundlage im Hinblick auf die Hypothesen zum Übergang vom Neandertaler zum anatomisch modernen Menschen in Europa und damit einen bedeutenden Beitrag zur Klärung einer der derzeit in der Urgeschichtsforschung meistdiskutierten Fragen liefern.

Figure 1: *View of Vogelherd from the west. Visible are the Southwest entrance and on right side of photograph, the south entrance (after Riek 1934).*

Figure 2: *Gustav Riek in front of the southwest entrance to Vogelherd during excavation in 1931.*

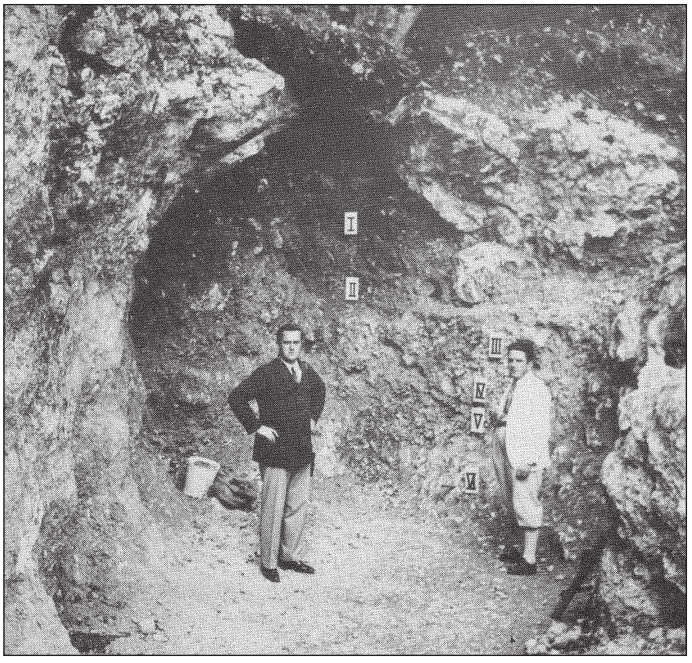

Figure 3: *Gustav Riek (left) and an unknown person standing in front of the southwest entrance to Vogelherd at beginning of excavation in 1931. Note tags in profile marking archaeological strata.*

Introduction

The cave of Vogelherd, near the village of Stetten in the Lone Valley 25 km northeast of Ulm, is one of the most important Upper Paleolithic sites in central Europe. The site was discovered in 1930 and excavated under the direction of Gustav Riek in the summer and autumn of 1931 in a single season lasting approximately 10 weeks (Figures 1 – 4). The excavators emptied the cave of virtually all of its sediments and collected an enormous amount of archaeological material dating mainly to the Middle and Upper Paleolithic that Riek presented in his classic monograph on the site (Riek 1934).

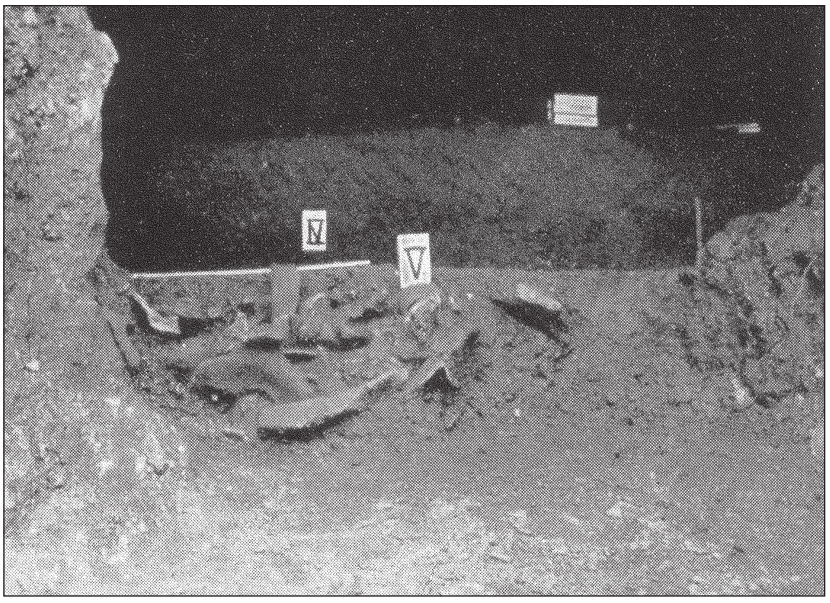

Figure 4: *Portion of bone pile that Riek called the* Mammutlager *in Layer V, southwest entrance of Vogelherd after Riek 1934.*

Riek excavated the sediments in this relatively long and narrow cave in segments that were several meters long, like one might slice a salami. In twelve places the team documented the stratigraphic profiles, which typically included about three meters of sediments (Figure 5). Riek divided the strata based on geological criteria and defined horizons with Roman numerals I-IX, running from the top toward the bottom of the sequence (Figures 6-7). Each find-bearing stratum was assigned to a cultural group based on the finds and the conventions of the early 1930s. Today the Roman numerals are still used to define the strata, but some changes have been made in the cultural designations. For example Riek's horizon VI, which he designated *Unteres Aurignacien*, is now classified as Mousterian (Table 1). Riek based his chronological assessment on stratigraphic and comparative analyses, and it was not until Joachim Hahn's research on the Aurignacian of Swabia that the first radiocarbon dates were produced using mixed samples of bones. These dates indicated that the Swabian Aurignacian dated to as far back as 32 ka uncalibrated radiocarbon years before present (bp) (Hahn 1977). The series of conventional dates on mixed bone also produced dates as young as 23 ka bp for the

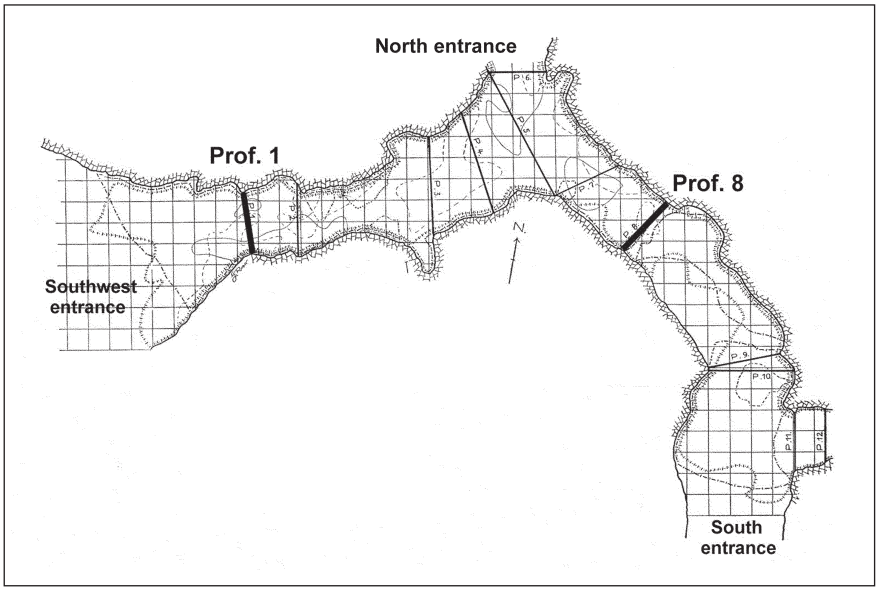

Figure 5: *Ground plan of Vogelherd, showing locations of Profiles 1 and 8 (see Figures 6 and 7). Adapted from Riek (1934:11, Abb. 2).*

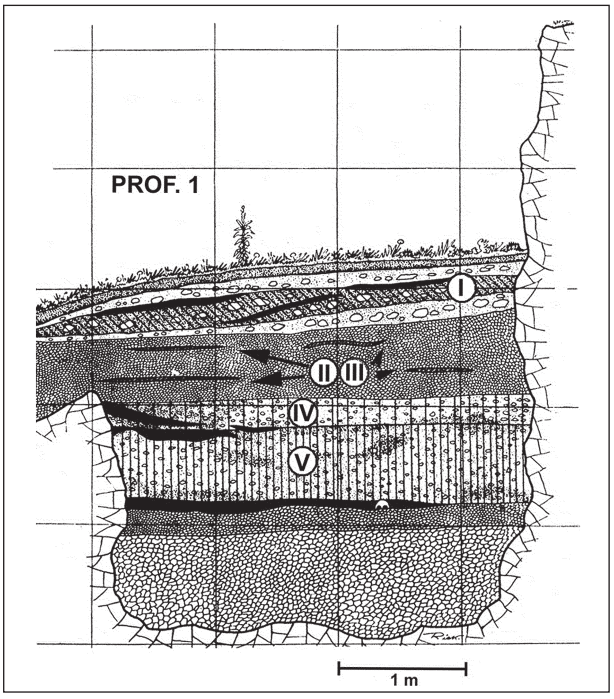

Figure 6: *Profile 1 from Vogelherd. Archaeological strata marked with Riek's numbering system and arrows. Adapted from Riek (1934: 41, Abb. 3).*

Aurignacian deposits of archaeological horizons IV and V. Thus as late as 1995, Hahn published that the Aurignacian in the Lone Valley spanned the period from about 32 to 23 ka bp (Hahn 1995).

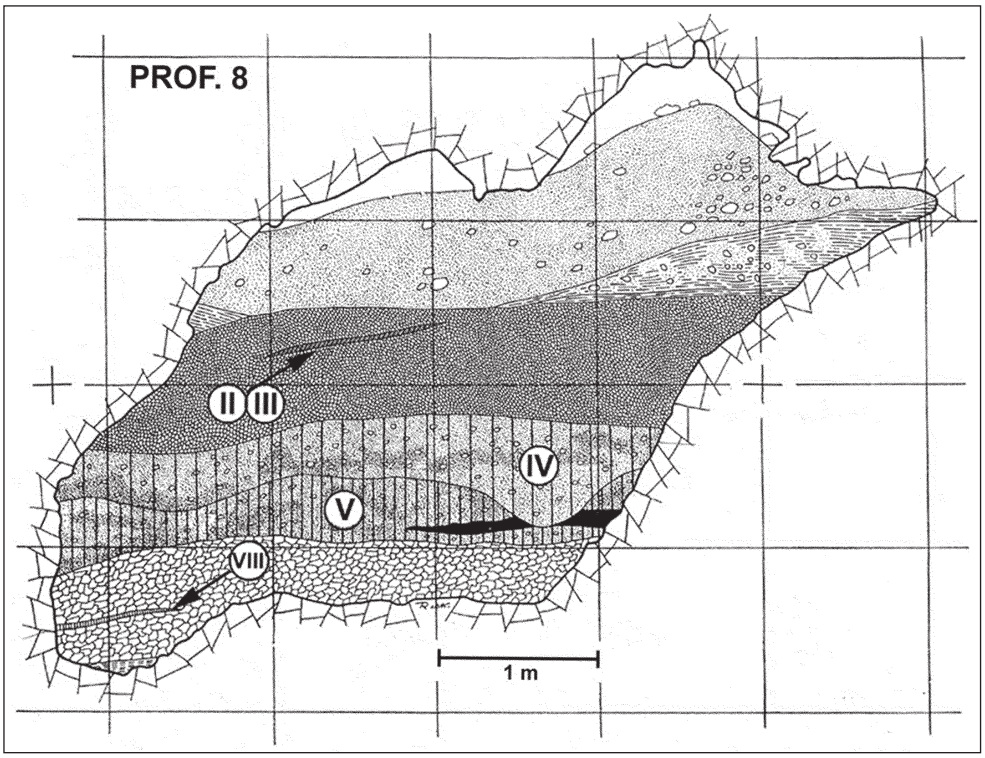

Figure 7: *Profile 8 from Vogelherd. Archaeological strata are marked with Riek's numbering system and arrows. Adapted from Riek (1934: 45, Abb. 5).*

As researchers became aware that the Gravettian was established quite early in the region, the relatively late dates for the Aurignacian from Vogelherd became increasingly implausible. Similarly, the old radiocarbon and thermoluminescence dates for the Aurignacian of Geißenklösterle in the nearby Ach Valley that appear to extend back to about 40 ka bp raised the question of whether the Aurignacian in the Lone Valley may perhaps predate 32 ka bp (Hahn 1988; Housley et al. 1997; Richter et al. 2000).

With these questions in mind, new attempts to use AMS radiocarbon dating at Vogelherd became necessary. A new series of dates was also needed in the context of Laura Niven's analysis of the large faunal assemblage from Vogelherd (Niven 2001, in press, in prep.). A number of AMS dates were produced at the laboratory in Oxford under Anthony Stuart's lead, with the goal of refining the extinction and regional last appearance dates of a number of Pleistocene mammalian species (Stuart and Lister, 2001; Stuart et al. 2002). In all, 15 new accelerator radiocarbon dates were measured at the facilities at the Universität Kiel, Oxford University, and Purdue University.

Another reason for investing much effort toward establishing a radiometric chronology for Vogelherd relates to the human skeletal remains from the site. The excavators at Vogelherd recovered cranial and postcranial remains from at least two individuals in the Upper Paleolithic strata of the site. Particularly important in this context are the finds including a cranium, mandible and humerus from just below the base of horizon V (see Figure 6). If the stratigraphic observations made by Riek are correct, these finds could well represent the oldest finds of modern humans in Europe (Riek 1932, 1934; Gieseler 1937; Churchill and Smith 2000a, 2000b). Since these human skeletal remains are important for hypotheses about the colonization of Europe by modern humans and the beginnings of the Upper Paleolithic, the specimens need to be directly dated to confirm their age. Given the importance of this undertaking, it would be foolish to try to date these human remains before a reliable chronostratigraphic framework for the site had been established.

AH	Riek's designation	Revised designation
I	Neolithic *(Neolithikum)*	Neolithic
II	Magdalenian *(Magdalénien)*	Magdalenian
III	Magdalenian *(Magdalénien)*	Magdalenian
IV	Upper Aurignacian *(Oberes Aurignacien)*	Aurignacian
V	Middle Aurignacian *(Mittleres Aurignacien)*	Aurignacian
VI	Lower Aurignacian *(Unteres Aurignacien)*	Middle Palaeolithic
VII	Mousterian *(Moustérien)*	Middle Palaeolithic
VIII	Upper Acheulean *(Jung Acheuléen)*	Middle Palaeolithic (bifacial)
IX	Cave floor *(Höhlensohle)*	Middle Pal. (basal assemblage)

Table 1. *Cultural horizons of Vogelherd: left column lists Riek's original designations, right column lists the revised layer designations.*

Results

All the available radiocarbon dates for Vogelherd are presented in Table 2. The collagen values of the faunal remains from Vogelherd are generally high and indicate that the dates are reliable. The sample preparation of the specimens should in general have been adequate to eliminate any significant contamination (Longin 1970; Hedges et al. 1989; Hedges and Klinken 1992; Elmore pers. com. 2000; Grootes pers. com. 2000). The most serious problem with the dates from Vogelherd relates to the early conventional dates published by Hahn. Very little documentation exists about these samples, and it appears that the samples each included a group of multiple bones and bone fragments. No information is available about whether or not these bones showed signs of human modification, and there is no reason to assume that the bones included in these mixed bone samples were strictly contemporaneous. On the contrary, there is every reason to suspect that the rich Aurignacian accumulations at Vogelherd are the result of numerous occupations, perhaps spanning thousands of years. Thus the more recent AMS dates are better indicators of the radiocarbon ages of the archaeological deposits.

In this context the reader should be reminded that with the exception of the concentration of mammoth and other bones that Riek recorded as the *"Mammutlager"*, no information is available on the specific provenience of the faunal remains from the site. Many of the nearly 19,000 faunal specimens are labeled with Roman numerals designating find layer (Riek 1934). These labels, which presumably date to the 1930s and appear to be in Riek's handwriting, form the basis for the analysis of the assemblage, and there is every reason to assume that the majority of these designations are correct. The most serious problem relates to the excavation techniques employed by Riek. While he can be commended for collecting nearly all of the fauna from the site, and in that regard can be seen as using progressive field techniques, the sheer speed of the excavation probably precluded a consistent and reliable separation of the find horizons. Even under the most favorable conditions such as those of the current excavations of Hohle Fels and Geißenklösterle (Conard 2002), a rigorous and 100% successful separation of finds from adjacent strata is not always possible due to the complex geology and taphonomy of the these cave sediments (Hahn 1988). Thus there is every reason to expect that some degree of mixing between the strata of Riek's excavation occurred. This situation further reduces the reliability of the mixed bone samples relative to the AMS dates from the site.

Here some of the methodological constraints of radiocarbon dating of Pleistocene material should be reiterated. Recent studies of terrestrial and marine systems have clearly demonstrated that there are major fluctuations in atmospheric and oceanic radiocarbon concentrations in the period prior to 30 ka calendar years bp (van der Plicht 1999; Voelker et al. 2000; Beck et al. 2001). The newest results from Geißenklösterle

Figure 8: *Incised brown bear (Ursus arctos) canine from Vogelherd, archaeological horizon unknown. Specimen AMS dated to 29 620 ± 210 ka bp (see Table 2). Photograph by Hilde Jensen.*

present the best terrestrial record for this phenomenon, and clearly indicate that researchers cannot expect consistent dates as they sample archaeological strata predating 30 ka bp (Conard 2002; Conard and Bolus 2003). The results from Geißenklösterle are also confirmed at other sites, most notably Fumane in northern Italy, where despite a clear stratigraphic sequence, the radiocarbon ages have been shown to fluctuate dramatically (Broglio 2002; Stefani 2003). Thermoluminescence dates have confirmed the importance of this phenomenon at Geißenklösterle, but this technique still lacks the precision needed to provide a reliable tool for high resolution calibration of the fluctuations in the radiocarbon record. We should not expect simple solutions to this problem and just as was the case when fluctuations in the Holocene radiocarbon record were discovered, researchers will probably need many years before high resolution global calibrations of the radiocarbon record will be possible.

Despite these limitations, the dates from Vogelherd have a bearing on all the topics mentioned above, and the results of this study point to Vogelherd as a continued source of new information on Paleolithic archaeology and Quaternary ecology.

Discussion and Implications

Cultural chronology

The dates for the Aurignacian horizons IV and V include a number of outliers, but the bulk of the AMS dates fall between 30 and 36 ka bp. These results are consistent with the dating of the Aurignacian from the nearby Hohlenstein-Stadel and sites in the Ach Valley including Hohle Fels and Geißenklösterle (Conard and Bolus 2003). Both conventional and AMS dates fall in this range, and at many sites in Swabia dates between 30 and 33 ka bp are particularly numerous. The only date prior to 36 ka bp is from the root of a woolly rhinoceros tooth from layer III. This specimen showed no anthropogenic modification and probably originates from a deeper stratigraphic position than Riek believed.

The seven dates between 30 and 20 ka bp require closer scrutiny, and it is unfortunate that only two of these specimens show unambiguous human modifications. Some of the other dates in this range are from mixed bone samples measured several decades ago. The reliability of the mixed bone samples in terms of measuring archaeological occupations cannot be determined, but the reliability of the AMS samples is not in doubt. Nonetheless, the question about the unmodified specimens is whether or not they reflect human occupations of the cave.

The two AMS dates of 13,015 ± 55 and 13,630 ± 410 ka bp reflect a Magdalenian context rather than the Aurignacian horizons IV or V as the labels indicate. As with the case of the four Oxford samples, which were all labeled by Riek as coming from horizon III (Magdalenian) but date to the Aurignacian or older, these specimens suggest that some mixing between strata occurred due to taphonomic processes or during excavation.

Quaternary ecology

Some of the dates presented here were made in the context of trying to identify the last appearances of extinct Pleistocene fauna in Eurasia (Stuart and Lister 2001; Stuart et al. 2002). For example, both dates of mammoth teeth from horizon III produced ages that are older than one would have expected based on the stratigraphic association with Magdalenian artifacts. The date of 31,680 ± 310 ka bp falls within the expected range for the Aurignacian of the site and probably is the result of sloppy excavation or mixing of materials between layers. The date of 25,780 ± 250 ka bp is harder to explain, but may correspond to a relatively ephemeral Gravettian occupation at the site that has not yet been identified in the archaeological material. Alternatively, the tooth could have lain on the landscape following an earlier natural death and then have been collected by people and brought to the cave during the Magdalenian. The cluster of three AMS dates and one conventional date around 26 ka bp suggests that humans used the cave at this time and were responsible for the accumulation of these bones. The giant deer *(Megaceros giganteus)* from horizon III dating to 26,110 ± 150 ka bp may also be the result of this occupation. Given that the sampling strategy for the extinction study focused on teeth, it is not surprising that anthropogenic modifications have not been documented on these specimens. The presence of a cutmarked longbone dating to 26,160 ± 150 ka bp can be seen as confirmation of the human use of the cave during this time. Finds of giant deer are rare in the Swabian Jura, but increasingly evidence is accumulating that multiple species of cervids occupied the region in the Pleistocene. For example, Münzel's work at Geißenklösterle has shown that along with the abundant finds of reindeer, a small number of red deer *(Cervus elaphus)*, roe deer *(Capreolus capreolus)*, and giant deer are occasionally recovered from Paleolithic deposits (Münzel pers. com. 2001). The presence of red deer is to be expected since this species is adapted to diverse climatic conditions and is well-documented in cold period loess deposits of the central European Middle and Late Pleistocene (Stuart 1982; Lister 1986; Turner 1990). The presence of the other cervids is less expected. These results suggest that warm-adapted species that are often associated with interglacials, including roe deer and giant deer (von Koenigswald 1988) sporadically occupied the Swabian Jura during warm interstadials of OIS 3.

The date of 39,700 ± 650 ka bp for woolly rhinoceros *(Coelodonta antiquitatis)* from horizon III can best be explained as the result of mixing between layers or as a result of imprecise excavation. This age predates all anthropogenically modified specimens that have been dated from Vogelherd and may originate from the uppermost Middle Paleolithic deposits (layer VII) in which woolly rhinoceros is the second most abundant taxon and comprises 10% of the assemblage (Niven in prep.).

Finally, the date of 29,620 ± 210 ka bp for a canine of brown bear *(Ursus arctos)* is surprising given the extreme rarity of brown bear in archaeological deposits from the Pleistocene. Although cave bear *(Ursus spelaeus)* is far more abundant in Swabian caves, this unusual occurrence confirms the presence of brown bear at the end the Aurignacian in the region. This find is all the more spectacular since it preserves deep grooves around the root and was clearly worn as jewelry by an inhabitant of the site around 30 ka bp. Although numerous pieces of Upper Paleolithic jewelry made from cave bear teeth are known from the Swabian Jura (Bolus 2001), this is the first find of an ornament made from remains of a brown bear (Figure 8). This date falls in the range of the latest Aurignacian and and earliest Gravettian of the region (Conard and Bolus 2003).

Implications for dating the human fossils

The new dates have important implications for dating the human skeletal remains from Vogelherd. If the skeletal finds are not intrusive, and if finds including the Stetten 1 cranium and mandible, the two lumbar vertebrae, the Stetten 3 humerus and the Stetten 4 left metacarpus did underlie the base of the Aurignacian, then they must predate horizon IV and predate or be contemporaneous with the assemblages of horizon V. In calendar years these finds won´t be close to 40 ka bp, and in radiocarbon years they would certainly be expected to predate 30 ka bp. Given the well-documented fluctuations in atmospheric radiocarbon concentrations in the period of interest, one cannot assume that the radiocarbon age will predate 36 ka bp, the earliest reliable age for the Aurignacian of Vogelherd. Riek's team recovered the Stetten 2 cranium from the top of layer IV at the site. Thus this specimen presumably postdates the Aurignacian complex and could be expected to produce a radiocarbon age younger than 30 ka bp. A date corresponding to the Gravettian or Magdalenian could be expected if the find is not intrusive.

Conclusions

The recent effort to build a more complete stratigraphic framework for Vogelherd through a series of AMS dates sets the stage for directly dating the human fossils. These additional dates also confirm the presence of a significant Aurignacian component at the site, dating between 29 and 36 ka bp. The question of whether a Gravettian occupation is represented remains open. Archaeological data do not support the case for a major Gravettian component, but some of the radiocarbon dates suggest that humans sporadically occupied Vogelherd during this time. A Magdalenian component dating to ca. 13 ka bp is also present, and mixing between the Magdalenian and Aurigacian horizons has occurred. A certain degree of mixing between archaeological strata is not unexpected considering the complex stratigraphy of cave deposits. In regards to Anthony Stuart's project on dating the extinction of mammoths and other fauna across Eurasia at the end of the Pleistocene, the Vogelherd specimens were unfortunately too old to be informative for the study. Labeled as coming from the Magdalenian deposit and thus suitable for the extinction study, these mammoth and rhinoceros teeth were undoubtedly from mixed strata. As a result, the Vogelherd specimens were excluded from the extinction database (but see Stuart and Lister, 2001; Stuart et al., 2002). Efforts to date additional faunal material from the Paleolithic deposits in Vogelherd are ongoing and will continue to be a critical factor in our understanding this important site.

Acknowledgements

This research was partially funded by the Deutsche Forschungsgemeinschaft's SFB 275 and the Natural Environment Research Council, Great Britain. Many thanks are due Piet Grootes of the Leibniz-Labor für Altersbestimmung und Isotopenforschung of the University of Kiel, David Elmore of Prime Lab at Purdue University, and the Oxford Radiocarbon Accelerator Unit. Colleagues in Tübingen including Michael Bolus, Harald Floss, Maria Malina, Susanne Münzel, and Hans-Peter Uerpmann have made important contributions to the research in the Ach and Lone Valleys. Fred Smith contributed to helpful discussions related to the work presented here. Thanks to Michael Bolus for the German abstract and to Hilde Jensen for her help with the photographs.

Lab Number	AH	Material	Modification	Date	Cultural group	Reference
AMS dates						
OxA-10196	III	mammoth tooth dentin (root)		25 780 ± 250	?	
OxA-10198	III	giant deer tooth dentin (root)		26 110 ± 310	?	
OxA-10195	III	mammoth tooth dentin (root)		31 680 ± 310	Aurignacian	
OxA-10197	III	woolly rhino. tooth dentin (root)		39 700 ± 650	?	
KIA 8966	IV	bovid/horse femur frag	cutmarks	13 015 ± 55	Magdalenian	
KIA 8957	IV	longbone frag	cutmarks	26 160 ± 150	?	Conard & Bolus, 2003
PL0001340A	IV/V	reindeer metatarsal	cutmarks	13 630 ± 410	Magdalenian	
KIA 19542	?	brown bear canine	incised	29 620 ± 210	Aurignacian	
PL0001339A	IV/V	horse tibia	cutmarks+fresh brk	32 180 ± 960	Aurignacian	Conard & Bolus, 2003
PL0001342A	IV/V	bovid/horse rib	cutmarks	34 100 ± 1100	Aurignacian	Conard & Bolus, 2003
KIA 8968	V ML	small artiodactyl tibia	impact fracture	31 790 ± 240	Aurignacian	Conard & Bolus, 2003
PL0001338A	V ML	horse tibia	cutmarks	32 400 ± 1700	Aurignacian	Conard & Bolus, 2003
KIA 8969	V	reindeer longbone frag	impact fracture	32 500 +260/-250	Aurignacian	Conard & Bolus, 2003
KIA 8970	V ML	horse longbone frag	impact fracture	33 080 +320/-310	Aurignacian	Conard & Bolus, 2003
PL0001337A	V	bovid/horse longbone frag	cutmarks	35 810 ± 710	Aurignacian	Conard & Bolus, 2003
Conventional Dates						
H-4035-3209	V	bone-Mammoth?		23 020 ± 400	?	Hahn, 1977
GrN-6583	IV/V	mixed bone sample		23 860 ± 190	?	Hahn, 1977
GrN-6662	IV/V	burned bone		27 630 ± 830	?	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 ± 1340	Aurignacian	Hahn, 1977
H-8500-8992	V	mixed bone sample		30 600 ± 1700	Aurignacian	Hahn, 1993
GrN-6661	V	burned bone		30 650 ± 560	Aurignacian	Hahn, 1977
H-4053-3211	IV	mixed bone sample		30 730 ± 750	Aurignacian	Hahn, 1977
H-8499-8991	V	mixed bone sample		31 350 ± 1120	Aurignacian	Hahn, 1993
H-4056-3208	V	mixed bone sample		31 900 ± 1100	Aurignacian	Hahn, 1977

Table 2. *Comprehensive summary of AMS (top) and conventional (bottom) radiocarbon dates from Vogelherd.*

References

Beck, J. W., Richards, D. A., Edwards, R. L., Silverman, B. W., Smart, P. L., Donahue, D. J., Hererra-Osterheld, S., Burr, G. S., Calsoyas, L., Jull, A. J. T. and Biddulph, D. (2001). Extremely large variations of atmospheric ^{14}C concentration during the Last Glacial Period. Science 292, 2453-2458.

Bolus, M. (2001). Zähne von Höhlenbären als Schmuck und Werkzeug. In (S. Köble and N. J. Conard, Eds) Höhlenbärenspuren: Bärenfunde aus Höhlen der Schwäbischen Alb. Blaubeuren: Urgeschichtliches Museum Blaubeuren Heft 5, pp. 39-43.

Broglio, A. (2002). Paleolitico e mesolitico. Sezione Scienze dell'Uomo No. 5, 11-56.

Churchill, S. E. and Smith, F. H. (2000a). A modern human humerus from the Early Aurignacian of Vogelherdhöhle (Stetten, Germany). American Journal of Physical Anthropology 112, 251-273.

Churchill, S. E. and Smith, F. H. (2000b). The makers of the Early Aurignacian of Europe. Yearbook of Physical Anthropology 43, 61-115.

Conard, N. J. (2002). Der Stand der altsteinzeitlichen Forschung im Achtal der Schwäbischen Mitteilungen der Gesellschaft für Urgeschichte 11, 65-77.

Conard, N. J. and Bolus, M. (2003). Radiocarbon dating the appearance of modern humans and timing of cultural innovations in Europe: new results and new challenges. Journal of Human Evolution 44, 331-371.

Gieseler, W. (1937). Bericht über die jungpaläolithischen Skelettreste von Stetten ob Lonetal bei Ulm. Verhandlung der Gesellschaft für Physische Anthropologie 8, 41-48.

Hahn, J. (1977). Aurignacien, das ältere Jungpaläolithikum in Mittel- und Osteuropa. Köln/Wien: Böhlau-Verlag.

Hahn, J. (1988). Die Geißenklösterle-Höhle im Achtal bei Blaubeuren I. Fundhorizontbildung und Besiedlung im Mittelpaläolithikum und im Aurignacien. Stuttgart: Konrad Theiss Verlag.

Hahn, J. (1993). Urgeschichtliche Forschung auf der Ostalb. Karst und Höhle 1993, 213-224.

Hahn, J. (1995). Neue Beschleuniger-^{14}C-Daten zum Jungpaläolithikum in Südwestdeutschland. Eiszeitalter und Gegenwart 45, 86-92.

Hedges, R.E.M. and van Klinken, G. J. (1992) A review of current approaches in the pretreatment of bone for radiocarbon dating by AMS. Radiocarbon 34, 279-291.

Hedges, R.E.M., Law, I.A., Bronk, C. R., Housley, R. A. (1989) The Oxford accelerator mass spectometry facility: technical developments in routine dating. Archaeometry 31, 99-113.

Housley, R. A., Gamble, C. S., Street, M. and Pettitt, P. (1997). Radiocarbon evidence for the Late glacial human recolonisation of northern Europe. Proceedings of the Prehistorical Society 63, 25-54.

Koenigswald, W. below (1988). Zur Paläoklimatologie des letzten Interglazials im Nordteil der Oberrheinebene. Paläoklimaforschung 4. Stuttgart: Gustav Fischer.

Lister, A. (1986). New results on deer from Swanscombe, and the stratigraphical significance of deer in the Middle and Upper Pleistocene of Europe. Journal of Archaeological Science 13, 319-338.

Longin, R. (1970). Extraction du collagèn des os fossiles pour leur datation par la méthode du carbone 14. Thèse de doctorat, Université de Lyon.

Niven, L. (2001). The role of mammoths in Upper Palaeolithic economies of southern Germany. In (G. Cavarretta, P. Gioia, M. Mussi, and M. Palombo, Eds) La Terra degli Elefanti - The World of Elephants: Proceedings of the 1st International Congress. Rome: CNR, pp. 323-327.

Niven, L. (in press). Patterns of subsistence and settlement during the Aurignacian of the Swabian Jura, Germany. In (Zilhão, J. and d'Errico, F. Eds) The Chronology of the Aurignacian and of the Transitional Technocomplexes: Dating, Stratigraphies, Cultural Implications. Trabalhos de Arqueologia, Lisbon.

Richter, D., Waiblinger, J., Rink, W. J. and Wagner, G. A. (2000). Thermoluminescence, electron spin resonance and ^{14}C-dating of the Late Middle and Early Upper Palaeolithic site of Geißenklösterle Cave in southern Germany. Journal of Archaeological Science 27, 71-89.

Riek, G. (1932). Paläolithische Station mit Tierplastiken und menschlichen Skelettresten bei Stetten ob Lontal. Germania 16, 1-8.

Riek, G. (1934). Die Eiszeitjägerstation am Vogelherd im Lontal. Tübingen: Akademische Buchhandlung Franz F. Heine.

Stefani, M. (2003). Contributo alla conoscenza del comportomento technologico dell'uomo moderno nel Paleolitico Superiore: La produzione laminare nell'Aurignaziano e nel Gravettiano. Ph.D. dissertation, Universitario di Bologna.

Stuart, A. J. (1982). Pleistocene Vertebrates of the British Isles. Longman, London.

Stuart, A. J. and Lister, A. (2001). The late Quaternary extinction of woolly mammoth (Mammuthus primigenius), straight-tusked elephant (Palaeoloxodon antiquus) and other megafauna in Europe. In (G.

Cavarretta, P. Gioia, M. Mussi, and M. Palombo, Eds) La Terra degli Elefanti - The World of Elephants: Proceedings of the 1st International Congress. Rome: CNR, pp. 722-723.

Stuart, A. J., Sulerzhitsky, L. D., Orlova, L. A., Kuzmin, Y. V. and Lister, A. (2002). The latest woolly mammoths (Mammuthus primigenius Blumenbach) in Europe and Asia: a review of the current evidence. Quaternary Science Reviews 21, 1559-1569.

Turner, E. (1990). Middle and Late Pleistocene Macrofaunas of the Neuwied Basin Region (Rhineland-Palatinate) of West Germany. Jahrbuch des Römisch-Germanisches Zentralmuseums Mainz 37.

van der Plicht, J. (1999). Radiocarbon calibration for the Middle/Upper Palaeolithic: a comment. Antiquity 73, 119 – 123.

Voelker, A. H. L., Grootes, P. M., Nadeau, M.-J. & Sarnthein, M. (2000). Radiocarbon levels in the Iceland Sea from 25-53 kyr and their link to the earth's magnetic field intensity. Radiocarbon 42, 437-452.