The Cultural and Chronostratigraphic Context of a New Leaf Point from Hohle Fels Cave in the Ach Valley of Southwestern Germany

Der kulturelle und chronostratigraphische Kontext einer neuen Blattspitze aus dem Hohle Fels im Achtal in Südwestdeutschland

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ABSTRACT

During the summer of 2020 the excavation team at Hohle Fels Cave in the Ach Valley of southwestern Germany recovered a leaf point (in German *Blattspitze*) made from gray Jurassic chert. The find is well-preserved and remarkable for a number of reasons. First this is the only leaf point recovered by a modern excavation in the Swabian Jura, and is the first leaf point discovered *in situ* since 1936, when Gustav Riek's crew recovered two well-preserved leaf points at the excavation of Haldenstein Cave in the Lone Valley. The leaf point and associated finds originate from archaeological horizon (AH) X, 120 cm below the base of the rich Aurignacian deposits at the site that dates with radiocarbon to ca. 42 ka cal BP. Four ESR dates made on the teeth of large mammals from AH IX overlying the new leaf point yielded an average age of

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62.5 ± 4 ka BP. This date represents a minimum age for the new horizons, which based on convention would be placed in the cultural taxonomic unit of the *Blattspitzengruppe*. Since the *Blattspitzengruppe* is typically interpreted as the last Middle Paleolithic cultural unit, we were intrigued to find an assemblage containing a *Blattspitze* in such an early chronostratigraphic context. While in Germany the *Blattspitzengruppe* is usually associated with the end of the Middle Paleolithic, many researchers across Europe have described these leaf point assemblages as being transitional industries at the interface between the Middle and Upper Paleolithic. Historically, some authors have even suggested a degree of cultural continuity between leaf point assemblages of the Middle and Upper Paleolithic. Here we present the stratigraphic and chronological context of the AH X and provide a preliminary description of the material cultural record from this horizon. Keeping in mind that we so far have only excavated parts of 6 m^2 of the new find horizon and the underlying find horizon AH XI, the paper provides initial observations that will need revision as the excavation proceeds. These findings suggest that leaf points represent a feature in the technological repertoire of the Late Pleistocene Neanderthals of southwestern Germany rather than a reliable cultural stratigraphic marker for the last phase of the Middle Paleolithic.
Keywords: Swabian Jura, Middle Paleolithic, *Blattspitzengruppe*, dating, stratigraphy

ZUSAMMENFASSUNG

Im Sommer 2020 hat das Ausgrabungsteam im Hohle Fels im südwestdeutschen Achtal eine Blattspitze aus grauem Jurahornstein geborgen. Der Fund ist gut erhalten und aus mehreren Gründen bemerkenswert. Zum Einen ist dies die einzige Blattspitze, die durch eine moderne Ausgrabung auf der Schwäbischen Alb gefunden wurde, und es ist darüber hinaus die erste Blattspitze, die seit 1936 in situ entdeckt wurde, als die Mannschaft von Gustav Riek bei der Ausgrabung der Haldensteinhöhle im Lonetal zwei gut erhaltene Blattspitzen fand. Die Blattspitze und die dazugehörigen Funde stammen aus dem archäologischen Horizont (AH) X, 120 cm unterhalb der Basis der reichen aurignacienzeitlichen Ablagerungen der Fundstelle, die durch Radiokohlenstoffmessungen auf ca. 42 ka cal BP datiert sind. Vier ESR-Daten, die an den Zähnen großer Säugetiere aus dem AH IX oberhalb der neuen Blattspitze ermittelt wurden, ergaben ein Durchschnittsalter von 62,5 ± 4 ka BP. Dieses Datum stellt damit ein Mindestalter für die neuen Fundhorizonte dar, die nach konventioneller Taxonomie in die kulturelle Einheit der Blattspitzengruppe eingeordnet würden. Da die Blattspitzengruppe typischerweise als letzte mittelpaläolithische Kultureinheit interpretiert wird, waren wir fasziniert, in einem so frühen stratigraphischen Kontext ein Inventar mit einer Blattspitze zu finden. Während in Deutschland die Blattspitzengruppe normalerweise mit dem Ende des Mittelpaläolithikums in Verbindung gebracht wird, haben viele Forscher in ganz Europa solche Blattspitzeninventare als Übergangsindustrie an der Schnittstelle zwischen Mittel- und Jungpaläolithikum beschrieben. Historisch gesehen, haben einige Autoren sogar ein gewisses Maß an kultureller Kontinuität zwischen Blattspitzen führenden Inventaren des Mittel- und Jungpaläolithikums vorgeschlagen. Hier stellen wir den stratigraphischen und chronologischen Kontext des AH X im Hohle Fels dar und

legen eine vorläufige Beschreibung der Hinterlassenschaften materieller Kultur aus diesem Horizont vor. Vor dem Hintergrund, dass wir bisher nur Teile von 6 m² des neuen Fundhorizonts und des darunterliegenden Fundhorizonts AH XI freigelegt haben, liefert der Beitrag erste Beobachtungen, die im weiteren Verlauf der Grabung überprüft werden müssen. Diese Ergebnisse legen nahe, dass Blattspitzen eher ein Merkmal im technologischen Repertoire der spätpleistozänen Neandertaler im Südwesten Deutschlands darstellen, als dass sie ein zuverlässiger kultureller stratigraphischer Marker für die letzte Phase des Mittelpaläolithikums wären.

Schlagwörter: Schwäbische Alb, Mittelpaläolithikum, Blattspitzengruppe, Datierung, Stratigraphie

Introduction

Early research into the Paleolithic of the Swabian Jura dates back to the beginnings of Ice Age archaeology in Central Europe in the 1860s (Fraas 1862). In the 1860s Oscar Fraas, who worked at the Königliches Naturalienkabinett in Stuttgart, conducted excavations at Hohlenstein-Bärenhöhle in the Lone Valley. Here, after initially having overlooked stone artifacts due to his focus on Ice Age fauna, he identified Middle Paleolithic finds that in the late 19th century were known to be associated with Neanderthals. Following his well-known excavation at the Schussenquelle near Bad Schussenried in 1866 (Fraas 1866, 1867; Schuler 1994), in 1870 and 1871 Fraas together with the pastor Theodor Hartmann began excavations at Hohle Fels in the Ach Valley (Fig. 1) on the northeastern edge of the town of Schelklingen (Fraas 1872; Conard and Wolf 2020; Walter 2021). This work led to the recovery of Magdalenian and Gravettian finds at

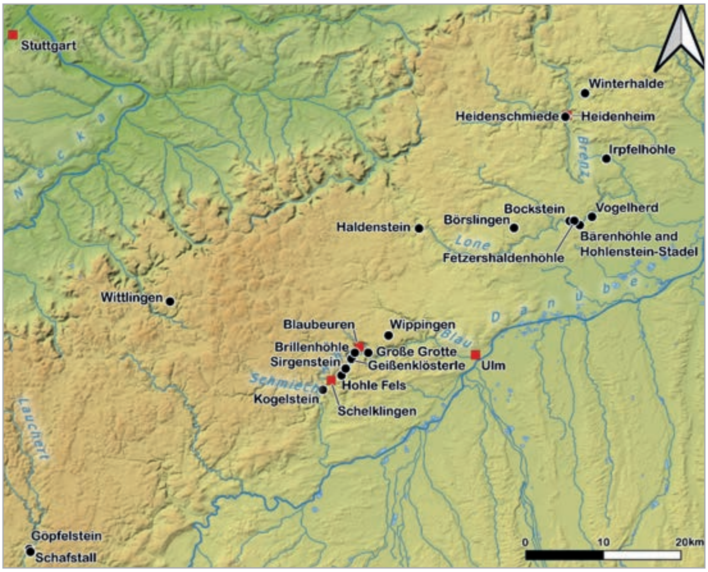


Fig. 1: Middle Paleolithic sites in the Swabian Jura. (Background map: https://doi.org/10.5281/zenodo.3460300).

Abb. 1: Mittelpaläolithische Fundstellen auf der Schwäbischen Alb. (Hintergrundkarte: https://doi.org/10.5281/zenodo.3460300).

Hohle Fels. Subsequent excavations most notably by Gustav Riek in 1958-1960 and by Joachim Hahn with interruptions from 1977-1996 also recovered significant material from the Magdalenian and the Gravettian. While Riek never published the results of his poorly documented excavations (Saier 1994), Hahn and his team published numerous field reports and a number of articles on this phase of research (Scheer 1994, 1999).

Following Hahn's death in 1997, Conard continued field work at Hohle Fels with excavations taking place every year from 1997-2021. This phase of research over the last 25 seasons has led to numerous important contributions to the region's Paleolithic record (Conard and Wolf 2020). Important in the current context is that this work, while greatly augmenting the Magdalenian and Gravettian assemblages from Hohle Fels, also uncovered a remarkably rich Aurignacian sequence that has received much international attention (Conard 2003, 2009, 2011, 2015; Conard and Bolus 2003; Conard et al. 2009; Bataille and Conard 2018) and a long Middle Paleolithic sequence, which has been described in a number of preliminary reports (Conard et al. 2012).

Among the important observations from the Middle Paleolithic of Hohle Fels is the radical drop of find density in the strata underlying the base of the Aurignacian deposits. This confirmed the observation from many other sites, including nearby Sirgenstein (Schmidt 1907, 1912) and Geißenklösterle (Hahn 1988; Conard et al. 2019a), that an occupational hiatus, or at a minimum a sharp drop in regional occupational intensity, separates the late Middle Paleolithic from the Aurignacian, thereby indicating that modern humans associated with the Aurignacian arrived in this part of the Upper Danube drainage during a period in which few or no Neanderthals occupied the regions (Conard et al. 2006). As the excavation team dug deeper into the Middle Paleolithic strata of Hohle Fels the densities of archaeological materials remained low for the most part, indicating that the cave was repeatedly visited by Neanderthals and that they usually inhabited the site for short periods in relatively small groups (Conard et al. 2006, 2012). This situation is broadly similar to that documented at the nearby site of Geißenklösterle 2 km further downstream in Ach Valley (Conard et al. 2019b). For the first time in 2020, excavators reached Middle Paleolithic deposits with much higher find densities that form the focus of this paper.

Stratigraphy of the Middle Paleolithic horizons

Following the conventions going back many generations in the Swabian Jura, geological horizons (GHs) are designated by Arabic numbers and archaeological horizons (AHs) by Roman numeral (Schmidt 1912; Bolus and Conard 2012). Over the course of excavation at Hohle Fels the team has identified six main Middle Paleolithic GHs that correspond to six AHs. These layers are all characterized by a matrix of silty clay with varying amounts of limestone debris from the ceilings and walls of the cave. The matrix comes from sediments that entered the cave through a chimney at the back of the cave and through cracks in the roof. Fine grain sediments also originate from weathered limestone and aeolian input from the entrance of the cave (Miller 2015). The bulk of the sediment accumulated to form a sediment cone in the main hall of the cave. The strata from the Middle Paleolithic at Hohle Fels correspond to GH 9 – 14 and AH VI – XI (Conard and Janas 2021).

Figure 2 presents north-south Profile 2 that provides an overview of the sequence, although, due to lateral facies shifts, the details of the sequence vary depending where one examines the stratigraphy. In general, the layers slope downward toward the north and the west (Fig. 3). This corresponds to a slope downward from the sediment cone in the main hall of the cave toward the entrance of the cave which opens toward the Ach River (Hahn 1999; Miller 2015; Barbieri et al. 2018, 2021). Depending on climatic conditions the surface of the cave could be relatively stable, but phases of downslope movement were common, and a major phase of erosion out the entrance to the cave with deposition toward the floodplain of the Ach Valley occurred in connection with the Last Glacial Maximum (LGM). This creates a situation in which the Magdalenian deposits rest directly on the Gravettian deposits with no sediments from the LGM. Barbieri and colleagues (2018, 2021) have reconstructed this process in detail and have documented the presence of sediments originating from the cave in front of Hohle Fels. Distinctive erosional channels are also visible at the top of the Gravettian deposits, which makes it difficult to separate cleanly the clayey silts that form the matrix of both the Gravettian and Magdalenian deposits (Scheer 1999). Such major phases of erosion are limited to the LGM and there appear to be no major sedimentary gaps in the Gravettian, Aurignacian and Middle Paleolithic sequences (Miller 2015). The zones of low find density between the Middle Paleolithic and the Aurignacian deposits and between the Aurignacian and Gravettian deposits (Fig. 3) support the hypotheses

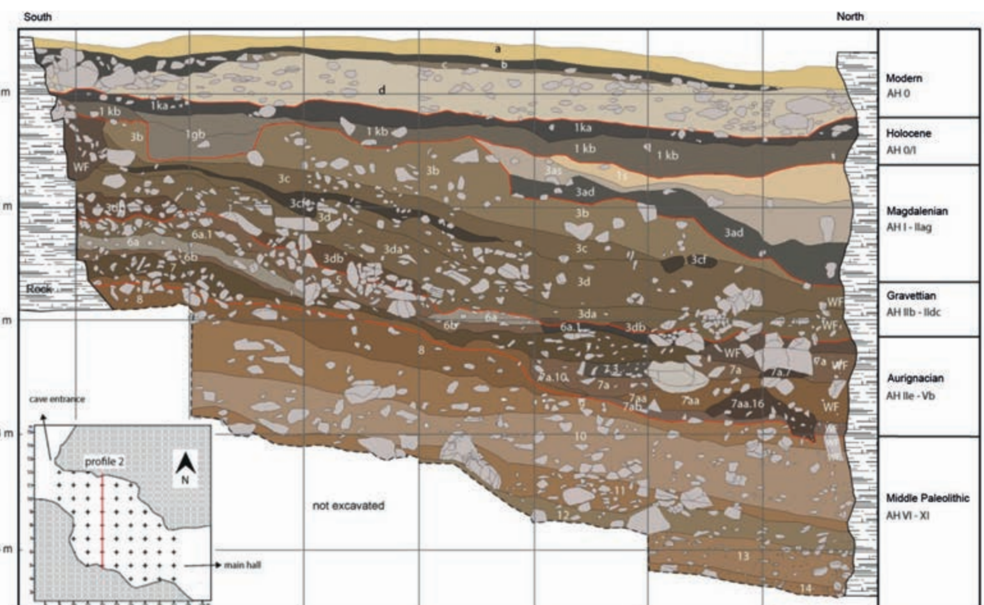


Fig. 2: Hohle Fels. Profile 2 with geological and archaeological horizons (after Conard and Janas 2021).

Abb. 2: Hohle Fels. Profil 2 mit geologischen und archäologischen Horizonten (nach Conard und Janas 2021).

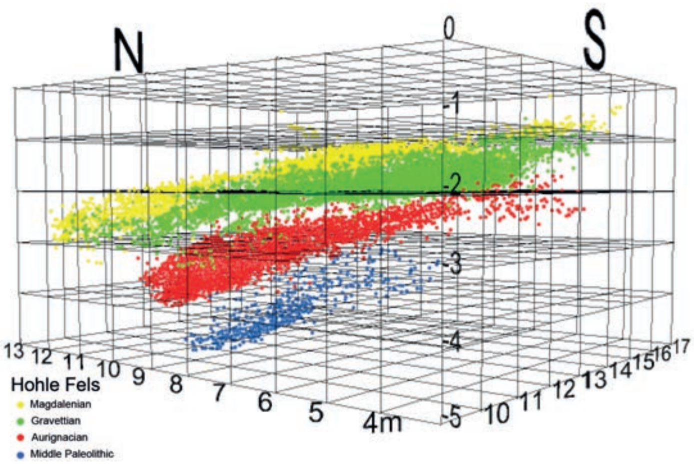


Fig. 3: Hohle Fels. Plot of the lithic artifacts from the Middle Paleolithic, Aurignacian, Gravettian and Magdalenian horizons (figure: A. Janas).

Abb. 3: Hohle Fels. Verteilung der Steinartefakte aus den mittelpaläolithischen, aurignacien-, gravettien- und magdalénienzeitlichen Horizonten (Abbildung: A. Janas).

for discontinuity in the use of the site between these perods (Conard et al. 2006; Conard and Moreau 2004).

The Middle Paleolithic deposits at Hohle Fels have characteristics that suggest a distinct mode of deposition when compared with those from the Upper Paleolithic (Miller 2015). In particular, AH IX and AH VIII are composed of calcareous clay that has been partially altered to phosphate through the decay of organic matter. Layers of clay that exhibit a clear horizontal orientation characterize these deposits, and are particularly prominent in AH IX. This suggests that, in contrast to the Upper Paleolithic deposits, low-energy flowing water played a role in the accumulation of these Middle Paleolithic layers. Other evidence for the role of water as a depositional agent can be found in AH IX, which contains clay intercalation and silty clay infillings. Sand-sized phosphate grains are common within both layers and are mainly derived from carnivore coprolites. Although similar grains are found throughout the Pleistocene deposits at Hohle Fels, they are noticeably more frequent in the Middle Paleolithic layers. In contrast to the coprolite fragments found in the Upper Paleolithic deposits, those found in the Middle Paleolithic are generally angular and subangular, indicating a low influence of downslope movement and cryoturbation on these layers (Miller 2015). Micromorphology samples from AH IX and AH VIII lack evidence for anthropogenic input, although lithic artifacts in both layers attest to a low level use of the cave by Neanderthals.

Recent analysis of geoarchaeological samples from AH XI paint a more nuanced picture of depositional processes acting at Hohle Fels during the Middle Paleolithic. Block sample HF-20-3123 includes sediments from AH XI and part of a combustion feature, designated AH XI Feature 1. As in AH VIII and AH IX, the matrix appears as partially phosphatized calcareous clay, but lacks any visible bedding structures (Fig. 4). The coarse components include sand-sized grains of phosphate, burnt and unburnt bone fragments, and fine gravel-sized fragments of limestone which exhibit both random and sub-horizontal, parallel orientations. Anthropogenic input into AH XI is much more pronounced when compared with AH VIII or AH IX, and it

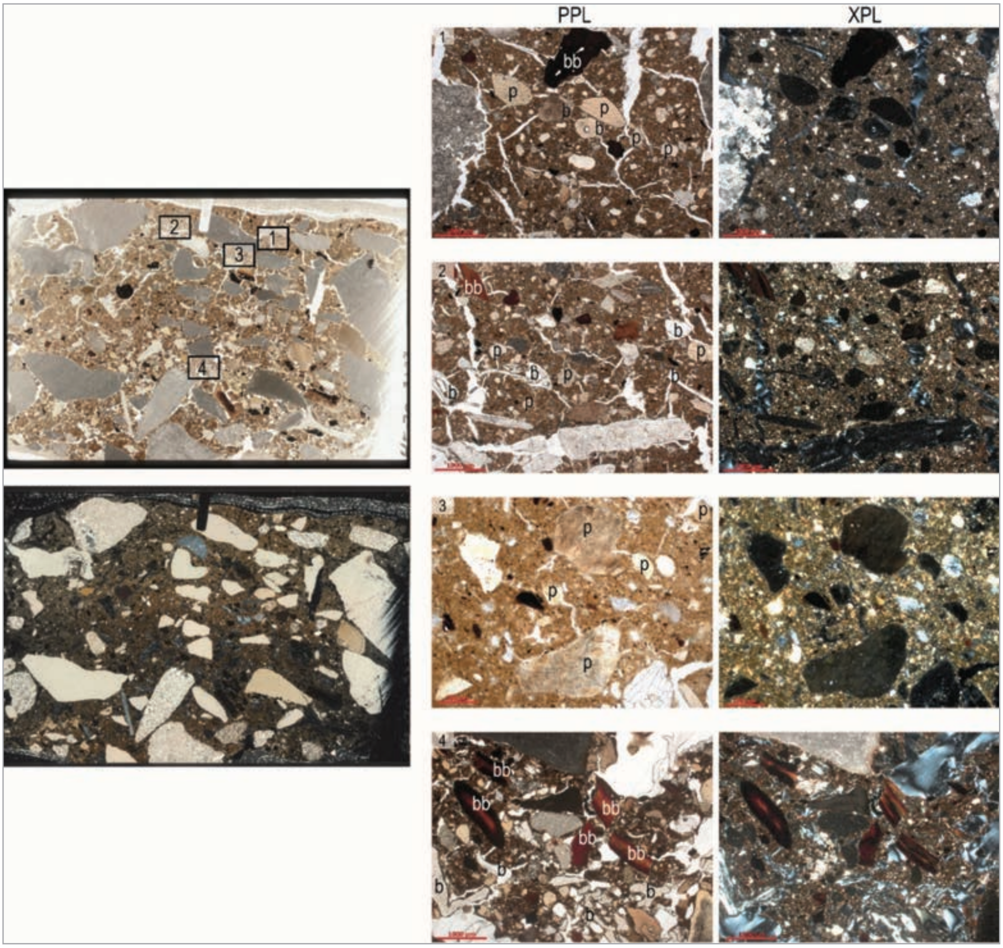


Fig. 4: Hohle Fels. Micromophological thin-sections from Middle Paleolithic horizons. Plane-polarized (PPL) and cross-polarized (XPL) light scans of HF U:20 ID:3123 from GH 14 AH XI and BEF 1. As a reference, the components have the following labels: (b) unburnt bone, (bb) burnt bone, and (p) phosphate grain. The photomicrographs are in PPL and XPL. (1) and (2) Overviews of the main components from GH 14 AH IX and the groundmass, with no bedding structures visible. (3) Detail of the phosphatic grains (p). (4) Overview inside the combustion feature (BEF 1) where the increase of the anthropogenic content is clear (photos: D. Marcazzan).

Abb. 4: Hohle Fels. Mikromorphologische Dünnschliffe aus den mittelpaläolithischen Horizonten. Linear polarisierte (PPL) und kreuzpolarisierte (XPL) Lichtscans von HF U:20 ID:3123 aus dem geologischen Horizont 14 archäologischer Horizont XI und Befund 1. Planpolarisierte (PPL) und kreuzpolarisierte (XPL) Lichtscans von HF-20-3123 aus GH 14 AH XI und BEF 1. Als Referenz sind die Komponenten wie folgt gekennzeichnet: (b) nicht verbrannter Knochen, (bb) verbrannter Knochen und (p) Phosphatkorn. Die Mikrofotografien sind in PPL und XPL. (1) und (2) Übersichtsaufnahmen der Hauptbestandteile von GH 14 AH IX und der Grundmasse, wobei keine Strukturen in der Schichtung sichtbar sind. (3) Detail der phosphatischen Körner (p). (4) Überblick über das Innere des Brandbefundes (BEF 1), in der die Zunahme des anthropogenen Anteils deutlich zu erkennen ist (Fotos: D. Marcazzan).

becomes predominant within the Feature 1 (Fig. 4). Micromorphological samples confirm that cryoturbation generally does not impact the accumulation of the Middle Paleolithic layers at Hohle Fels. Comparing AH XI with the stratigraphically higher layers of AH VIII and AH IX, we see that running water played a more significant role in later phases of the Middle Paleolithic, although slope action may account for the presence of oriented fragments of limestone found in AH XI. AH XI also records evidence for a marked increase in anthropogenic input to the deposits, in the form of burnt and unburnt bone fragments.

Discovery and context of the new leaf point

On July 2, 2020 Mario Mata-Gonzalez excavated a leaf point, in German *Blattspitze*, knapped from Jurassic chert from the Swabian region. The find lay in a silty-clay matrix with angular and slightly rounded limestone fragments and blocks of limestone debris with dimensions up to 20-30 cm (Fig. 5, Fig. 6). The *Blattspitze* lay in AH X in a roughly horizontal position about 1.2 meters south of the wall of the cave in sediments containing numerous lithic artifacts and fragments of burnt bone and diverse faunal material. It is difficult to comment on the spatial distribution of finds since so far only parts of six square meters have been excavated. What, however, is clear is that the leaf point comes from deposits with far higher find densities of all classes of archaeological material than the overlying deposits of AH IX, VIII, VII and VI (Fig. 7). Clearly, Neanderthals were spending more time in Hohle Fels during this phase of occupation and presumably engaging in more diverse activities than during the subsequent phases of occupation.

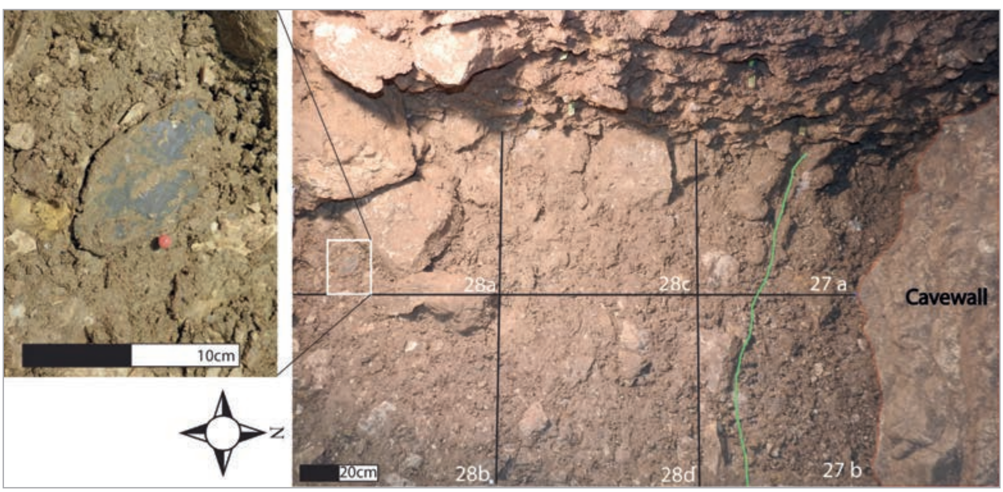


Fig. 5: Hohle Fels. Position of the leaf point found July 2, 2020 in the second Abtrag of AH X. The green line shows the limit of the wall-facies (photos and figure: A. Janas).

Abb. 5: Hohle Fels. Position der Blattspitze, gefunden am 2. Juli 2020 im zweiten Abtrag des AH X. Die grüne Linie zeigt die Grenze der Wandfazies an (Foto und Abbildung: A. Janas).

The new leaf point has dimensions of 7.6 cm long, 4.1 cm wide, 0.9 cm thick and weighs 28 grams. An accompanying paper in this volume presents a detailed techno-functional assessment of the *Blattspitze* and concludes that it served as a projectile point, most likely hafted on a thrusting spear, although further research and larger samples of such tools would be helpful in testing this interpretation (Rots et al. 2021). Here we focus our attention on the stratigraphic, chronological and archaeological context of the find and consider the implications of this artifact.

Fig. 6: Hohle Fels. Leaf point from AH X, length 7.6 cm, width 4.1 cm, thickness 0.9 cm, weight 28 grams (photo: A. Janas).

Abb. 6: Hohle Fels. Blattspitze aus AX X, Länge 7,6 cm, Breite 4,1 cm, Dicke 0,9 cm, Gewicht 28 Gramm (Foto: A. Janas).

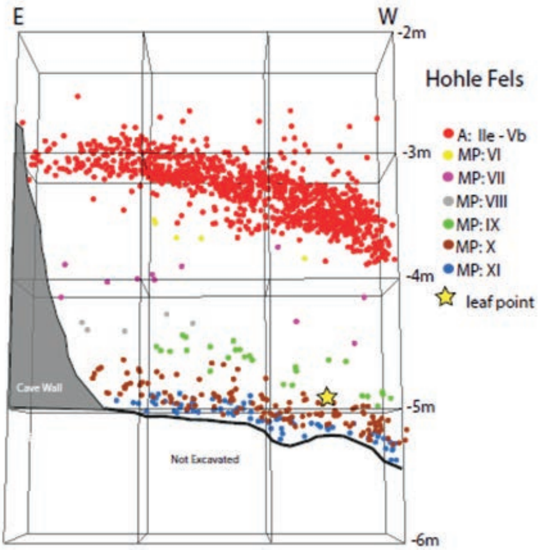


Fig. 7: Hohle Fels. Profile projection of the lithic artifacts from the Middle Paleolithic and Aurignacian horizons. Star indicates the position of the leaf point. Note the increased find densities in AH XI and X (figure: A. Janas).

Abb. 7: Hohle Fels. Profilprojektion der Steinartefakte aus dem Mittelpaläolithikum und Aurignacien. Der Stern zeigt die Lage der Blattspitze an. Die Zunahme der Funddichte in AH XI und X wird hier deutlich (Abbildung: A. Janas).

Leaf points and the *Blattspitzengruppe* of central Europe have long been viewed as belonging to the last phase of the Middle Paleolithic (Bosinski 1967; Conard and Fischer 2000; Bolus 2013). Prior to our work, the best-preserved leaf-points from the Swabian Jura came from Haldenstein Cave near the source of the Lone and were discovered by Gustav Riek's team in 1936 (Fig. 8, Fig. 9) (Riek 1938). The new find which underlies the base of the Aurignacian deposits at

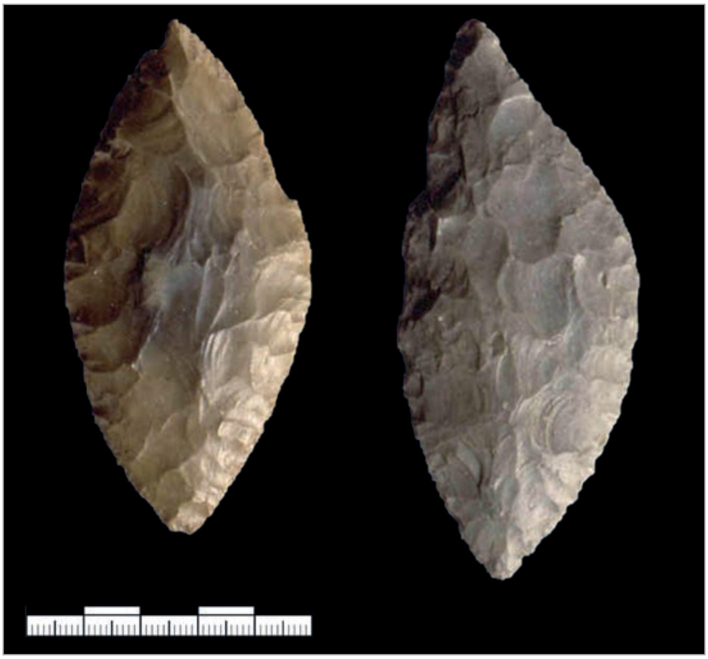


Fig. 8: Haldenstein. Leaf points from Haldenstein Cave (modified after Bosinski 1967).

Abb. 8: Haldenstein. Blattspitzen von der Haldenstein-Höhle (verändert nach Bosinski 1967).

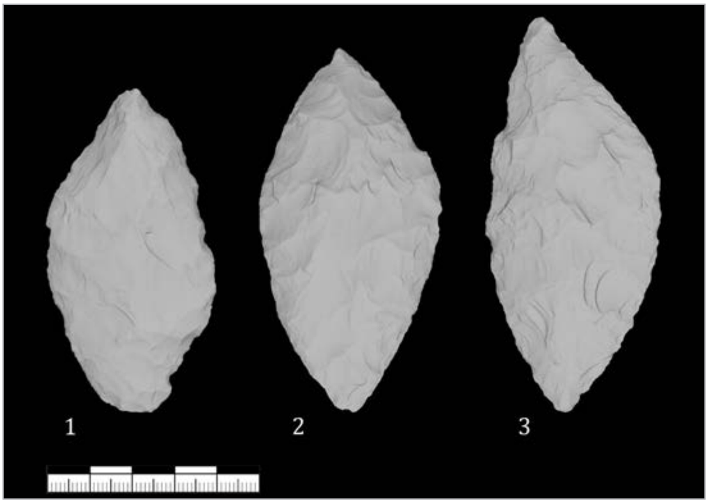


Fig. 9: 3-D models of the leaf-points from: 1 Hohle Fels, 2 and 3 Haldenstein (3D-Scans: M. McCartin).

Abb. 9: 3-D Modelle von Blattspitzen: 1 Hohle Fels, 2 und 3 Haldensteinhöhle (3D-Scans: M. McCartin).

Hohle Fels by 1.2 meters as well as multiple Middle Paleolithic find horizons shows that the leaf point and the other finds from AH X were not used by late Neanderhals during the final phase of the Middle Paleolithic. The base of the Aurignacian in the Ach Valley sites of Hohle Fels and nearby Geißenklösterle dates to roughly 42 ka cal BP (Conard 2009; Higham et al. 2012; Bataille and Conard 2018). The last Middle Paleolithic horizons in the Swabian Caves usually date to roughly 45 ka BP (Richter et al. 2000; Higham et al 2012; Richard et al. 2019). To determine the age of AH X and the new leaf point, new radiometric dates would be needed.

Radiometric dating

Working closely with the excavation team and Chantal Tribolo in Bordeaux, Maïlys Richard, who earlier conducted ESR/U-series dating at Geißenklösterle and Hohlenstein-Stadel (Richard et al. 2019, 2020) agreed to use the same methods to try to establish a chronology for the Middle Paleolithic of Hohle Fels, which dates beyond the reliable limit of radiocarbon dating. We sampled four herbivore teeth including one equid molar, one rhinoceros molar, and two cervid molars (Table 1), from AH IX for combined electron spin resonance-uranium series (ESR/U-series) dating. These finds all overlay the AH X, which yielded the new leaf point in 2020. This dating method is based on the property of the enamel hydroxyapatite to record a dose of ionizing rays

Sample #	Coordinates (m)			Taxon	Equivalent dose (Gy)	Dose rate (µGy/a)			Age (ka)
	x	y	z			Sediment (β + γ)* + cosmic	Tooth (α + β)	Total (α+ β + γ)	
HF 3008	27	60	4.85	*Rhinoceros*	10.92 ± 1.51	184 ± 16	1 ± 1	185 ± 16	59 ± 10
HF 2956	91	18	4.55	*Equus*	10.93 ± 0.69	167 ± 16	7 ± 1	174 ± 16	63 ± 7
HF 2976	83	17	4.59	*Cervus*	13.93 ± 1.00	232 ± 17	-	232 ± 17	60 ± 6
HF 2997	32	91	4.85	*Cervus*	15.70 ± 1.38	211 ± 16	8 ± 1	219 ± 16	72 ± 8

Table 1: Hohle Fels. ESR/U-series ages. Coordinates, taxonomic determination, equivalent dose, dose rate and ESR/U-series ages of the teeth in this study. All ages were calculated using the US model (Grün et al. 1988) except for HF 2956 for which the EU model was applied (see text). The dose rate from the sediment was derived taking into account a water content (wet weight %) of 19 ± 2% (measured value).
*For HF 2997, HF 2976 and HF 3008, the external part of the enamel was in contact with the sediment from which the beta dose rate was derived using measured U (0.93 ± 0.01 ppm), Th (3.87 ± 0.04 ppm) and K (0.19 ± 0.01%) content. For HF 2956, the enamel was covered by cementum from which the beta dose rate was derived using U-content measured in this dental tissues.

Tabelle 1: Hohle Fels. ESR/U-Reihen Datierungen. Koordinaten, taxonomische Bestimmungen, Äquivalenzdosis, Dosisrate und ESR/U-Reihen-Datierungen der in dieser Studie analysierten Zähne. Alle Datierungen wurden mit dem US Model (Grün et al. 1988) berechnet, Ausnahme ist HF 2956, welches mit dem EU Model berechnet wurde (siehe Text). Die Dosisrate des Sediments kam unter Beachtung des Wassergehalts (Nassgewicht %) von 19 ± 2% (gemessener Wert) zu Stande.
*Bei HF 2997, HF 2976 und HF 3008, war der äußere Teil des Zahnschmelzes in Kontakt mit dem Sediment, von dem die Beta-Dosis stammt, dazu wurden U (0,93 ± 0,01 ppm), Th (3,87 ± 0,04 ppm) und K (0,19 ± 0,01%) gemessen. Bei HF 2956 war der Zahnschmelz von Zahnzement bedeckt, aus dem die Beta-Dosisrate durch den im Zahngewebe gemessenen U-Gehalt zustande kommt.

produced from radioactive disintegrations in the sample and the surrounding sediment, as well as from cosmic rays. The teeth themselves provide radiation from U-series decay, while the sediments contribute radiation from U and Th-series decay, and from radioactive K. The dose absorbed is a function of the burial time and the radioactivity to which the teeth have been exposed. An age is obtained by dividing the equivalent dose - the dose recorded by the sample since burial - by the dose rate, which corresponds to the radioactive dose received per year.

Richard prepared and measured samples according to the procedure for ESR and U-series dating in established protocols (Richard et al. 2015). The carbonate hydroxyapatite T1-B2 signal (Grün 2000) was measured five times on one natural aliquot and 10 artificially irradiated aliquots (from 2.2 to 150 Gy) using an EMX micro-6/1 Bruker ESR spectrometer. Irradiation using a Gammacell-1000 equipped with a ^{137}Cs source and measurements took place at the CENIEH (Burgos, Spain). The U-series measurements were conducted at the LSCE (Gif-sur-Yvette, France). U and Th fractions were combined for the measurement on a Multi-Collector inductively coupled plasma mass spectrometer (MC-ICP-MS) Thermo Scientific TM Neptune Plus fitted with a jet pump interface and a desolvating introduction system (aridus II) following Pons-Branchu et al. (2014). We used U-content, $^{234}U/^{238}U$ and $^{230}Th/^{234}U$ to model the alpha and beta dose rate from the dental tissues (enamel, dentine and, for the equid tooth, cementum) using the US model (Grün et al. 1988) with the DATA program (Grün 2009). The gamma dose from the sediment and the cosmic dose rate were measured *in situ* using Al_2O_3:C dosimeters, placed

Sample #	Tissue	Lab #	^{238}U (ppb)	$^{234}U/^{238}U$	$^{230}Th/^{234}U$	Enamel thickness (µm)			p-value
						Initial	Removed side 1	Removed side 2	
HF 3008	enamel	8516	10.36 ± 0.09	1.8527 ± 0.0034	0.1464 ± 0.0230	2439 ± 244	312 ± 31	80 ± 8	1.30 ± 0.79
	dentine	8517	1698.57 ± 13.73	1.8891 ± 0.0004	0.0769 ± 0.0004				2.14 ± 0.76
HF 2956	enamel	8583	16.05 ± 0.13	1.1256 ± 0.0038	0.9165 ± 0.0131	1168 ± 117	312 ± 31	105 ± 11	-1
	dentine	8584	78.07 ± 0.63	1.6344 ± 0.0005	0.1238 ± 0.0029				-1
	cementum	8585	387.79 ± 3.10	1.5149 ± 0.0006	0.1900 ± 0.0013				-1
HF 2976	enamel	8586	2.24 ± 0.02	1.6163 ± 0.0045	0.2396 ± 0.0382	687 ± 69	195 ± 20	17 ± 10	-0.07 ± 0.4
	dentine	8587	259.09 ± 2.08	1.7021 ± 0.0004	0.0947 ± 0.0012				0.00 ± 1.41
HF 2997	enamel	8588	58.96 ± 0.47	1.8752 ± 0.0008	0.1030 ± 0.0054	818 ± 82	13 ± 10	43 ± 4	3.84 ± 0.75
	dentine	8589	4918.24 ± 39.68	1.8987 ± 0.0002	0.0742 ± 0.0002				5.81 ± 0.45

Table 2: Hohle Fels. U-series data (U-content and isotopic ratios), initial and removed enamel thickness on side 1 (dentine) and side 2 (cementum or sediment) (used for beta attenuation) and p-values (describing U-uptake, ranging from -1, for an early uptake which occurred soon after burial, to positive values, describing a recent uptake) obtained on the teeth.

Tabelle 2: Hohle Fels. U-Reihen-Daten (U-Gehalt und Isotopenverhältnisse), ursprüngliche und entfernte Zahnschmelz-Dicke auf Seite 1 (Dentin) und Seite 2 (Zement oder Sediment) (für die Beta-Dämpfung verwendet) und p-Werte (zur Beschreibung der U-Aufnahmerate, von -1, für eine frühe Aufnahme direkt nach der Einbettung, bis zu positiven Werten, welche eine kürzliche Aufnahme beschreiben), die mit den Zähnen erzielt wurden.

in the section for 12 months and analyzed following Kreutzer et al. (2018). We used a mean value of 167 ± 16 µGy/a for the age calculation. For all samples, except for HF 2956 that was covered by cementum (see Table 1), we derived the beta dose rate from U, Th and K content measured in the sediment using a high resolution low-background gamma-ray spectrometer applying the conversion factors of Adamiec and Aitken (1998) available in the DATA program.

Table1, Table 2 and Figure 10 report the ages for the four samples. Richard calculated ages using the US model except for HF 2956, for which an early uptake (EU) was assumed (Table 2). Indeed, for this sample, high $^{230}Th/^{234}U$ in the enamel (0.9165 ± 0.0131), limits the use of the US model, because the U-series age on this tissue is higher than the EU age (Grün et al. 1988). However, due to low U-content in the teeth (< 5 ppm; Table 2), the alpha and beta dose rates from the dental tissues are negligible. Thus, EU or US age cannot be distinguished except for HF 2997, for which positive p-values describe a recent uptake. The combined ESR/U-series ages range from 72 ± 8 ka (HF 2997) to 59 ± 10 (HF 3008). Based on the four results, we obtained a weighted mean age of 63 ± 4 ka for the AH IX overlying the AH X from where the *Blattspitze* originated. This result from four distinct measurements on teeth of large mammals confirms our suspicion that the *Blattspitze* does not come from the end of the Middle Paleolithic.

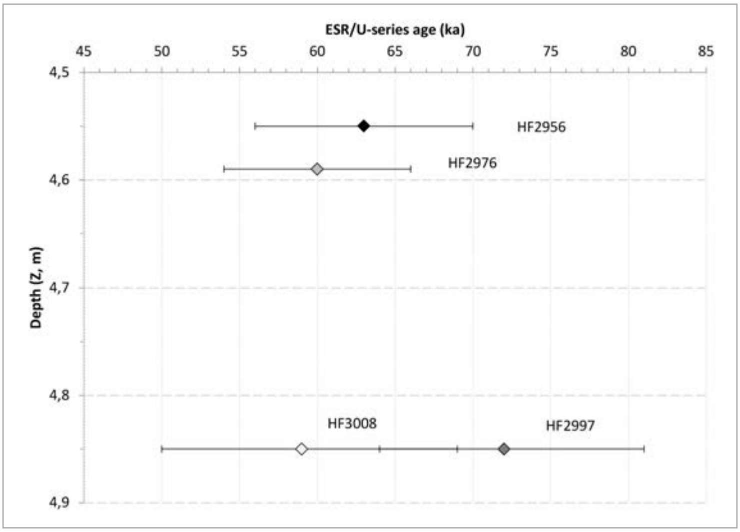
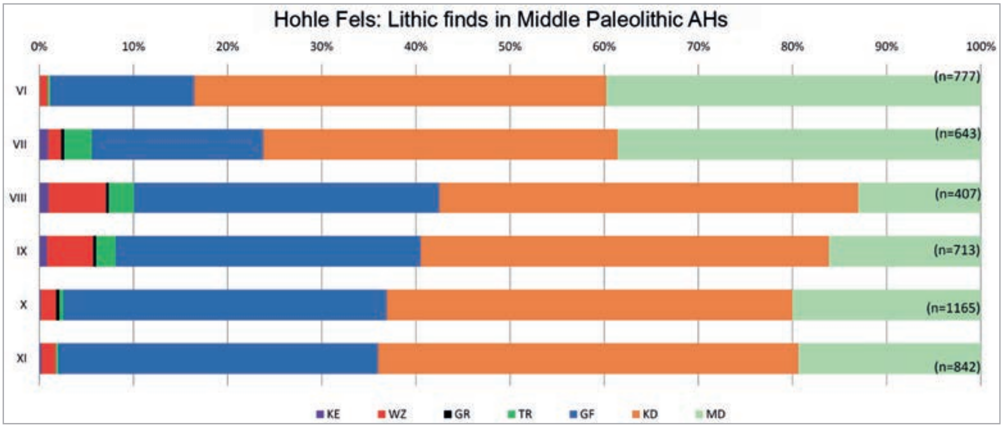


Fig. 10: Hohle Fels. Representation of the ages obtained as a function of the sample depth (figure: M. Richard).

Abb. 10: Hohle Fels. Darstellung der ESR Datierungen in Abhängigkeit zur Probentiefe (Abbildung: M. Richard).

Find densities and the lithic assemblage of AH X

The following description of lithic finds from the Middle Paleolithic layers of AH X and XI is based on piece-plotted finds and the finds recovered waterscreening during the excavation campaigns of 2019 and 2020. While we focus on AH X, we present information on the other assemblages from Hohle Fels to provide an overview on the size and general features of the Middle Paleolithic assemblages (Fig. 11). Only small parts of layers X (V=0.2 m^3) and XI (V=0.8 m^3)



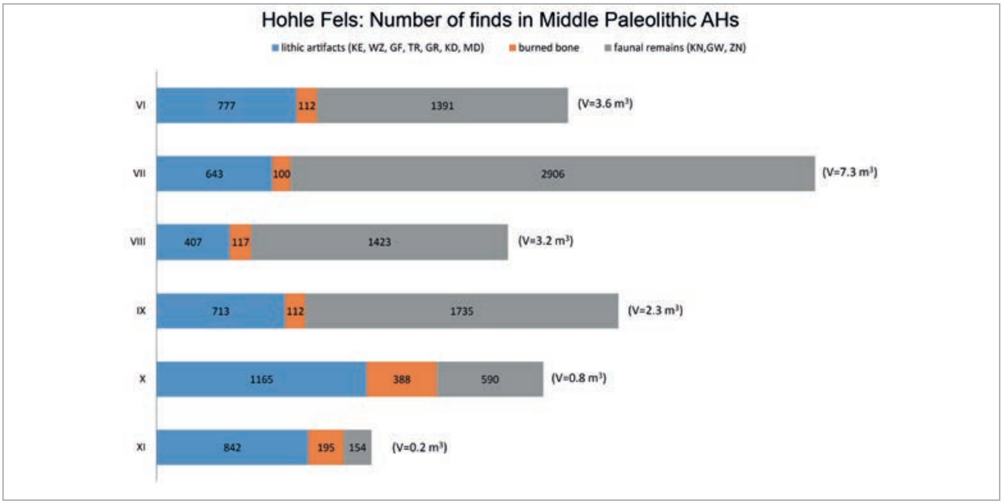
AH	KE	WZ	GR	TR	GF	KD	MD	Total
VI	0	7	0	2	119	340	309	777
VII	6	9	2	19	117	242	248	643
VIII	4	25	1	11	132	181	53	407
IX	6	35	2	15	231	309	115	713
X	2	19	4	5	400	502	233	1165
XI	2	13	0	2	286	376	163	842

Fig. 11: Hohle Fels. Overview of the stone artifacts from the entire Middle Paleolithic. KE, core; WZ, tool; GR, cobble; TR, angular debris; GF, flake; FD, small debris; MD, microdebitage (figure: A. Janas).

Abb. 11: Hohle Fels. Übersicht zu den Steinartefakten aus dem gesamten Mittelpaläolithikum. KE, Kern; WZ, Werkzeug; GR, Geröll; TR, Trümmer; GF, Grundform; KD, Kleindebitage; MD, Mikrodebitage (Abbildung: A. Janas).

have been excavated so far. Nonetheless, it is already apparent that AH X and XI are very rich in finds compared to the overlying Middle Paleolithic horizons. So far, AH X and XI have produced 1,165 and 842 lithic artifacts, with lithic densities of 1,456 and 4,210 finds per m^3 (Fig. 12). The overlying AHs VI – IX have far lower find densities ranging from 216 – 310 finds per m^3. The proportions of lithic artifacts, burnt bones and faunal remains also show noteworthy variation with lithic artifacts and burnt bones being more abundant in AH X and XI (Fig. 12). Faunal remains, however, are not so frequent in these horizons. This is likely the result of increased human activity during the formation of the lower layers. This increase is nevertheless far below the find densities observed for the Aurignacian (AH III, IV, Va, Vaa, Vb) (Fig.13).

The main raw material used in AH X is Jurassic chert (Table 3). The local Jurassic chert is beige or gray and several outcrops of this material are located in the Blaubeurer Jura (Floss and Schürch 2015; Schürch 2017). Beyond gray Jurassic chert, brown varieties of Jurassic chert are present in layer X. Excavators also recovered fragments of sandstone. Other lithic raw materials including microquartzite, quartz and quartzite come from the gravels of the Danube and also occur on the plateau of the Blaubeurer Jura in the gravels of the ancient Danube (*Urdonau*). One of the quartz artifacts is an unretouched flake, and the other is a large heavily used ham-



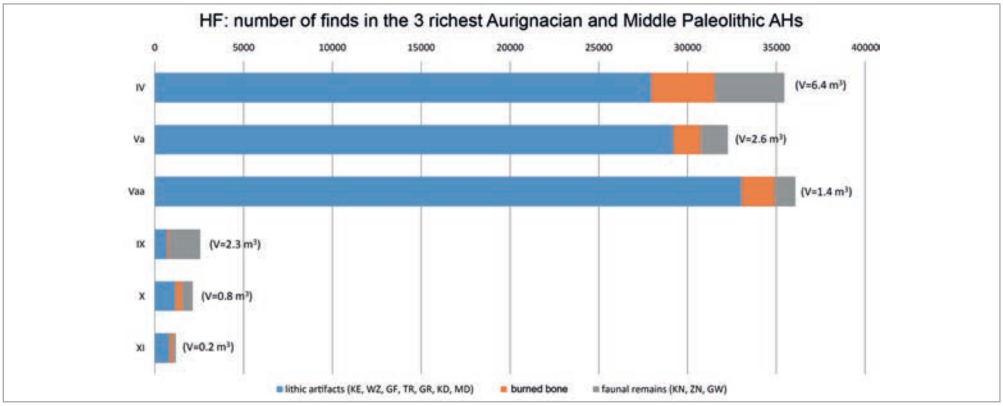
AH	lithic artifacts (KE, WZ, GF, TR, GR, KD, MD)	lithic artifacts per m³	burned bone	burned bone per m³	faunal remains (KN, GW, ZN)	faunal remains per m³
VI	777	216	112	31	1391	386
VII	643	88	100	14	2906	398
VIII	407	127	117	37	1423	444
IX	713	310	112	49	1735	754
X	1165	1456	388	485	590	738
XI	842	4210	195	975	154	770

Fig. 12: Hohle Fels. Overview of finds and find densities from all Middle Paleolithic archaeological horizons. KE, core; WZ, tool; GR, cobble; TR, angular debris; GF, flake; FD, small debris; MD, microdebitage (figure: A. Janas).

Abb. 12: Hohle Fels. Übersicht zu den Funden und Funddichten aus allen mittelpaläolithischen archäologischen Horizonten. KE, Kern; WZ, Werkzeug; GR, Geröll; TR, Trümmer; GF, Grundform; KD, Kleindebitage; MD, Mikrodebitage (Abbildung: A. Janas).

merstone with maximum dimension of 100 mm and weighing 539 g (Conard and Janas 2021, Fig. 39 Nr. 16). Based on our initial sample, hard-hammer percussion was a frequent mode of knapping, although other modes of knapping were used, for example, during the bifacial shaping of the *Blattspitze*. The percentage of raw materials varies slightly between the Middle Paleolithic layers at Hohle Fels. In all layers, however, Jurassic chert is by far the dominant raw material. Comparable raw material compositions can also be found at the other Middle Paleolithic sites of the Ach and Blau valleys (Çep 2013; Conard et al. 2019b).

All cores from AH X except for one core of microquartzite are made of Jurassic chert (Fig. 14). Thus, no raw materials from distant raw material sources were used. In AH X, a wide variety of cores is present. They include Levallois cores (n=3), one of which with laminar preparation; cores on ventral surfaces of flakes (n=2); single platform flake cores (n=1); as well as non-diagnostic flake cores (n=2). All of these classes of cores have previously been described for the



AH	lithic artifacts (KE, WZ, GF, TR, GR, KD, MD)	lithic artifacts per m³	burned bone	burned bone per m³	faunal remains (KN, GW, ZN)	faunal remains per m³
IV	27974	4371	3543	554	3942	616
Va	29227	11241	1516	583	1535	590
Vaa	33058	23613	1851	1322	1163	831
IX	713	310	112	49	1735	754
X	1165	1456	388	485	590	738
XI	842	4210	195	975	154	770

Fig. 13: Hohle Fels. Comparison of finds from the richest Aurignacian and Middle Paleolithic archaeological horizons. KE, core; WZ, tool; GR, cobble; TR, angular debris; GF, flake; FD, small debris; MD, microdebitage; KN, bone; GW, antler; ZN, teeth (figure: A. Janas).

Abb. 13: Hohle Fels. Vergleich der Funde aus den fundreichsten aurignacienzeitlichen und mittelpaläolithischen archäologischen Horizonten. KE, Kern; WZ, Werkzeug; GR, Geröll; TR, Trümmer; GF, Grundform; KD, Kleindebitage; MD, Mikrodebitage; KN, Knochen; GW, Geweih; ZN, Zahn (Abbildung: A. Janas).

Table 3: Hohle Fels. Raw material composition of a sample of lithic single finds from AH X.

Tabelle 3: Hohle Fels. Rohmaterialzusammensetzung einer Stichprobe der lithischen Einzelfunde aus AH X.

Raw materials	n	Percentage
Jurassic chert	113	93.4%
Microquartzite	3	2.5%
Quartz	2	1.7%
Quartzite	1	0.8%
River Cobble	1	0.8%
Sandstone	1	0.8%
Total	**121**	**100%**

Middle Paleolithic of the Swabian Jura. Levallois cores are abundant in almost all Middle Paleolithic assemblages of the Swabian Jura (Bolus 2011; Bolus and Conard 2019; Çep 2019). Flake cores on ventral faces have been reported at Große Grotte before (Frick et al. in prep.). The combination of a Levallois core on the upper side and laminar preparation on the under-side has also been observed before at Heidenschmiede (Çep et al. 2021).

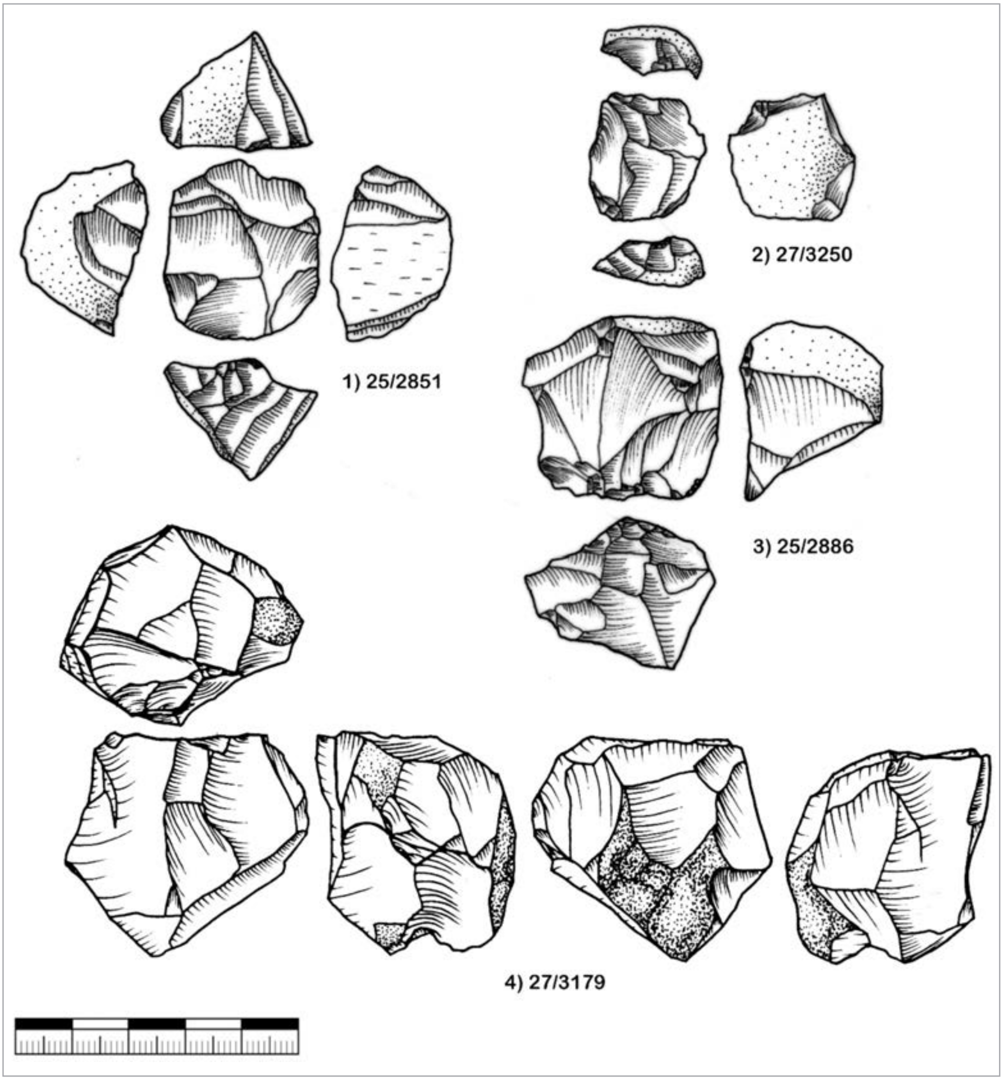


Fig. 14: Hohle Fels. Cores from AH X: 1) Levallois core with a laminar preparation on the lower side, Jurassic chert; 2) Levallois core, Microquartzite; 3) non-diagnostic flake core, Jurassic chert; 4) platform flake core, Jurassic chert (drawings: 1-3 B. Schürch; 4 after Conard and Janas 2021).

Abb. 14: Hohle Fels. Kerne aus AH X: 1) Levallois-Kern mit lamellarer Präparation auf der Unterseite, Jurahornstein; 2) Levallois-Kern; Mikroquarzit 3) Undiagnostischer Abschlag-Kern; Jurahornstein 4) Plattform-Kern. Jurahornstein (Zeichnungen: 1-3 B. Schürch; 4 nach Conard und Janas 2021).

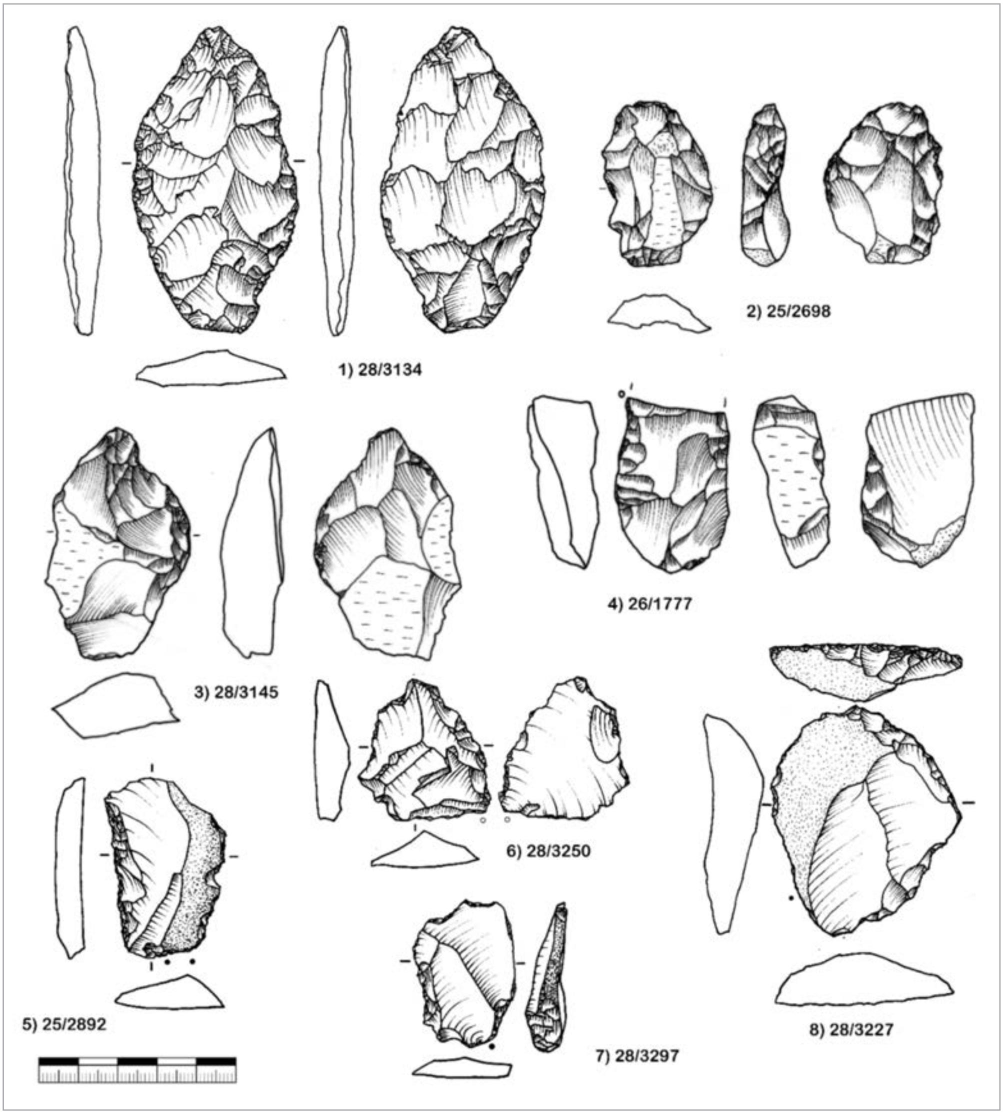


Fig. 15: Hohle Fels. Tools from AH X: 1) leaf point, Jurassic chert; 2) bifacial side-scraper, burnt Jurassic chert; 3) bifacial piece, Jurassic chert; 4) bifacial piece, Jurassic chert; 5) side-scraper, Jurassic chert; 6) side-scraper, Jurassic chert; 7) retouched *éclat débordant*, Jurassic chert; 8) side-scraper, Jurassic chert (drawings: 1, 5-8 after Conard and Janas 2021; 2-4 B. Schürch).

Abb. 15: Hohle Fels. Werkzeuge aus dem AH X: 1) Blattspitze, Jurahornstein 2) bifazieller Schaber, gebrannter Jurahornstein; 3) bifazielles Stück, Jurahornstein; 4) bifazielles Stück, Jurahornstein; 5) einfacher Schaber; Jurahornstein; 6. Schaber, Jurahornstein; 7. retuschierter *éclat débordant*, Jurahornstein; 8. Schaber, Jurahornstein (Zeichnungen: 1, 5-8 nach Conard und Janas 2021; 2-4 B. Schürch).

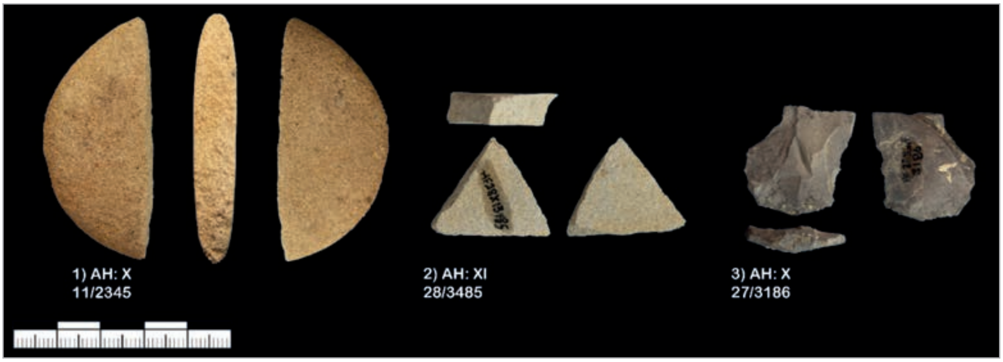


Fig. 16: Hohle Fels. 1) sandstone with ochre coating; 2) sandstone fragment; 3) flake with black adherence (possibly pitch) at proximal end and at platform (Photo: B. Schürch).

Abb. 16: Hohle Fels. 1) Sandstein mit Ockerauflagerung; 2) Sandsteinfragment; 3) Abschlag mit schwarzer Anhaftung (möglicherweise Pech) am Proximalende und am Schlagflächenrest (Foto: B. Schürch).

Nineteen tools are currently present in the lithic assemblage from AH X. One leaf point, four other bifacial tools, nine side-scrapers and five laterally retouched flakes (Fig. 15). Scrapers are abundant in most Middle Paleolithic horizons in the Swabian Jura. Leaf points, however, are extremely rare in the region's the Middle Paleolithic. The other bifacial tools from AH X show bifacial knapping, but are irregular in form, incomplete or examples of unsuccessful knapping. They are not of clear cultural stratigraphic significance.

In each AH X and XI one fragment of strongly abraded sandstone is present (Fig. 16). Traces of ochre are visible in the depressions of the artifact from layer X. This piece of sandstone may have been used to produce ochre powder. Another exceptional artifact is a burnt flake of Jurassic chert (Fig 16). This piece has a black substance adhering to the proximal end. We hope that future studies will show whether or not this material represents traces of mastic.

Middle Paleolithic assemblages overlying and underlying AH X

The other Middle Paleolithic horizons from Hohle Fels show a distribution of lithic raw materials similar to those of AH X (Fig. 17). Differences between the composition can mostly be seen in individual pieces of exotic raw materials. For example, in AH XI there is a single piece made of *Muschelkalk* chert. Today this material can be found in the river gravels of the Neckar in a distance of about 40 km. A common feature of all Middle Paleolithic strata is the presence of the Levallois artifacts. Nevertheless, other reduction concepts also occur. Layer X and XI differ from the other horizons in having more elaborated bifacial artifacts (Conard and Malina 2006, 2007, 2008, 2010, 2013, 2019, 2020; Conard et al. 2017; Conard and Janas 2018, 2021). As we gain more information on the Middle Paleolithic sequence from Hohle Fels, the site, as one of very few that have been excavated using modern techniques, should provide new insights into the cultural stratigraphic sequence of the Swabian Jura and into the changing technologies and lifeways of the region's Late Pleistocene Neanderthals.

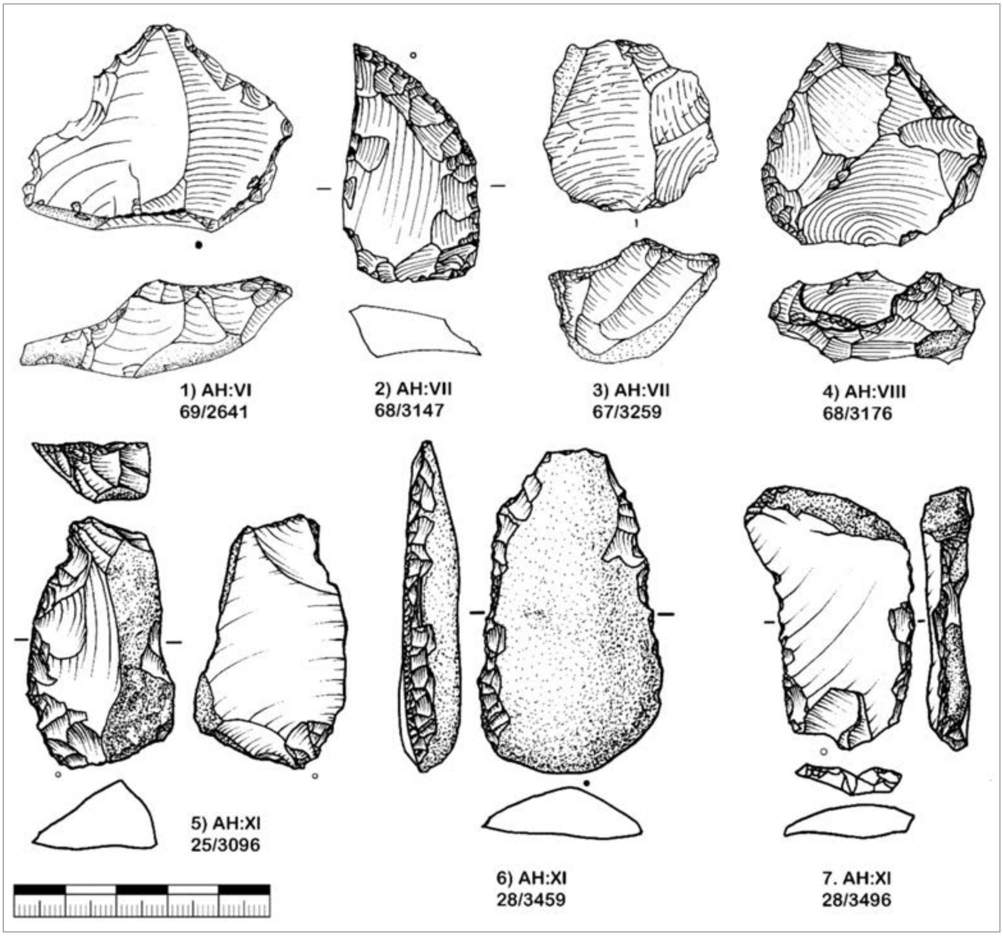


Fig. 17: Hohle Fels. Middle Paleolithic stone artifacts from horizon VI-IX and XI: 1) retouched Levallois flake, Jurassic chert; 2) side-scraper, Jurassic chert; 3) Levallois core, Jurassic chert; 4) Levallois core, Jurassic chert; 5) side-scraper, Jurassic chert; 6) side-scraper, Jurassic chert; 7) side-scraper, Jurassic chert (drawings: 1 after Conard et al. 2012; 2 after Conard and Malina 2007; 3 after Conard and Malina 2006; 5-7 after Conard and Janas 2021).

Abb. 17: Hohle Fels. Mittelpaläolithische Steinartefakte aus den Schichten VI-IX und XI: 1) retuschierter Levallois-abschlag, Jurahornstein; 2) Schaber, Jurahornstein; 3) Levallois-Kern, Jurahornstein; 4) Levallois-Kern, Jurahorn-stein; 5) Schaber, Jurahornstein; 6) Schaber, Jurahornstein; 7) Schaber, Jurahornstein (Zeichnungen: 1 nach Conard et al. 2012; 2 nach Conard und Malina 2007; 3 nach Conard und Malina 2006; 5-7 nach Conard und Janas 2021).

Discussion and conclusions

The ongoing excavations at Hohle Fels present a unique opportunity to revise the Middle Paleolithic cultural stratigraphic and chronostratigraphic sequence of the Swabian Jura. This is because the history of research on what in Germany is usually called the *Blattspitzengruppe* has often linked this cultural taxonomic unit with the Upper Paleolithic or latest Middle Paleolithic. Initially, Gustav Riek (1938) assumed that there must be some sort of link between bifacial finds from Haldenstein and the Solutrean. A generation later Gisela Freund (1952) also postulated such a link between *Blattspitzen* assemblages and the Solutrean. While in more recent years, very few researchers have continued to suggest such cultural connections, many researchers link *Blattspitzen* assemblages with the end of the Middle Paleolithic or even as a transitional industry between the Middle and the Upper Paleolithic (e.g., Müller-Beck 1956, 1983; Bosinski 1967; Allsworth-Jones 1986; Valoch 1993; Conard and Fischer 2000; Flas 2000-2001; Bolus 2004a, 2004b; Hopkinson 2004; Bolus and Conard 2019).

In the German tradition, Gerhard Bosinski's 1967 monograph, *Die mittelpaläolithischen Funde im westlichen Mitteleuropa*, represents a hallmark of Middle Paleolithic research that argued that the *Blattspitzengruppe* corresponds to the last of the Middle Paleolithic cultural groups (*Formengruppen*). This view was also reflected in the key works from Hansjürgen Müller-Beck (1956, 1983), who also viewed the leaf point assemblages of the Swabian Jura and central Europe as the last phase of the Middle Paleolithic. Given that at until the late 1980s, most paleoanthropologist and Paleolithic archaeologists favored models supporting continuity between Neanderthals, who were responsible for the Middle Paleolithic, and modern humans, who were responsible for the Upper Paleolithic, it is not surprising that various leaf point assemblages across Europe were often considered to be transitional industries. The rise of prominence of models favoring the African origins of modern humans (Bräuer 1984; Stringer and Andrews 1988), however, led to an increased tendency to see discontinuity between the Middle and Upper Paleolithic. With the recent documentation of interbreeding between Neanderthals, Denisovans and modern humans (Slon et al. 2018; Hajdinjak et al. 2021), it is not entirely surprising that so-called transitional assemblages remain a focus of research across Europe. This is certainly the case for the Initial Upper Paleolithic (Fewlass et al. 2020; Hublin et al. 2020), the Uluzzian (Riel-Salvatore 2009; Benazzi et al. 2014; Douka et al. 2014) and the Châtelperronian (d'Errico et al. 1998; Mellars et al. 2007; Julien et al. 2019) to name a few such cultural units.

Parallel to these broad trends in recent decades, in Germany, thanks to the work of researchers including Richter (1997), Bolus (2004a, 2004b) and Jöris (2004), the status of bifacial assemblages of the Middle Paleolithic has attracted considerable attention. Prominent among these ideas is Richter's concept of a fluidity between Mousterian and Micoquian (*Keilmesser*/Pradnik) assemblages in what he refers to as the MMO or Mousterian with Micoquian Option. While this work did not reject the interpretation that the *Blattspitzengruppe* represents the latest cultural unit of the Middle Paleolithic, it raised many questions about the tendency to distinguish sharply between assemblages with and without bifacial tools. Although Richter's concepts have been hotly debated, they have contributed to a willingness to question the cultural units defined by Bosinski and many earlier colleagues.

The recovery of the first stratified leaf point from the Swabian Jura in more than 80 years will likely enliven these discussions and will lead to revisions of the Middle Paleolithic cultural stratigraphic sequence. Although so far only one typical leaf point together with several other bifacial tools (Fig. 15) has been recovered from Hohle Fels, leaf points are so rare that it seems reasonable to attribute AH X to the *Blattspitzengruppe*. The fact that AH X at Hohle Fels predates 62.5 ka BP and lies ca. 1.2 meters beneath the base of the Aurignacian contradicts the interpretation that leaf points from the Swabian Jura invariably correspond to the end of the Middle Paleolithic and perhaps even a transition to the Upper Paleolithic. Instead, the new Middle Paleolithic horizons at Hohle Fels support the hypothesis that bifacial technology in general and *Blattspitzen* more specifically, are not in and of themselves reliable cultural and chronostratigraphic markers. Instead *Blattspitzen* appear to be part of a diverse repertoire of technologies that Neanderthals of the Late Pleistocene were able to draw upon. With luck the ongoing excavations at Hohle Fels will provide more information on these debates and will also bring more clarity into these discussions.

Acknowledgements

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