The Archaeological Significance of the Reindeer Antlers from the Hohlenstein-Complex in the Lone Valley of Southwestern Germany

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Abstract: *Archaeological sites of the Swabian Jura (southwestern Germany) have revealed unique mobile art assemblages made from mammoth ivory. The largest figurine is the* Löwenmensch *from the Hohlenstein-Stadel in the Lone Valley. Within the same archaeological context as the* Löwenmensch, *a remarkable number of reindeer antlers have been found. Antlers are often excluded from faunal analysis because they do not necessarily represent dead animals and hence potential food resources; however, there must be some reason for the fact that they occur within the archaeological context.*

This study investigates the significance of small reindeer antlers within the Hohlenstein-Complex through the analysis of the materials from the excavations in 1997 and 1998 in front of the cave and from Robert Wetzel's excavations in the 1930s in the 19^th^ and 20^th^ excavation meter inside Hohlenstein-Stadel. To analyze accumulation agents, we classified reindeer antler remains into fragments, cast antlers and antlers attached to the skull. We also used morphology and metric analysis to identify the sex and age of the animals. The annual cycle of antler growth enabled us to establish the season when reindeer migrated through the Lone Valley during the Paleolithic. Finally, we considered the context of the Löwenmensch *figurine, which dates to the early Aurignacian.*

Reindeer antlers outnumber reindeer bones from the excavations in 1997 and 1998. All small reindeer antlers not only indicate one season, but also specify the location where the group of females and young reindeer passed through the Lone Valley during their spring migrations. While the collection of reindeer antlers in front of the Hohlenstein-Complex presumably represent a natural accumulation, the cast antlers inside Hohlenstein-Stadel appear to result from anthropogenic activities. These anthropogenically modified antler fragments were also found in the context of the Löwenmensch *figurine.*

The consistent use of the Lone Valley as a migration route between summer and winter pastures indicates

the predictability of reindeer as a resource not only for raw materials but also for food. During this study, small cast reindeer antlers turned out to be an informative find category, especially in the context of the analysis of subsistence strategies. The certainty of resources, as in time and location of reindeer migrations, was likely an important factor for the settlement dynamics of Paleolithic hunter-gatherers, and not only in the Lone Valley. Furthermore, the way these antlers were introduced into the archaeological context as an organic non-food source provides additional insights into the use of resources in the past.
Keywords: *Germany, Swabian Jura, reindeer, antler, resources, raw material, subsistence*

Die archäologische Bedeutung der Rentiergeweihe vom Hohlenstein-Komplex im Lonetal in Südwestdeutschland

Zusammenfassung: Archäologische Fundstellen von der Schwäbischen Alb haben einzigartige aurignacienzeitliche Inventare von Kleinkunstwerken aus Mammutelfenbein geliefert. Die größte dieser Figurinen ist der „Löwenmensch" aus dem Hohlenstein-Stadel im Lonetal. Im selben Kontext wie der „Löwenmensch" wurde auch eine bemerkenswerte Anzahl an Rentiergeweihen angetroffen. Oft werden Geweihe bei der Faunenanalyse ausgeklammert, da sie im Falle von Abwurfstangen keine toten Tiere und von daher keine potentiellen Nahrungsressourcen repräsentieren, jedoch müssen sie aus bestimmten Gründen in den archäologischen Fundzusammenhang gelangt sein.
In der vorliegenden Studie wird die Bedeutung kleiner Rentiergeweihe aus dem Hohlenstein-Komplex durch eine Analyse desjenigen Fundmaterials untersucht, das bei den Ausgrabungen in den Jahren 1997 und 1998 vor der Höhle und bei Robert Wetzels Ausgrabungen in den 1930er Jahren im 19. und 20. Abbaumeter innerhalb des Hohlenstein-Stadel geborgen wurde. Um die Gründe für Akkumulationen zu ermitteln, haben wir die Rentiergeweihe in Fragmente, Abwurfstangen und schädelechte Geweihe eingeteilt. Darüber hinaus wurden die Geweihmorphologie sowie metrische Analysen herangezogen, um das Geschlecht und das Alter der Tiere zu ermitteln. Der Jahreszyklus des Geweihwachstums wurde verwendet, um die Jahreszeit zu bestimmen, in welcher Rentiere im Paläolithikum durch das Lonetal wanderten. Schließlich berücksichtigten wir den Fundkontext des „Löwenmenschen", der in das frühe Aurignacien datiert.
In den Grabungsflächen der Jahre 1997 und 1998 übersteigt die Zahl der Rentiergeweihe diejenige der Rentierknochen deutlich. Drei Ergebnisse der Untersuchungen sind hervorzuheben. Zum einen deuten alle kleinen Rentiergeweihe nicht nur auf dieselbe Jahreszeit hin, sondern sie lassen auch diejenige Stelle erkennen, an der die weiblichen und die jungen Rentiere während ihrer Frühlingswanderung das Lonetal passiert haben. Zum anderen stellt die Häufung der Rentiergeweihe vor dem Hohlenstein-Komplex wahrscheinlich eine natürliche Akkumulation dar, während die Abwurfstangen aus dem Inneren des Hohlenstein-Stadel das Ergebnis anthropogener Aktivitäten zu sein scheinen. Schließlich ist zu betonen, dass diese anthropogen modifizierten Geweihstücke im engen Kontext des „Löwenmenschen" lagen.
Aus der beständigen Nutzung des Lonetals als Wanderroute der Tiere zwischen Sommer- und Winterweideplätzen resultiert im Paläolithikum die Möglichkeit, Rentiere nicht nur als Rohmaterialquelle, sondern auch als Nahrungsquelle im Voraus einzuplanen. Im Verlaufe der Studie erwiesen sich kleine Abwurfstangen von Rentieren als informative Fundkategorie, besonders im Zusammenhang mit der Analyse der Subsistenzstrategien. Die Ressourcensicherheit durch Zeit und Ort der Rentierwanderung spielte wahrscheinlich eine wichtige Rolle bei der Siedlungsdynamik der paläolithischen Jäger und Sammler nicht nur im Lonetal. Darüber hinaus gewährt die Art und Weise, wie diese Geweihe als organische Nicht-Nahrungsreserve in den archäologischen Fundkontext eingebracht wurden, weitere Einblicke in die Ressourcennutzung in der Vergangenheit.
Schlagwörter: Deutschland, Schwäbische Alb, Rentier, Geweih, Ressourcen, Rohmaterial, Subsistenz

Introduction

The Swabian Jura

The Swabian Jura in southwestern Germany is known for its high density of caves and rockshelters, such as Vogelherd, Hohlenstein, Bockstein in the Lone Valley and Hohle Fels, Geißenklösterle, Brillenhöhle, and Sirgenstein in the Ach Valley. Researchers recognized some time ago the extraordinary potential in prehistoric sites in this region. During the late mid-19th century they began to explore the Lone Valley sites systematically, which led to a long history of important paleontological and archaeological discoveries (Bolus 2015; Conard et al. 2015). Most renowned are the unique assemblages of mobile art representing small animal figurines made from mammoth ivory discovered at Vogelherd Cave (Riek 1934) as well as the ivory fragments of the *Löwenmensch* (lion man) from Hohlenstein-Stadel (Schmid 1989). Later discoveries of other ivory figurines were made in the Aurignacian deposits in the caves of Geißenklösterle (Hahn 1988) and Hohle Fels (Conard 2003), both located in the Ach Valley. In the cave of Hohlenstein-Stadel, many small-sized reindeer antlers were found associated with the *Löwenmensch*. These finds have long been regarded as remarkable in the archaeological material because of their high numbers in relation to the number of reindeer bone remains (Hahn et al. 1985, 76; Schmid 1989, 84; Ulmer Museum 1994, 42).

Although antlers are often excluded from faunal analysis because they do not necessarily represent dead animals and were not used as food resources (Spiess 1979; Niven 2006), they had to have been brought to the archaeological sites for some reason. During the Upper Paleolithic, the production of organic tools rises significantly, with antler becoming an important raw material resource. Within the larger context, which involves the formation processes behind archaeological sites, analyses of subsistence strategies and settlement dynamics have become of great interest among researchers. These analyses include questions related to animal selection, and not only as a source of food, and how animal resources were used in terms of organic raw material, time management, settlement, site occupation duration, and seasonality.

This study investigates the archaeological significance of small reindeer antlers within the Hohlenstein-Complex in terms of seasonal indicator, raw material character and distribution. To analyze the accumulation agents, we classified reindeer antlers into fragments, cast antlers and antlers attached to skull. Morphology and metric analysis helped us to specify the sex and age of the animals. We used the annual cycle of antler growth to determine the season when reindeer used the Lone Valley for migrations during the Paleolithic. Additionally, we considered whether or not the cast antlers found in the context of the *Löwenmensch* show traces of anthropogenic modifications.

Research history of Hohlenstein

The karstic Hohlenstein-Complex includes three archaeological sites: the two cavities of Hohlenstein-Stadel and Bärenhöhle as well as the small rockshelter Kleine Scheuer (Fig. 1). The caves are parallel in orientation and are approximately 30 meters apart from each other, with both facing the northwest in the direction of the Lone Valley. These sites have a long archaeological history. In 1861, Oscar Fraas excavated various early test pits in the caves of Hohlenstein-Stadel and Bärenhöhle, with Ernst von Koken and Robert Rudolf Schmidt investigating the material in the following years. Robert Wetzel and Otto Völzing undertook the first systematic excavations from 1935 to 1939 (Beck 1999). In the back of the Hohlenstein-Stadel vestibule, corresponding to the 19th and 20th excavation meter, excavators found nearly 300 pieces of worked ivory (Fig. 1). Although Wetzel had realized that some of the fragments displayed traces of anthropogenic modification, these fragments were not recognized as pieces of a carved figurine until Joachim Hahn reassembled them in 1969, forming the now famous *Löwenmensch*. To this day,

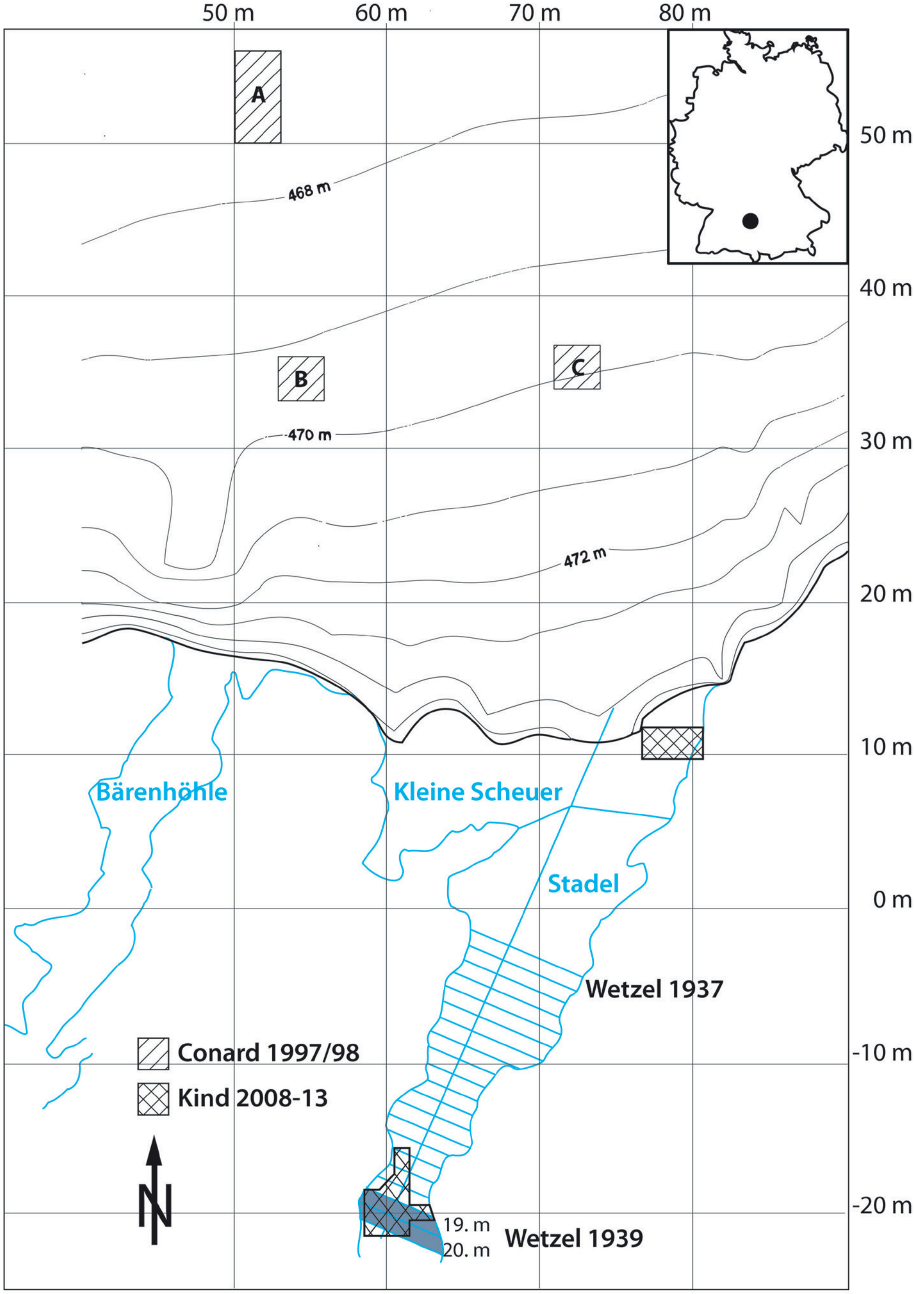

Fig. 1: *Map of the Hohlenstein-Complex in the Lone Valley (Swabian Jura) with its archaeological sites and Wetzel's excavations in one-meter spits beginning in the outer vestibule of Hohlenstein-Stadel Cave and ending in the back of the cave. Modern excavations were conducted in three areas in front of the Hohlenstein-Complex, at the entrance of Hohlenstein-Stadel and in the inner vestibule of the cave (after Schmid 1989; Bolus et al. 1999; Conard et al. 2015).*

the *Löwenmensch* figurine found in Hohlenstein-Stadel is considered an outstanding archaeological discovery. Its ivory fragments were recently supplemented by finds recovered by Claus-Joachim Kind's team working at the site from 2008 to 2013, leading to a new reconstruction of the figurine (Schmid 1989; Ebinger-Rist et al. 2013; Wolf et al. 2013; Kind et al. 2014).

Between 1954 and 1961, Wetzel continued excavations in other areas of the cave. Recent excavations from 2008 to 2013 conducted by the State Conservation Office (Fig. 1) identified the old borders of the 1939 excavation from Wetzel and confirmed the presence of intact sediments (Kind and Beutelspacher 2009, 2010; Ebinger-Rist et al. 2013; Ulmer Museum 2013; Beutelspacher and Kind 2014). In summary, the cultural remains found in over four-meter deep cave sediments revealed a stratigraphy and absolute chronology that includes Middle Paleolithic ("Black Mousterian," "Red Mousterian"), Upper Paleolithic (Aurignacian, Magdalenian) and Holocene periods (Neolithic, Bronze, Iron, Roman, and Medieval).

Research project and site location

In order to study the Middle Paleolithic paleoecology of the Lone Valley in more detail and to detect open-air sites in this region, the University of Tübingen's DFG research project (SFB 275) conducted a series of sediment corings in the Lone Valley during the years 1996 and 1997 (Bolus et al. 1999; Schneidermeier 2000). We chose locations for test excavations according to the content of the sediment cores and variation in the density of faunal remains, charcoal, archaeological artifacts, and limestone debris. In front of the Hohlenstein-Complex, the corings contained layers with a high density in faunal remains that suggested anthropogenic accumulation. In 1997-1998, the Tübingen Institut für Ur- und Frühgeschichte und Archäologie des Mittelalters excavated three areas (Bolus et al. 1999) (Fig. 1). These excavations revealed numerous faunal remains, some cultural remains, and a high number of small-sized reindeer antlers. In the light of previous research in the Lone Valley and the recurring appearance of reindeer antlers within archaeological contexts, questions arose concerning the circumstances that led to the accumulation of these finds inside the cave of Hohlenstein-Stadel and in nearby open-air contexts.

Reindeer ethology

Reindeer antlers are a specific archaeological category of finds in terms of their characteristics. First, both females and males grow and shed antlers, although the timing of such does vary throughout the year due to sex and age (Fig. 2a). Reindeer give birth at the end of spring (from May until the beginning of June) (Berke 1987, 108). Pregnant females shed their antlers within days of calving (Reimers et al. 2013), while calves can build their first antlers directly after birth. Most neonates already bear tiny outgrowths on their frontalia at birth; these are fully grown after 6 months.

The antler growth cycle of females and all young specimens (up to an age of three years) is very similar, and the timing at which both shed their antlers is roughly the same, corresponding to the end of spring (May). Subadult males change their antler growth cycle due to shifts in the levels of hormones (Napierala 2008, 59). Males grow

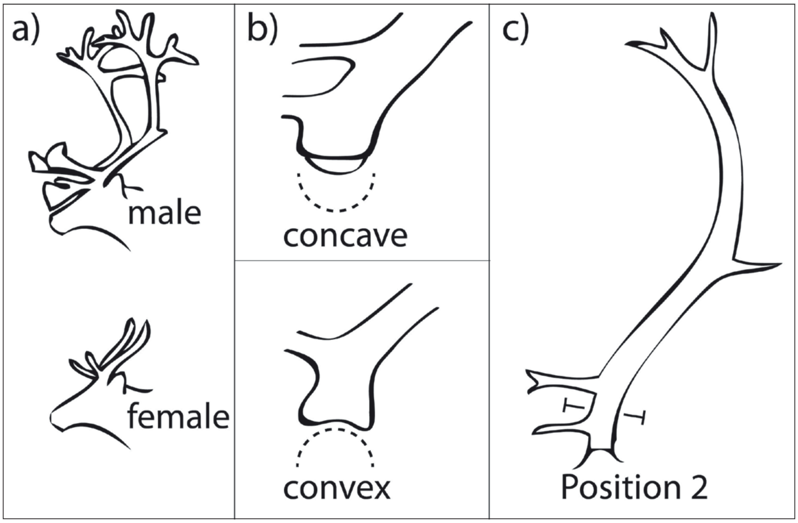

Fig. 2: Reindeer antler structure and morphological differences between male and female antlers: a) complex palmation structure in males and simpler, smaller and strait beam in females; b) morphologies at the antler base can be differentiated between concave and convex; c) measurements were taken on Position 2 over the 1st brow tine (after Sturdy 1975).

antlers starting in early autumn and shed them in late autumn. Additionally, the antlers of grown males are larger and show increased palmation compared to the antlers of females and subadults, which are metrically shorter, thinner and less complex (Fig. 2a). In this sense, antler accumulations can be used to locate calving grounds (Miller et al. 2013). During the Paleolithic, antlers were used as raw material for projectile points and an array of other artifacts. Fully-grown antlers are highly useful in providing raw material to make organic tools. While antlers have a growth cycle throughout the year, their fully compact stage is reached after the antler velvet is peeled off. This occurs in females and young individuals during mid-autumn, while males reach this stage in early autumn. The easiest access to fully compact antlers is after the animals shed them off, which occurs for females and subadults in late spring and for males in late autumn. Reindeer are migratory animals that move long distances during the transitional seasons of spring and autumn. They normally follow established migration routes between winter and summer pastures. Consequently, we investigate reindeer antlers in the following study in order to reconstruct the seasonal migration routes of reindeer in the Lone Valley.

Material

Excavations in front of the Hohlenstein-Complex: Bergmahd/ Hohlenstein 1997 and 1998

According to coring records, three areas located 15-30 m north of the Hohlenstein-Complex were chosen for excavation: Area A, called Bergmahd, was excavated in 1997 and Area B and C in 1998 (Fig. 1). Test excavations consisted of one area of 6 m x 3 m and another two with dimensions of 3 m x 3 m each (Bolus et al. 1999). The excavations, which reached a maximum depth of 2.20 m in Area A, followed modern standards with work proceeding in quarter-meter squares, with piece plotting of artifacts, and so on. The stratigraphy of these excavations revealed archeological remains belonging to cultural periods that span from the Middle Paleolithic to the Iron Age. The excavators recovered more than a thousand archaeological finds. Lithic artifacts (some attributed to the Middle Paleolithic), anthropogenically modified bones and a high number of small-sized reindeer antlers were among the materials found.

During the excavation, we identified two major Geological Units (GU) with further subdivisions (Fig. 3, Table 1). The upper part (GU1) contains topsoil without limestone debris and clayey deposits that are probably affected by water movement, solifluction, and bioturbation. These deposits contained mainly finds from the Holocene as well as Pleistocene archaeological material near the base of the GU. Increasing water activity within these sediments can be associated to climatic shifts towards more humid conditions at the beginning of the Holocene. Soil formation and decalcification destroyed the bones in these layers and chemical weathering rounded the limestone blocks found at the base of GU1 (Schneidermeier 2000). The stone artifacts found in GU1 (A: n=282; B: n=342; C: n=449) include finds from the Mesolithic and/or Early-Middle Neolithic periods (Bolus et al. 1999).

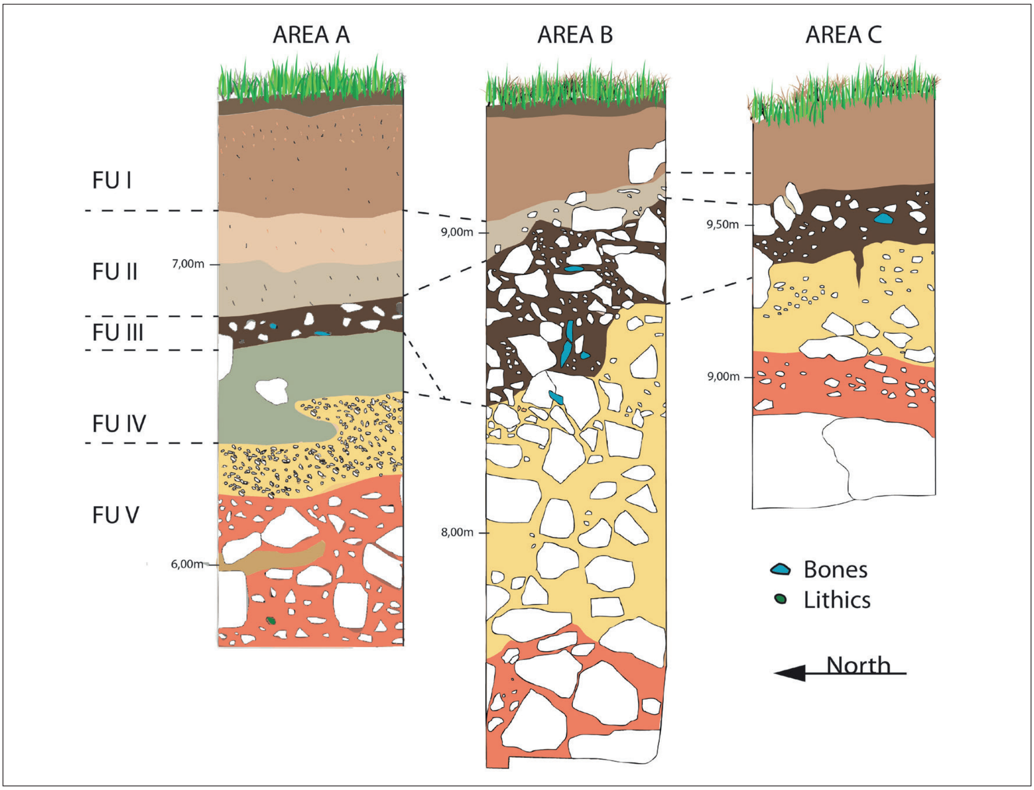

Fig. 3: *Hohlenstein. Sections of the east profiles with find units from excavation areas A, B and C in front of the Hohlenstein-Complex. FU = Find Unit.*

Geological Unit (GU)	Matrix	Find Unit	Archaeological remains	Periods
1	Soil formation: *Parabraunerde*	FU-I	no bone preservation	Holocene/Pleistocene mixture
1	few rounded limestones	FU-II	rich in finds, more bone damage, root etching	(Late) Pleistocene
2	rich in limestone debris	FU-III	rich in finds, more bone damage, root etching	Pleistocene
2	flood sediments	FU-IV	few finds, manganese punctures	Pleistocene
2	red-brown sediments with angular limestone debris/ blocks	FU-V	few finds, only slight bone damage	Pleistocene

Table 1: *Hohlenstein. Context and matrix of find units in the open-air excavations in front of the Hohlenstein-Complex.*

The faunal composition and geological context with much limestone debris indicate a Pleistocene age for the lower part (GU2) (Fig. 3, Table 1). These layers revealed a small Paleolithic lithic assemblage (A: n=5; B: n=7; C: n=13; see Fig. 1) including wide flakes with faceted striking platforms that imply a Middle Paleolithic origin (Bolus et al. 1999). GU2 contains much limestone debris with banded dark brown to gray silty clay, $CaCO_3$ concretions and iron and manganese oxides. The lowest sections in all excavation areas are marked by an increase of angular-shaped limestone fragments. A layer with olive gray sediments including mollusks may refer to flood sediments and only appears in Area A, the topographically lowest situated area of excavation. An additional indicator for Pleistocene climate conditions is the presence of an ice wedge in Area C.

The interior of Hohlenstein-Stadel: 19th/20th excavation meter, Wetzel 1939

For the sake of comparison, we have included in this study, along with finds from recent excavations, reindeer antlers from the interior of Hohlenstein-Stadel found associated with the *Löwenmensch* (Hahn et al. 1985, 76; Schmid 1989, 84; Wehrberger 1994, 42). Wetzel excavated the interior of Hohlenstein-Stadel in one-meter cuts (“Abbaumeter”) oriented orthogonally to the longitudinal axis of the cave, starting from the entrance into the inner cave. Excavations were conducted in spits of roughly 20 cm. Wetzel and Völzing defined a long cultural sequence corresponding to the following cultural units: “Black Mousterian,” “Red Mousterian,” Aurignacian, Magdalenian, Neolithic, and Bronze-Medieval Age.

The materials included in this study come from the 19th and 20th “Abbaumeter” from Wetzel’s excavations in 1939 (Fig. 1). The chosen area samples the surroundings of the *Löwenmensch* that have long been known to contain many examples of reindeer antlers. Other finds from this area include ivory beads and teeth pendants from red deer, wolf and fox found in spit 6 of the 20th meter (Kind et al. 2014; Conard et al. 2015). The first and second spits contain many reindeer antlers and might represent a Late Pleistocene period, most likely the Magdalenian. The faunal material has been recently reanalyzed (Kitagawa 2014). New excavations organized by the State Conservation Office found the borders of the old Wetzel excavations and were able to sample the same levels excavated in 1939 for re-dating (Kind and Beutelspacher 2009, 2010; Beutelspacher and Kind 2014). Together with a series of new dates on the Swabian Jura (Conard and Bolus 2003, 336), all available radiocarbon dates supply an Aurignacian age for spit 6 and 7 of the 19th and 20th excavation meters (Table 2).

Excavation	Location	^{14}C	Uncertainty	Lab-Code	Period	Reference
Wetzel 1939	19m, spit 6	31 440	± 250	KIA 8951	Aurignacian	Conard and Bolus 2003
Wetzel 1939	20m, spit 6	31 750	+1150/-650	H 3800-3025	Aurignacian	Hahn 1977
Wetzel 1939	20m, spit 6	32 000	± 550	ETH-2877	Aurignacian	Schmid 1989
Wetzel 1939	20m, spit 6	32 270	+270/-260	KIA 13077	Aurignacian	Conard and Bolus 2003
Wetzel 1939	19m, spit 7	33 920	+310/-300	KIA 8949	Aurignacian	Conard and Bolus 2003
Wetzel 1939	19m, spit 7	36 910	+490/-460	KIA 8950	Aurignacian	Conard and Bolus 2003
Wetzel 1939	19m, spit 8	41 710	+570/-530	KIA 8948	Aurignacian?	Conard and Bolus 2003
Wetzel 1939	19m, spit 9	42 410	+670/-620	KIA 8947	Aurignacian?	Conard and Bolus 2003
Wetzel 1939	19m, spit 10	39 970	+490/-460	KIA 8946	Aurignacian?	Conard and Bolus 2003
Wetzel 1939	19m, spit 11	40 220	+550/-510	KIA 8945	Aurignacian?	Conard and Bolus 2003
Kind Stadel	Ao	31 950	± 210	ETH-41231	Aurignacian	Beutelspacher and Kind 2014
Kind Stadel	Am	33 390	± 245	ETH-41232	Aurignacian	Beutelspacher and Kind 2014
Kind Stadel	Au	35 185	± 270	ETH-38797	Aurignacian	Beutelspacher and Kind 2014
Kind Stadel	C	39 805	± 420	ETH-38798	Middle Paleolithic	Beutelspacher and Kind 2014
Kind Stadel	A2	41 920	± 545	ETH-38799	Middle Paleolithic	Beutelspacher and Kind 2014
Kind Stadel	D	40 560	± 480	ETH-38800	Middle Paleolithic	Beutelspacher and Kind 2014
Kind Stadel	E	46 440	± 1050	ETH-41234	Middle Paleolithic	Beutelspacher and Kind 2014
Kind entrance	GKS-2	33 845	± 225	ETH-38792	Aurignacian	Kind and Beutelspacher 2010
Kind entrance	KKS	23 495	± 85	ETH-38793	Gravettian	Kind and Beutelspacher 2010
Kind entrance	BG	>50000		ETH-38795	Black Mousterian	Kind and Beutelspacher 2010

Table 2: *Hohlenstein. Radiocarbon dates for the 19th and 20th excavation meter from 1939 and recently excavated layers from the entrance of Hohlenstein-Stadel (after Conard and Bolus 2003, 336; Kind and Beutelspacher 2009, 2010; Beutelspacher and Kind 2014).*

Methods

The analysis of the faunal remains from the 1997 and 1998 excavations in front of the Hohlenstein-Complex concentrated on four aspects: 1) determination of animal species, skeletal elements represented and reindeer antler remains; 2) morphological categorization of the represented reindeer antlers; 3) evaluation of taphonomic alterations of the reindeer antlers to identify their accumulation agents; 4) evaluation of the provenance and archaeological context of the antlers.

To mitigate these research questions, the faunal remains were identified anatomically and taxonomically with the help of the Tübingen vertebrate reference collection; Number of Identified Specimens (NISP) were counted and the Minimum Number of Elements (MNE) was calculated. We grouped faunal remains that could not be classified to the level of species according to size classes, which correspond to bear-horse size (large) and reindeer-red deer size (medium). The Inverse of Simpson's Dominance Index (1/D) was used to explore the change in species diversity over time (Simpson 1949). The value 1 corresponds to one dominant species, while a higher value reflects the higher variety of species. Further analysis focused on antler fragments attributed to reindeer. According to their base, these were additionally classified in subcategories as either shed antlers or attached to skull, corresponding to fragments with antler roses and pedicles or frontal fragments with antler outgrowths. We recorded the morphology of the pedicle to ascertain if this attribute might serve as an indicator for sexing, with concave forms coming from females and convex from males (Fig 2b) (Sturdy 1975, 55-57; Spiess 1979, 97). In addition, we measured the dimensions of the cast antlers between the 1st and 2nd brow tine (Position 2: Fig. 2c) (Sturdy 1975, 56), which is most reliable for comparison, since measurements on the base vary mostly due to individual morphologies. We recorded the state of preservation and modifications to gain information on the taphonomic context of the accumulation. In order to establish the accumulation agents, the breakage patterns were recorded based on the distinction between fresh-green fractures versus old-dry fractures (Villa and Mahieu 1991) or recent fractures. Further modifications were evaluated such as thermo-alterations, manganese coating (Marín-Arroyo et al. 2008), traces of carnivore or rodent activities (Binford 1981), as well as weathering stages (Behrensmeyer 1978), root etching and dissolution (Fisher 1995). Finally, we examined the distribution of antlers amongst the areas of excavation using their three-dimensional provenance records.

Results

Quantification

The analysis of the fauna from the excavations in 1997 and 1998 included 1699 bones, teeth and antler remains (Table 3). Together, more than half of the remains were identified to the level of species or genus (n=632; 38,7%) and size classes (n=16,35%).

Excavation Area	All Antler Fragments	n Cast Antlers	n Attached Antler	Ivory	Bone	Teeth	Total
Open-air 1997 and 1998	105	*36*	*3*	1	1498	95	1699
Hohlenstein-Stadel 19th/20th m	154	*44*	*4*				154
Total all	259	*80*	*7*	1	1498	95	1853

Table 3: *Hohlenstein. Overview of the faunal material included in this study from the 1997 and 1998 excavations in front of the Hohlenstein-Complex and the antler remains from inside Hohlenstein-Stadel. Faunal material is summarized from excavation Areas A, B and C. Cursive column indicates categorized antler fragments.*

In general, horse, reindeer and bear bones dominate the faunal assemblage. While reindeer specimens (2166.6 g; n=235) are dominant within the assemblage, horse (5883 g; n=145) constitutes the greatest bone weight. Bear is the third most abundant animal within the collection (1975.2 g; n=94). An index for fragment size (bone weight subdivided by NISP) shows that horse bone fragments (≈40.5 g/n) are twice as big as bear bones (≈21 g/n) and bear bones twice as big as reindeer bones (≈9.2 g/n).

Geological Unit Find Unit	GU 1 FU-I	GU1 FU-II	GU2 FU-III	GU2 FU-IV	GU2 FU-V	Total
Mammuthus primigenius **(mammoth)**		4	4		2	**10**
Equus ferus **(horse)**	1	46	58	20	24	**149**
Rangifer tarandus **(reindeer)**	2	144	113	12	39	**310**
Capreolus capreolus **(roe deer)**	1		2			**3**
Megaloceros giganteus **(giant deer)**			2		1	**3**
Cervus elaphus **(red deer)**	1	4				**5**
Cervidae		1		1		**2**
Bos/Bison **(auerochs/bison)**		6	2		1	**9**
Capra ibex **(ibex)**		1	1			**2**
Sus scrofa **(boar)**		2				**2**
Ursus spelaeus **(cave bear)**	4	14	9	3	9	**39**
Ursus arctos **(brown bear)**		1	2			**3**
Ursus **sp.**		17	24	2	17	**60**
Canis lupus **(wolf)**		5	5		1	**11**
Vulpes/Alopex **(fox)**		7	2		1	**10**
Crocuta spelaea **(cave hyena)**		1				**1**
Panthera leo spelaea **(cave lion)**		1		1		**2**
Lepus **sp. (hare)**		5			1	**6**
Aves (birds)		2			3	**5**
Total NISP	9	261	224	39	99	**632**
1/D	**(3,52)***	**2,59**	**2,80**	**2,52**	**3,11**	**2,88**

Table 4: *Hohlenstein. Species representation of 1997 and 1998 excavations Bergmahd/Hohlenstein. The Inverse of Simpson's Index (1/D) is calculated for each find unit while bird specimens (Aves) were excluded.*this value is biased by low NISP.*

The archaeological remains are summarized in five find units (FU) (Table 1). The two upper units FU-I and FU-II belong to the Geological Unit 1 (GU1), where various herbivore and carnivore species are present that are typical for Holocene and Pleistocene habitats (Table 4). According to sediments and archaeological artifact composition, FU-Ia has a colluvial character and contains modern finds (Fig. 4a). The richest find unit FU-II revealed an Inverse of Simpson's Index of 1/D=2.59 that shows two dominant herbivore species, horse and reindeer. The lower section GU2 contains three subunits: FU-III, FU-IV and FU-V. The FU-III horizon shows a more even dominance of the three main species, while NISP of horse and bear bones increased compared to reindeer. Species diversity decreases from 15 represented species to 11. This layer is also rich in limestone debris, which may be the result of stadial conditions. With four identified species, the diversity of FU-IV is relatively small, given that this layer shows flood sediments that might correspond to an isolated event only represented in the lowest portions of excavation Area A. The lowest FU-V shows the most even dominance of the three species horse, reindeer, and bear (1/D=3,11) and infers stable sediment conditions.

Fig. 4: *Hohlenstein. Faunal material from the 1997 and 1998 excavations with anthropogenic and carnivore modifications: a) Find Unit (FU)-I: red deer scapula with metal knife marks; b) FU-II: horse metapodial with carnivore gnawing, cave hyena canine, brown bear metapodials, joint reindeer tarsal-talus-calcaneus bone, cut marks (arrow) and impact marks (triangle) on reindeer radii; c) cave bear teeth of different ages and reindeer metapodial; d) cave bear vertebra with cut marks and cave lion metapodial; e) cave bear humerus and tooth, horse phalanx, mammoth tooth fragment and examples of lithic artifacts.*

Diverse anthropogenic modifications were identified on reindeer, horse, and bear bones. Some reindeer long bones display cut marks and intentional bone cavity opening through impact marks (Fig. 4b). One skull fragment with attached antler shows cut marks on its base opposite a small depression of the compact bone indicating Paleolithic hunter-gatherer slaughtering activity. A cave bear thoracic vertebra displays four cut marks located parallel to the body axis on its left side between the *Processus transversus* and the *Processus spinosus*. These kinds of marks would occur during the removal of meat from bones while cuts reach deep into protuberant bone parts (Fig. 4d). Cut marks on horse bones were identified on a pelvis and a humerus.

The assemblage from the excavation areas in front of the Hohlenstein-Complex contains 105 antler remains. A further 154 reindeer antler specimens were included from the inner Hohlenstein-Stadel resulting in a total of 259 reindeer antler fragments analyzed. Together, a MNE of 80 was identified for cast reindeer antlers; 36 from the areas in front of the Hohlenstein-Complex and 44 from the Hohlenstein-Stadel. Characteristic structures of cast antlers are found on their proximal part, called the pedicle. These cast antler fragments, however, do not represent dead/killed animals, given that antlers do re-grow and are replaced by a living animal on an annual cycle. The assemblage contains seven additional skull remains with attached antlers representing dead animals. Seven of these antlers (3 outside and 4 inside the cave) show a "cast line" or "demarcation line." The cast line is a circo-linear structure around the antler base that is attached to the skull and occurs when osteoclast cells dissolve bone structures before the dead antler is shed and a new one is built. This line can be used to time the animal's death, given that this degeneration process lasts only a few days to up to one month (Sturdy 1975). Depending on the age and sex of the animal, this process occurs during different seasons: for adult males it occurs in late autumn (December) and in females during summer. Pregnant females and young animals of both sexes, however, shed their antlers within very similar periods in early spring.

Morphology: Aging and sexing

The morphology of the pedicle has been used to differentiate male from female cast antlers, as based on concave and convex curvature, respectively (Fig. 2b). Accordingly, the assemblage contains 10 male and 20 female antlers, with not all being categorized due to the lack of clear differentiation.

Together, all antlers from the excavations in front of the Hohlenstein-Complex in 1997 and 1998 and from Wetzel's excavations inside the Hohlenstein-Stadel were used to investigate reindeer antler size variation (Fig. 5). The obtained metrical data of breath and thickness on Position 2, which is located between the 1st and 2nd brow tine, correspond to different size groups. Accordingly, concave antlers with smaller dimensions of 10-17 mm breadth indicate a group of females. The antlers with a convex base, corresponding morphologically to males, can be divided into two groups based on size, with a smaller one of 13-15 mm breadth and a larger one of 16-20 mm breadth. The group of smaller antlers could correspond to males in their first year. Males continue developing small antlers until their third year, a period before they start to contribute to herd reproduction. Since all antlers are relatively small compared to known antler dimensions of adult males with a breadth larger than 25 mm and a thickness larger than 32 mm, this

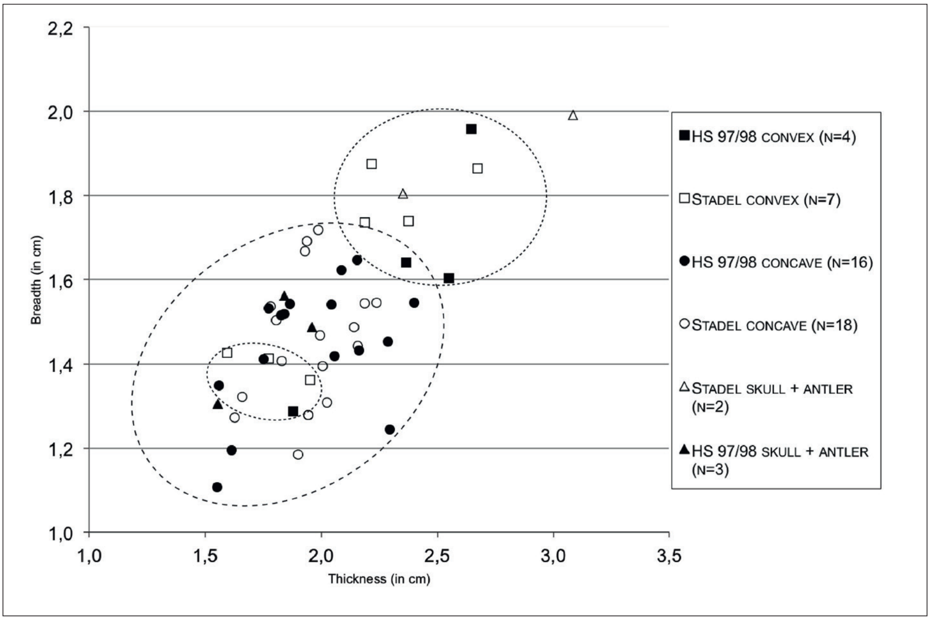

Fig. 5: *Hohlenstein. Distribution of reindeer antler dimensions on Position 2 (after Sturdy 1975) plotted by breadth and thickness. Included are antlers from the open-air excavations and from the interior of Hohlenstein-Stadel. Measurements cluster in three groups: antlers of small dimensions with concave basis, another with convex basis, and larger antlers with convex basis.*

categorization is based on a comparison with the Stellmoor reindeer population (Sturdy 1975). Altogether, all the variations within the group of small reindeer antler represent females of different ages and young males, either in their first year or definitely before they begin contributing to the group's reproduction. In males, the annual cycle of antler growth and the dimensions of the antlers shift with the transition to adulthood. Antler development starts in female and young reindeer in summer (June/July); it is fully compact during the entire winter/spring, with antlers cast in late spring (May/June) (Berke 1987). Therefore, all reindeer antlers indicate that they were shed in the area around Hohlenstein in the (late) spring season.

Antlers from the excavations in front of the Hohlenstein-Complex: Taphonomy and distribution

The antlers from the 1997 and 1998 excavations show a broad variety of weathering stages; however, most of them show similar patterns with very slight exfoliations. Despite the fact that soil formation processes preserved hardly any organic materials in the first centimeters under the excavation surface, calcareous and a relatively humid milieu produced favorable conditions for bone conservation in the underlying sediments. The antlers from the 1997 and 1998 excavations are stained in different colors (Fig. 6). Coloration ranges from white to light gray with brown and black stains. White colors are related to decalcification processes and occur on other finds close to the excavation surfaces. Light gray-brown colorations might be the result of surrounding sediments and

Fig. 6: *Hohlenstein. Morphology of antlers from the open-air excavations and from the interior of Hohlenstein-Stadel: a) cast antler base fragments from the open-air excavations; b) antlers attached to cranium from the open-air excavations, upper one with cast line; c) cast antler base fragments from inside Hohlenstein-Stadel; d) nearly complete cast antlers from inside Hohlenstein-Stadel; e) antlers attached to cranium from inside Hohlenstein-Stadel, upper one with cast line.*

decalcification processes through weathering. Brown and black colorations in antlers (and bones) come from iron and manganese staining processes (Marín-Arroyo et al. 2008). It is difficult to recognize the origin of modifications as natural or anthropogenic on heavily weathered specimens. For that reason, further investigations must concentrate on the analysis of antler modifications and breakage patterns.

Breakage patterns are subdivided into green, dry and recent fractures; fresh fractures are further categorized by whether they occur through human or carnivore activities. Fractures have been found on three positions: fracture on beam (FRAC-0), fracture on 1st brow tine (FRAC-1) or fracture on 2nd brow tine (FRAC-2) (Table 5). Within the 1997 and 1998 excavations, the antler fracture pattern in more than 50% of the cases corresponds to sediment pressure fractures. Recent fractures are common with 20% at FRAC-1 and FRAC-2. Fresh fractures could in some cases be attributed to human or carnivore activity, while an anthropogenic-related use of these small cast antlers was not clearly discernable. Nevertheless, three antlers attached to the cranium, with one revealing a cast line (Fig. 6b), were found. All shed antlers thus identified show very similar even distributions throughout the three excavation areas in front of the Hohlenstein-Complex; with 11 cast antlers in Area A, 13 in B, and 12 in C.

Excavation	**Open-air 1997 and 1998**			**Hohlenstein-Stadel 1939**		
n	Frac-0:37	Frac-1:28	Frac-2:5	Frac-0:28	Frac-1:23	Frac-2:6
Recent	35%	14%		7%		
Sediment	48%	54%	60%	43%	52%	50%
Fresh/green	3%	21%	20%	14%	22%	17%
Carnivore	11%	11%		22%	22%	17%
Anthropogenic	3%		20%	14%	4%	17%

Table 5: *Hohlenstein. The breakage patterns of the antlers are recorded on: fracture on beam (FRAC-0), fracture on 1st brow tine (FRAC-1), or fracture on 2nd brow tine (FRAC-2).*

Antlers from the interior of Hohlenstein-Stadel: Taphonomy and distribution

In contrast, reindeer antlers from Hohlenstein-Stadel show taphonomic differences in conservation, coloration, breakage, and distribution pattern, among others. The antler remains from the 19th and 20th excavation meter include 44 cast antlers. Occasionally they kept their shiny surface, which is typical for fresh reindeer antlers, and show light brown colorations, a result of good preservation conditions in the interior of the cave. Less intense weathering allows us to differentiate more accurately between the modification marks on the antlers. Most cast antlers (n=38) from Hohlenstein-Stadel show a similar breakage pattern: broken on the beam above the 2nd brow tine, and both brow tines broken close to the beam (Fig. 6c). Four antlers are nearly complete; they have a straight morphology and show very simple structure without palmation, a form typical for female or young reindeer individuals (Fig. 6d). Four pieces were found with cut marks and seven with chop marks. Moreover, eight antlers attached to skull fragments were identified, three of them with cut marks and two with a cast line (Fig. 6e). The broken cast antlers often show small depressions on the fracture on one side. These marks can be differentiated from carnivore punctures or scoring, given that they have one deep depression located on one side contrary to carnivores, which normally produce multiple marks (gnawing) on opposing sides.

Two concentrations of antler fragments were found within the 19th and 20th excavation meter in Hohlenstein-Stadel: one at the top at spits 1 and 2 another in spits 6 and 7. The lower concentration belongs to the layers that are attributed to the Aurignacian. The 6th spit of the 20th excavation meter contained most of the ivory fragments belonging to the *Löwenmensch* figurine (Hahn 1986, 30; 1991, 118).

Discussion

Small reindeer antlers as a seasonal indicator

The excavations in front of Hohlenstein revealed an assemblage rich in antlers, where reindeer antler fragments outnumbered reindeer bones. The antlers attached to the cranium with cut marks indicate that Paleolithic hunter-gatherers were present when reindeer migrated through the Lone Valley; they presumably hunted them, as has been observed through investigations at nearby sites (Niven 2006; Krönneck 2012). Additionally, cut marks found on the cave bear thoracic vertebra indicate the removal of meat from bones (Fig. 4d). Cave bears die naturally during hibernation inside caves, despite clear evidence of hunting or other anthropogenic modifications (Münzel and Conard 2004). Therefore, the accumulation of cave bear bones in front of Hohlenstein might have an anthropogenic background. The faunal remains from excavations in front of Hohlenstein seem to be the result of sporadic human hunting activity accompanied by predominant carnivore activities around a carnivore den (Gamble 1999; Kitagawa 2014).

The antler finds in front of Hohlenstein are not only the result of peripheral waste from anthropogenic activities around the cave entrance and/or carnivore activities, but may represent some form of natural accumulation of organic remains. Reindeer shed their antlers at specific times of the year, especially females and young animals within the calving grounds (Miller et al. 2013), and as group sizes today can reach up to thousands of animals, they might leave an accumulation of antlers.

Based on the morphology of the antlers pedicles (base) in combination with their dimensions, we can distinguish between females and males. The collection of reindeer antlers from the interior of Hohlenstein-Stadel and from the excavation areas in front of Hohlenstein shows morphometric similarities. All antler measurements vary within ranges of ca.10-20 mm breadth and ca.15-27 mm thickness on Position 2, defined as the diameter between the first and the second tine. These actual sizes are very small compared to known antler dimensions of adult males which, at a minimum, measure 25 mm breadth and 32 mm thickness (Sturdy 1975). The antlers analyzed here represent a group of females and young animals up to their third year according to metrical parameters. Equivalent bone fusion stages of reindeer from the 1997 and 1998 excavations, such as unfused distal metapodial, calcaneus and proximal tibia, also indicate that these animals were less than 3 years old. Groups of female and young reindeer show a distinctive antler growth cycle different from that of adult males (Berke 1987). While males shed their antlers in a late phase of early winter, females and young reindeer shed theirs in spring. The spring season would therefore be the period in which reindeer were present in the Lone Valley. Nowadays and presumably in Paleolithic times reindeer migrate in transitional seasons between their summer and winter pastures by following the snow line. The composition of reindeer groups also varies between these time periods, especially in spring when females lead the group from their winter quarters to the summer pastures. During these migrations, females and young reindeer shed their antlers leading to natural antler accumulations, similar to the ones recovered in front of the Hohlenstein-Complex. The Lone Valley represents a shallow crossroad between lower and higher altitudes on the Swabian Jura, which might be used as a corridor between winter and summer pastures (Niven 2006; Krönneck 2012; Kitagawa 2014). If reindeer herds were using the Lone Valley as a migration route during transitional seasons, they might be a highly predictable resource for Paleolithic hunter-gatherers of the Swabian Jura.

In this context, accumulations of reindeer antlers found in some sites, mostly rockshelters, in the highlands of southern Lower Saxony should be mentioned here (see Grote 1982). In the early 1960s, a large number of more than 800 fragments of reindeer antlers, now dated to the Magdalenian, were found during excavations at the Aschenstein rockshelter in Freden near Hildesheim, along with only few stone artifacts (Grote 1982, 59-61; Staesche 1999; Terberger et al. 2009). Grote (1982, 61) stressed that most of them were remarkably small in size. Very few of them display possible anthropogenic modifications, and modern analyses could not confirm the assertion that more than 100 of the antlers had been used as tools (see Terberger et al. 2009). While the use of some of the antlers as a raw material resource seems plausible, most of them seem to have been accumulated naturally, which may also be the case for the accumulation of small reindeer antlers found during the excavations in front of the Hohlenstein-Complex. M. Baales (1996; see also Terberger et al. 2009) suspects that the accumulation at Aschenstein rockshelter might be seen in the context of spring migrations of female reindeer to reach the places where they will give birth to their offspring.

A Magdalenian find layer at Stendel XVIII rockshelter near Groß Schneen in Lower Saxony yielded a large number of small shed reindeer antlers along with horse ribs and stone artifacts (Grote 1998). Ulrich Staesche (2005, 265) provided an interesting interpretation for this, by stating the following: "As the ribs as well as the antlers are not strong enough to serve as raw material for tool production, a more profane use of this special accumulation is here proposed: it might have been used as base of the resting places, an isolation against moisture and coldness of the earth."

In addition to the examples discussed above, considerable debate has also centered upon the sources of accumulations and the possible use of shed antlers of red deer as tools in Lower and Middle Paleolithic contexts. Some have claimed that red deer antlers were used as hacking and hammering tools at sites including Taubach near Weimar (Götze 1892; Behm-Blancke 1960) and Bilzingsleben (Mania 1986). These claims, however, are questionable in the light of the many examples of antlers that have been broken *in situ* to produce similar finds from Tönchesberg (Conard 1992) and Plaidter-Hummerich (Street 2002). While these studies have helped to clarify the natural patterns in which antlers break, in many cases researchers are unable to determine whether or not accumulations of red deer antlers are primarily of natural or anthropogenic origin.

Small reindeer antlers as raw material

The faunal material from the open-air excavations are characterized by decalcination through soil formation, with iron and manganese staining, which indicates humid conditions probably associated with fluctuations in the Lone River. These environmental conditions led to poor preservation of the finds, which reveal mostly dry breakage patterns due to sediment pressure. Clear anthropogenic modifications were not detected in the open-air cast antler fragments, while some reindeer bones (radius, etc.) show cut marks or impact marks (Fig. 4).

The even distribution of cast antlers seems to represent a natural scattering throughout the 1997 and 1998 excavation areas. In contrast, the collection of antlers inside Hohlenstein-Stadel is not natural for several reasons. The most fundamental point is that reindeer do not lose their antlers inside caves. The collection of antlers from the interior of Hohlenstein-Stadel also shows a different taphonomic pattern. First, the antlers reveal good surface preservation, suggesting a collection and placement in the cave's interior shortly after they were shed. Mineral rich antlers tend to be gnawed by reindeer themselves, by rodents or carnivores when winters are long and the availability of mineral sources is scarce (Wika 1982; Berke 1987, 109; Schuler 1994, 55). Such alterations were identified on only very few antler specimens from the cave. Second, a uniform representation in antler parts is visible. A regular breakage pattern implies controlled breakage by humans. This fractured pattern includes the antler's base and the beam directly above the 2nd brow tine. Third, some of these antler ends show fractures with small depression on one side that likely reflect an intentional breakage pattern. This pattern breaks the antler in two parts and is possibly associated with anvil (stone, etc.) use. Especially in female and young reindeer antlers the beam grows fairly straight, displaying very simple or no palmation. Researchers have speculated whether these antler beams were used in a manner different to antlers from adult males. Several authors suggest that the whole beams from small reindeer antlers were used for hafting lithic tools, but until now no archaeological evidence has been found to confirm this (Berke 1987, 99; Albrecht et al. 1994, 45; Barth 2007, 121). In this sense the cast antler base fragments may be considered a waste product after removal of the beam.

In Oeger Cave in Westphalia, an accumulation of 360 small shed reindeer antlers without archaeological context was discovered. Baales (1996, 100) interprets this as a possible cache or raw material deposit and even considers a ritual context, while Terberger et al. (2009, 99) remain cautious, pointing to the possible role of carnivores in causing such accumulations.

Deposited in the dark?

Most of the small reindeer antlers inside Hohlenstein-Stadel were found in the same levels as the *Löwenmensch* figurine. Other finds associated with this find include 14 perforated animal teeth and two ivory beads that display a clearly anthropogenic component within these Aurignacian layers (Hahn, 1986, 30, Abb. 9; 1991, 118, Abb. 31). However, all these finds are complete artifacts, and the sediments around this area lack traces of ivory carving activities. These observations raise the following question: Did

Aurignacian people deposit the *Löwenmensch* and the symbolic artifacts deep in the cave together with the antlers? (Kind and Wehrberger 2013; Kind et al. 2014).

The *Löwenmensch* and the pendants are, possibly, part of one collection. It is unlikely that these objects were manufactured in the cave given that the surrounding sediments are not rich in cultural remains as is the case at sites such as Hohle Fels, Geißenklösterle, and nearby Vogelherd (Conard et al. 2015). The worked ivory fragments found in the sediments by recent excavations are possibly part of the *Löwenmensch* itself and not manufacture debris. In the Hohlenstein-Stadel vestibules, an unworked mammoth tusk with a similar morphology to the *Löwenmensch* was found (Kind and Wehrberger 2013). Despite this find, other arguments mentioned above indicate that the figurine was not made at Hohlenstein. The recent excavations in the interior of Hohlenstein-Stadel revealed additional cast reindeer antlers that display anthropogenic modifications and were used as raw material for antler tool production (Kind 2011). Some small reindeer antlers were deposited in the dark interior of the cave together with the *Löwenmensch*. It is probable that the cast antler bases are waste products, but their relation to the symbolic appearance of associated finds cannot be explained. Reindeer were present regularly in the Lone Valley at certain seasons; their small cast antlers could have been collected in front of the Hohlenstein-Complex and further processed either outside or in the interior of Hohlenstein-Stadel.

Seven reindeer antlers still attached to their respective craniums, with two of them displaying a cast line associated with cut marks, were identified in the faunal assemblages from inside the cave. This indicates that hunter-gatherers were present at the time when antlers were shed during spring. Most antler fragments with cut marks are from the first and second spits (0-20 cm and 20-40 cm) from Hohlenstein-Stadel and associated with Late Pleistocene conditions, presumably the Magdalenian. In contrast, more antlers with small depressions are from the lower part of the sequence in spits 6 and 7, and associated with the Aurignacian. A change from depressions to cut marks might be associated with a general shift in the technical process of antler working to the groove and splinter technique from the Gravettian onwards (Pétillon and Ducasse 2012). Niven's (2006) study of the fauna from nearby Vogelherd Cave documents reindeer hunting during the fall based on the presence of males and females within the faunal assemblage. Both seasons are transitional, and indicate a time when reindeer presumably used the Lone Valley as a migration corridor.

The data from the sites of the Lone Valley demonstrate that the valley served as a corridor for migrations of reindeer during the spring. Our results also show that both Aurignacian and later Upper Paleolithic groups at Hohlenstein-Stadel regularly collected and sometimes manufactured small cast reindeer antlers shed by females and juvenile animals in the herd. Finally, the faunal remains from Hohlenstein-Stadel and Vogelherd clearly demonstrate that Upper Paleolithic hunters and gatherers systematically hunted reindeer during all of the cultural phases documented in the Lone Valley.

Summary

The large number of small reindeer antlers from the open-air excavations conducted in 1997 and 1998 were used to study the accumulation of such antler pieces at the

Hohlenstein-Complex. The specimens have been analyzed for their use as seasonal indicator, for taphonomic modifications, and contextual deposition. The major results of our analysis can be summarized as follows: First, small reindeer antlers are useful indicators for seasonality; they specify the location where the groups of females and young reindeer traveled on their spring migrations. Second, the collection of reindeer antlers from the excavation areas outside the Hohlenstein-Complex presumably represents a natural accumulation; the cast antlers from inside Hohlenstein-Stadel, on the other hand, seem to be the result of anthropogenic collections and regular antler breakage. Finally, many antler fragments were found in the context of the *Löwenmensch* figurine dating to the early Aurignacian.

During this study, small cast reindeer antlers turned out to be an informative find category, especially for the analysis of subsistence strategies and the predictability of resources. Time and location of reindeer migrations during the Paleolithic are also an important factor for settlement choices and settlement dynamics of hunter-gatherers, and not only in the Lone Valley. Furthermore, the way these antlers were introduced into the archaeological context as a non-food source adds further insights into the use of resources in the past.

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