Everything lost? Reconstruction of Middle- and Upper Paleolithic occupations at the Felsenhäusl-Kellerhöhle, Lower Altmühl Valley (Franconian Jura, SE Germany)

Alles verloren? Rekonstruktion mittel- und jungpaläolithischer Begehungen der Felsenhäusl-Kellerhöhle, Unteres Altmühltal (Fränkischer Jura, SO Deutschland)

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Abstract - The present article is dedicated to the Paleolithic site of Felsenhäusl-Kellerhöhle in the Lower Altmühl Valley, Germany. The small cave was almost completely excavated in 2000 by the owner of the property in artificial spits, but without additional documentation of changes in sediment and without precise registration of the spatial distribution of the numerous lithic artifacts and faunal remains found in the cave filling. Instead, all finds were separated into six assemblages mainly according to their excavation depths or their provenance from a distinct part of the cave. We compared these assemblages based on two parameters, typo-technology and raw material spectrum, and conducted geoarcheological investigations to assess their stratigraphical context. Remnants of Pleistocene sediments were found in two different locations inside of Felsenhäusl-Kellerhöhle (section West and section East). While the results of the lithic analysis suggest heavy stratigraphic mixing, geoarchaeological analyses proved the existence of an intact stratigraphy at least in parts of the cave. We identified inappropriate excavation methods as the main factor for this. Based on the lithic analysis, it was possible to distinguish two Paleolithic assemblages, one from the Upper Paleolithic characterized by several backed tools, and one from the Middle Paleolithic identified by bifacial tools. Comparisons with multi-layered sites in the vicinity of Felsenhäusl-Kellerhöhle revealed strong similarities with the regional Magdalenian and Micoquian, respectively.

Zusammenfassung - *Im Fokus des vorliegenden Artikels steht die paläolithische Fundstelle Felsenhäusl-Kellerhöhle im Unteren Altmühltal. Die kleine Höhle wurde im Jahr 2000 vom Besitzer des Grundstücks in vier Abträgen von jeweils 30 cm ausgegraben. Weitere Angaben zur Lage der Funde, die aus Steinartefakten und Faunenüberresten bestehen, liegen nicht vor. Aufgrund der fehlenden Grabungsdokumentation wurden die Grabungseinheiten anhand ihrer typo-technologischen Zusammensetzung und mit Hilfe ihres jeweiligen Rohmaterialspektrums auf die Relevanz für eine Identifikation chronologischer Einheiten hin untersucht. Überreste pleistozäner und holozäner Sedimente konnten an zwei verschiedenen Stellen innerhalb der Felsenhäusl-Kellerhöhle geoarchäologisch untersucht werden. Während die Analysen der Steinartefakte nahelegen, dass die Funde von starker stratigraphischer Durchmischung betroffen sind und daher analog zu einem Lesefundkomplex behandelt werden müssen, bewiesen die geoarchäologischen Analysen die Existenz einer intakten Stratigraphie zumindest in Teilen der Höhle. Angesichts des komplexen Prozesses der Fundplatzentstehung ist davon auszugehen, dass große Teile der Vermischungen auf eine unangemessene Grabungsmethodik zurückzuführen sind. Es konnten zwei paläolithischen Einheiten unterschieden werden: „Inventar 1" gehört in ein mittleres und/oder spätes Jungpaläolithikum und wird durch rückengestumpfte Werkzeuge charakterisiert, während „Inventar 2" in ein spätes Mittelpaläolithikum gehört und durch zahlreiche Biface-Geräte gekennzeichnet ist. Vergleiche mit anderen Fundstellen im Unteren Altmühltal zeigten große Ähnlichkeiten zu Fundstellen des regionalen Magdalénien und Micoquien.*

Keywords - **Lower Altmühl Valley, Middle Paleolithic, Upper Paleolithic, MMO, Magdalenian, geoarchaeology**
Unteres Altmühltal, Mittelpaläolithikum, Jungpaläolithikum, MMO, Magdalénien, Geoarchäologie

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Introduction

Together with the Swabian Jura, the Lower Altmühl Valley (Fig. 1) in the Franconian Jura represents one of the two major clusters of Paleolithic sites in Southern Germany (Freund 1963, 1998: 11; Uthmeier 2004a; Conard 2015). Systematic Paleolithic research in the Lower Altmühl Valley began in the early 20th century with excavations in the Klausenhöhlen and Fischleitenhöhle led by H. Obermaier (e.g. 1914) and F. Birkner (1917, 1918), respectively. Although these early campaigns represent milestones in the regional history of research, less rigorous excavation methods were applied and the stratigraphic contexts of archaeological finds was only poorly documented (Böhner 2008: 15; Sorcan 2011: 36ff.). Modern excavation methods, inspired by those applied by H. Movius in Abri Pataud (Movius 1975), were introduced by G. Freund (1998) during her and L. Zotz´s excavations of the Sesselfelsgrotte between 1964 and 1981.

The most important sites excavated after World War II are Sesselfelsgrotte (Weißmüller 1995; Richter 1997; Freund 1998; Dirian 2003; Böhner 2008), Abri am Schulerloch (Böhner 2008) and Abri im Dorf (Prufer 1961). Sesselfelsgrotte yielded one of the most detailed sequences from MIS 5 to MIS 1 in Central Europe (Weißmüller 1995; Richter 1997; Freund 1998; Dirian 2003; Böhner 2008), including Paleolithic occupations of the Mousterian, the Mousterian with Micoquian-Option (MMO)/ *Keilmessergruppen* (for the definition of the term see Richter 1997; Jöris 2004) and the Magdalenian. In addition, Sesselfelsgrotte is one of the few sites in Southern Germany that yielded Middle Paleolithic human remains. In the "Lower Levels" and the "G-Complex", fossils of at minimum two juvenile Neanderthals (*Homo sapiens neanderthalensis*) and one neonate of the same sub-species were found (Rathgeber 2006). Other important sites of the Lower Altmühl Valley are the karstic system of Klausenhöhlen (Uthmeier et al. 2019), where Klausennische yielded occupations of the MMO/ *Keilmessergruppen* and Mittlere Klause assemblages discussed for their classification as Gravettian or Magdalenian (Beck et al. 2006). Mittlere Klause gained international attention due to the fact that it contained the oldest burial of a modern human (*Homo sapiens sapiens*) in Germany, probably dating to the Badegoulian (Street et al. 2006). Due to a shift of focus to the loess region between Regensburg and Passau, scientific excavations in the Franconian Jura were rare, until the Institute of Pre- and Protohistory of the Friedrich-Alexander-University Erlangen-Nürnberg (FAU) commenced new fieldwork in Klausennische (Uthmeier et al. 2019). This new series of research campaigns in the Lower Altmühl Valley aims at a reevaluation of existing archaeological sequences. Parallel to novel field work at selected sites, the status of sites reported to be largely or totally excavated is evaluated. The site of Felsenhäusl-Kellerhöhle (Hattermann 2018) belongs to the latter group. In this paper, we present preliminary results of our ongoing investigations (Uthmeier et al. in press) at the site.

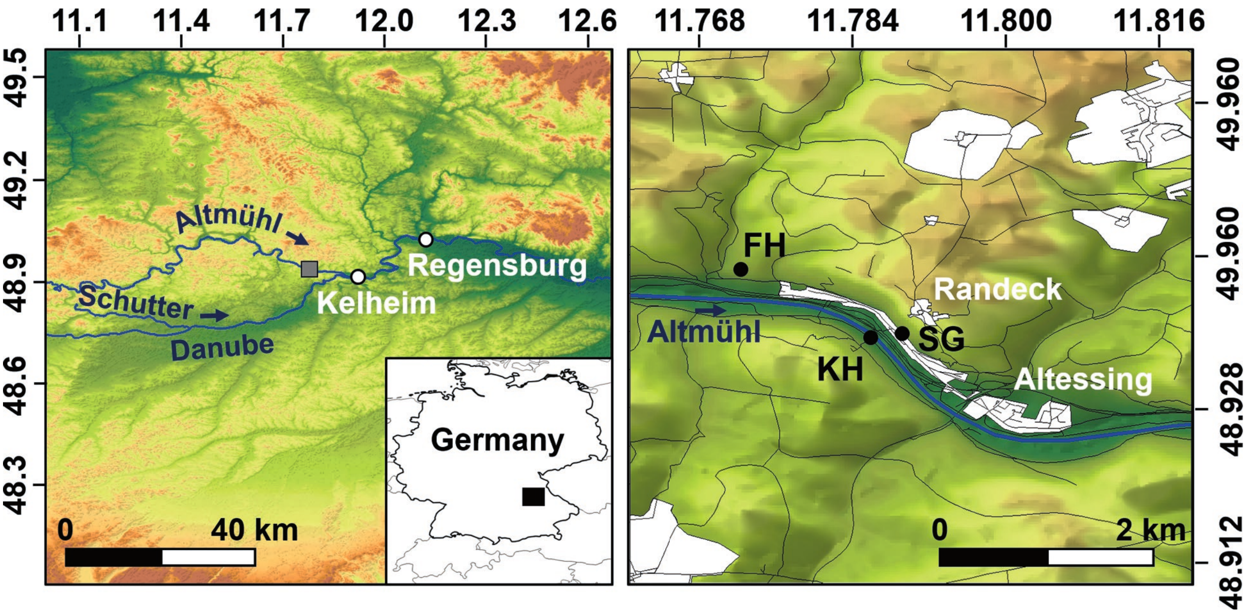


Fig. 1. Paleolithic Sites in Lower Altmühl Valley: Detail 1: Overview of the Altmühl Valley in the Franconian Jura. The gray square indicates the location of the map displayed on the right. Detail 2: Location of Sesselfelsgrotte (SG), Klausenhöhlen (KH) and Felsenhäusl Caves (FH) in the Lower Altmühl Valley.

Abb. 1. *Paläolithische Fundstellen im Unteren Altmühltal. Detail 1: Überblick über das Altmühltal im Fränkischen Jura. Das graue Kästchen zeigt die Position der Karte auf der rechten Seite an. Detail 2: Position der Sesselfelsgrotte (SG), Klausenhöhlen (KH) und Felsenhäusl-Höhlen (FH) im Unteren Altmühltal.*

The site of Felsenhäusl-Kellerhöhle

The Felsenhäusl Caves (FH in figure 1) are located approximately 2 km west of two major Paleolithic sites in the region. While Sesselfelsgrotte (SG in figure 1) is situated on the same river bank of the Altmühl, the Klausenhöhlen (KH in figure 1) are on the opposite one. The karstic system of the Felsenhäusl (which translates in English as "Small Rock House") comprises at least three separate cavities formed within a 14 m high and 50 m wide, almost vertical limestone cliff. The Altmühl, which became part of the artificial Rhein-Main-Donau-Canal, is in a distance of approximately 200 m and not more than 20 m below the opening of the caves. Two of the Felsenhäusl Caves were partly destroyed during the construction of buildings and subsequently excavated by their private owner. Because finds were restricted to Pleistocene fauna, excavations were conducted in close cooperation with the Bayerische Staatssammlung für Paläontologie und Geologie. In the year 2000, the owner of the Felsenhäusl Caves continued fieldwork in the third cavity named Kellerhöhle (which translates in English as "Cellar Cave"). From here on we will refer to this site as "Felsenhäusl-Kellerhöhle".

Felsenhäusl-Kellerhöhle is a karstic cave consisting of a 6 m long phreatic tube with two entrances situated at approximately right angle to each other. The larger entrance opens towards the South to a small, almost horizontal limestone terrace void of any sediments. The opening measures about 1.4 m in height and 2 m in width. The much smaller second entrance is directed towards the West and still covered by sediments in its lowermost part, but will not have been much larger than the visible opening, which is 0.3 m wide and 0.2 m high (Figs. 2 & 3). The western entrance is difficult to access due to the steepness of the cliff in front of it. Therefore, the southern opening must be considered the main entrance at least for humans entering the cave. The cave itself exhibits a maximum height of 1.2 m and a maximum width of 2.4 m in the front part near to the southern entrance. Towards the western entrance, the cave interior becomes narrow and low. The space suitable for human occupations was even more limited, because the cave floor is uneven (depending on the filling) due to the occurrence of gullies that carved the bedrock (for more details see result section and figure 9). The small dimensions of the cave are best illustrated by our 3D-model (Fig. 3).

The excavator dug the deposits of the Felsenhäusl-Kellerhöhle by artificial spits (labelled as "layers"), each measuring 30 cm in thickness, down to a maximum depth of 120 cm. The finds comprise lithic artifacts and faunal remains and were stored mainly according to these spits. The depths of the spits were measured in relation to the top of respective filling and without

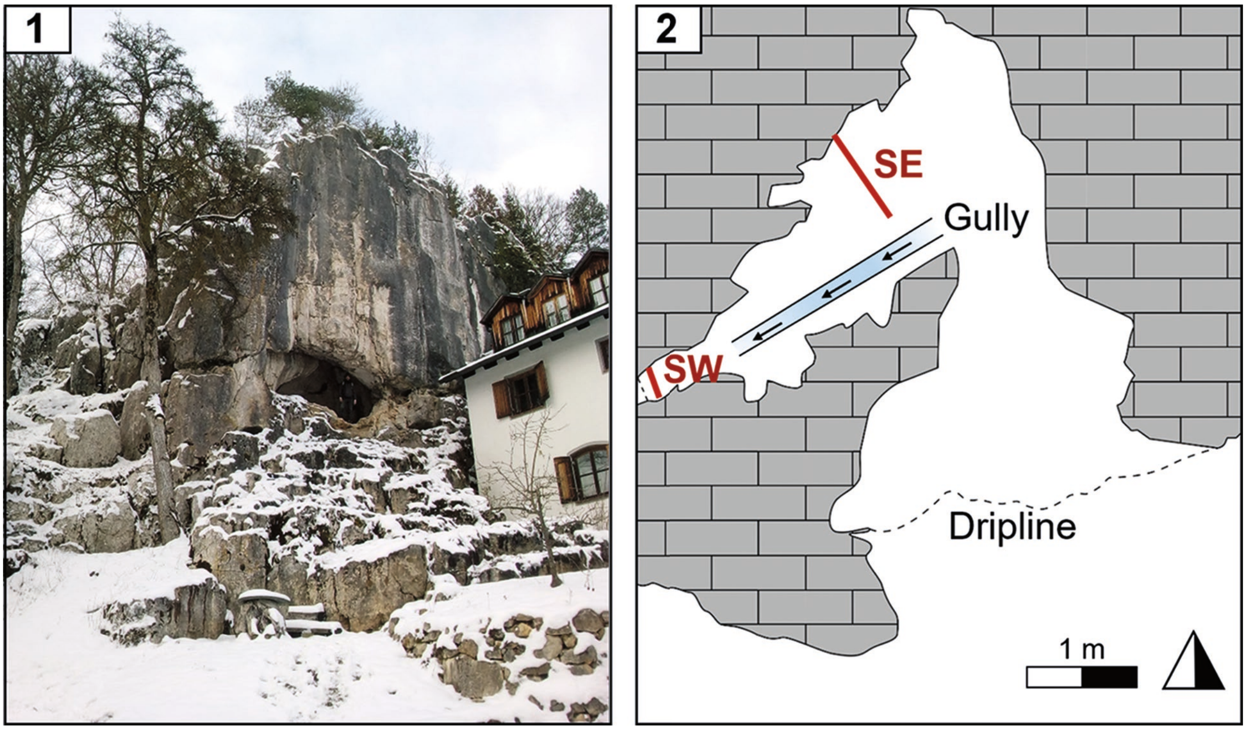


Fig. 2. Felsenhäusl-Kellerhöhle. Detail 1: Entrance to Felsenhäusl-Kellerhöhle, two caves have been incorporated within the building on the right. Detail 2: Sketch map of Felsenhäusl-Kellerhöhle depicting the location of Section West (SW), Section East (SE) (modified from Kaulich & Weißmüller 2003).

Abb. 2. *Felsenhäusl-Kellerhöhle. Detail 1: Eingang zur Felsenhäusl-Kellerhöhle, zwei Höhlen wurden in das Gebäude auf der rechten Seite integriert. Detail 2: Skizze der Felsenhäusl-Kellerhöhle mit Markierungen der Positionen von Abschnitt West (SW) und Abschnitt Ost (SE) (bearbeitet nach Kaulich & Weißmüller 2003).*

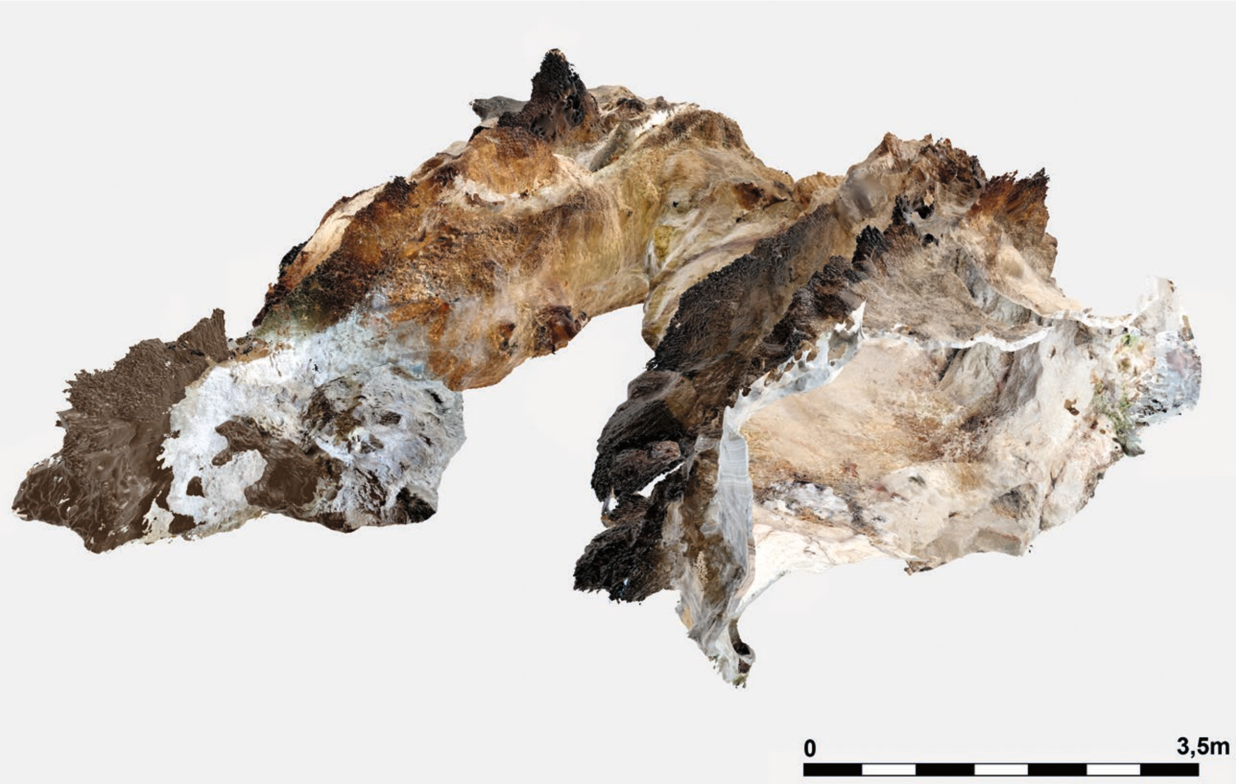


Fig. 3. Felsenhäusl-Kellerhöhle. 3D-Model of the Felsenhäusl-Kellerhöhle made with SfM (Structure from Motion); view from the South (figure: C. Mischka).

Abb. 3. *Felsenhäusl-Kellerhöhle. 3D-Modell der Felsenhäusl-Kellerhöhle, das mit SfM (Structure from Motion) erstellt wurde; Blick von Süden (Abb. C. Mischka).*

consideration of changes in sediment. The sediments were only roughly sieved and, therefore, the assemblage includes only few small items. After the owner reported the discovery of cultural remains, the Bayerisches Landesamt für Denkmalpflege classified the site as an archaeological monument and prohibited further excavations. At this stage, the sediment infilling of the cave had already been largely removed. In general, there is very few documentation of the excavation and the stratigraphical context of the finds. With regard to the finds, the observation that ceramics and glass of Holocene age were not only found in the upper spits, but also near to the bedrock (interview with the excavator), is of major importance as it indicates stratigraphical mixing. However, if this applies to the entire cave is uncertain. In addition, for nearly 1/3 of the material, there is no information about the excavation depth at all. After the excavations were ceased, B. Kaulich and W. Weißmüller (2003) documented and published a section exposed in front of the western entrance and briefly inspected the lithic assemblages. According to them, the section was composed of several distinct *in-situ* Pleistocene layers and the artifacts were supposed to belong to the Middle- and the Upper Paleolithic. In the following years, the Felsenhäusl-Kellerhöhle was mentioned and mapped in articles and book chapters providing an overview over the Bavarian Paleolithic (Beck & Kaulich 2006; Kaulich & Weißmüller 2003; Sorcan 2011: 173). Apart from these brief mentions, the material remained unpublished.

Research Questions

In this paper, we elucidate the archeology and geoarcheology of the Felsenhäusl-Kellerhöhle in greater detail for the first time. Research questions, which guided the investigations, were the following:

- Integrity of the stratigraphical sequence: Whereas the excavator reported the cave filling being heavily mixed, the documentation of the section preserved in the back of the cave by B. Kaulich and W. Weißmüller (2003) suggested an *in-situ* sequence. These two conflicting hypotheses have to be tested by modern methods.
- Integrity of the artificial spits: The excavator assumes that the excavation spits correlate to geological layers. In this paper, we test the archaeological material for differences between these spits, and elucidate, in case of differences, whether these indicate the presence of a chronological sequence.
- Classification and dating of the lithic assemblage(s): After clarifying their context, we aim at differentiating the lithic artifacts as detailed as possible. Furthermore, we try to classify and date the industries recognized.

Material and Methods

The material used and methods applied in this article concern the geological sequences documented in different areas of the Felsenhäusl-Kellerhöhle and the lithic artifacts recovered from the cave filling. In the following, the material and methods are described for each part of this interdisciplinary approach separately.

Geoarchaeological material and methods

Inside Felsenhäusl-Kellerhöhle, we documented two exposures of sediment. In the back of the cave, below the western opening, we recognized the remnant of the section published by B. Kaulich and W. Weißmüller (2003). This profile, which we named "Section West", measures 100 cm in height and 90 cm in maximum width (Figs. 2 & 7). About 2 m east from the southern opening, we documented a second exposure, which was previously not published. We labelled this section "Section East" (Figs. 2 & 9). It exhibits heights between 35 cm in the southern and 45 cm in the northern part, and a width of 80 cm. Furthermore, along the cave walls we observed brecciated sediments, which appeared covered and cemented by laterally continuous secondary calcium carbonate features (Fig. 10).

From both sections we collected samples for micromorphology; these are still under study. We described lithological properties of sediment exposures and micromorphological blocks, distinguishing a total of 9 geological layers (GL). For each GL we described depth, transition to the next lower sediment (according to Fitzpatrick 1983), and amount of coarse (>2 mm) and fine (<2 mm) fraction by comparison with frequency charts (Chilingar et al. 1967). For the fine fraction we described Munsell color and grain size by "feel" (Vos et al. 2016). For the gravel, we reported color, composition, frequency (Chilingar et al. 1967), sizing (according to the ISO 14688-1:2002 standard), shape (Zingg 1935), roundness (Powers 1953) and sorting (Stoops 2003: 48).

Lithic artifacts and methods of investigation

The analyzed lithic assemblage from Felsenhäusl-Kellerhöhle comprises 2 741 artifacts. The excavator distinguished six assemblages. To indicate that these do not correlate to geological layers *per se*, we refer to them as "Evaluation Units" ("EU": Fig. 4).

The six "EUs" can be divided into two groups:

- Group 1 consists of four units, EU. 1 to EU. 4, for which information is available concerning the depth of the artificial spits in relation to the respective ground surface.
- Group 2 consists of two units, EU. 5.1 and EU. 5.2, for which such information is not available. EU. 5.1, to a small extent (approximately 70 artifacts), is the result of a subjective selection of pieces from the EUs of Group 1 by the excavator mainly based on the state of preservation. In addition EU. 5.1 contains further finds for which the excavator could not provide any information. Artifacts from EU. 5.2 were excavated in the "Eastern Part" of the cave (according to the excavator) without differentiation of depth; a more precise localization of the finds is impossible due to the lack of documentation.

In sum, 68.8 % of the artifacts have rough estimations about the depth in which they were found grouped in 30 cm spits. For the remaining 31.2 %, no such information is available.

To test the plausibility of EUs, we compared their typological- and technological features as well as their raw material spectrum. The basic hypothesis, which has to be tested, is that the EUs, despite their static definition and horizontal orientation, still represent a chronological succession with the older EUs at the base and the latest EUs at the top. In this case the original sequence would go back to a more or less horizontal sedimentation not severely altered by post-depositional processes.

The results of the lithic analysis are independently crosschecked by the geoarchaeological investigations presented in this article. The research design for the

Evaluation Units Group 1	Depth	Other Information	Finds (N)	Finds (%)
EU. 1	0-30 cm	/	76	*2.8*
EU. 2	30-60 cm	/	330	*12.0*
EU. 3	60-90 cm	/	752	*27.4*
EU. 4	90-120 cm	/	727	*26.5*
Evaluation Units Group 2	**Depth**	**Other Information**	**Finds (N)**	**Finds (%)**
EU. 5.1	?	In parts selection by the excavator	381	*13.9*
EU. 5.2	?	From the "Eastern Part" of the cave	475	*17.3*
	Total		**2 741**	**100**

Fig. 4. Felsenhäusl-Kellerhöhle. Definition of the "Evaluation Units" (EUs) sorted into two groups: Group 1, for which there is stratigraphical information available, consists of EU. 1 - EU. 4. Group 2, for which there is no stratigraphical information available, consists of EU. 5.1 and EU. 5.2.

Abb. 4. *Felsenhäusl-Kellerhöhle. Definition der „Auswertungseinheiten", die in zwei Gruppen aufgeteilt sind: Gruppe 1 beinhaltet EU. 1 - EU. 4; zu diesen liegen stratigraphische Informationen vor. Gruppe 2 beinhaltet EU. 5.1 und EU. 5.2; zu diesen liegen keine stratigraphischen Informationen vor.*

evaluation of the excavation spits using the lithic artifacts is visualized in figure 5.

Most important variables are tool types and technological marker pieces defined as being chronologically sensitive on the broad scale of periods (e.g. Middle Paleolithic and Upper Paleolithic). The resulting assemblages are labelled "basic assemblages". Raw material is seen as an attribute of secondary importance, because the same outcrop might have been in use in the course of different periods. Only in cases when raw material units were exclusively used during one period ("raw material exclusivities"), these are on the whole considered to belong to that period. This applies to all artifacts of the respective raw material unit including otherwise chronologically indifferent pieces. These merged assemblages are called "expanded assemblages". In a last step, expanded assemblages are tested for their correlation to the EUs.

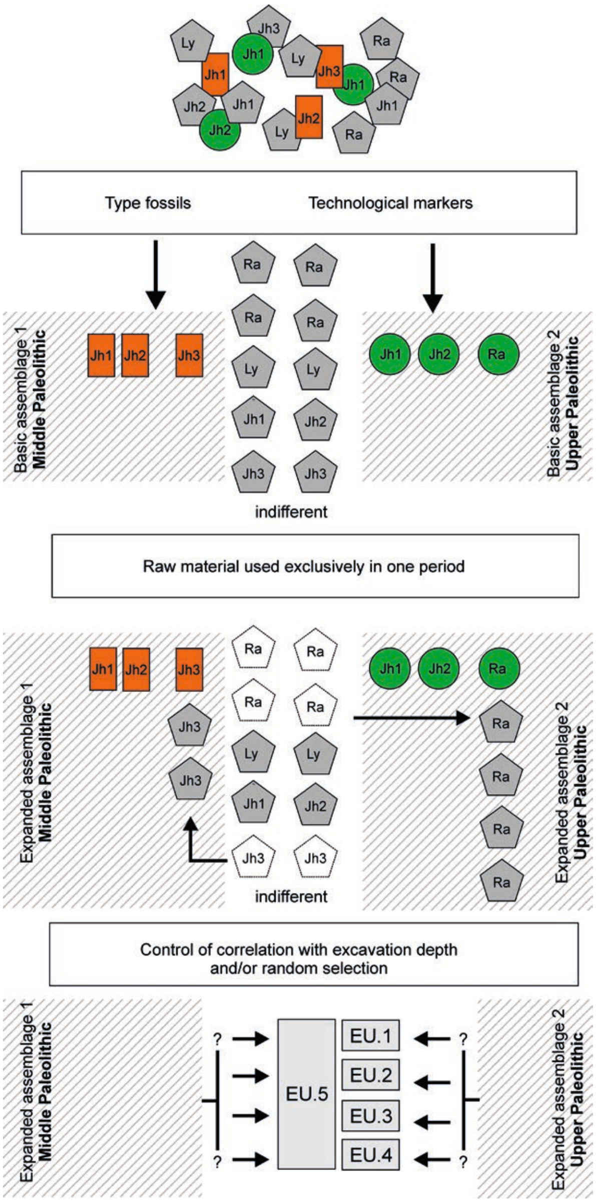


Fig. 5. Felsenhäusl-Kellerhöhle. Overview of the research design applied: After the identification of chronologically sensitive lithic type fossils and technological markers ("basic assemblages"), raw material units exclusively used during one period are added ("expanded assemblages"). Both types of assemblages are tested for their correlation with the excavation spits.

Abb. 5. *Felsenhäusl-Kellerhöhle. Überblick über die angewandten Methoden der Inventarzusammenstellung: In einem ersten Schritt werden Leitformen und chronologisch empfindliche Marker identifiziert („Basis-Inventare"), denen in einem zweiten Schritt, anhand von Rohmaterialexklusivitäten, chronologisch indifferente Artefakte zugeordnet werden können („Erweiterte Inventare"). Auf beiden Auflösungsniveaus werden Untersuchungen zur Korrelation mit den Auswertungseinheiten durchgeführt.*

Furthermore, we applied two cluster analyses based on the "Unweighted Pair Group Average" (UPGMA) algorithm and the "Manhattan" similarity index. Cluster analyses were executed with Past (Hammer et al. 2001) with the EUs being the units. In one cluster analysis, the relative frequencies of artifacts classified as Middle or Upper Paleolithic (basic assemblages) were used as variables. The second cluster analysis was calculated for the frequencies of different raw material units within the EUs. In general, the chronological information of differences in the raw material composition of the EUs must be viewed with caution. It is often assumed that the availability of raw material outcrops varies even on smaller temporal scale (see Richter 1997 for the assemblages of the MMO/*Keilmessergruppen* of the G-complex of Sesselfelsgrotte). However, if regional raw material sources are limited, similar preferences will lead to equifinal acquisition strategies. Due to their random nature, EUs of Group 2 serve as a control group to estimate the value of EUs from Group 1. The more similar the typological and technological spectra of EUs from Group 1 are to those from Group 2, the less valid is the hypothesis of a chronological meaning in the EUs, and consequently in the excavation depths.

To identify raw material units (RMU) among the lithic artifacts, macroscopic attributes such as color, texture, inclusions and preservation of cortex were used following the criteria given in Uthmeier (2004b). We aimed at classifying not only the geological provenance, e.g. Jurassic Hornstone (JH), but also units representing either outcrops or single nodules (indicated by a numeral suffix, e.g. JH1). The numeral suffix "0" is indicating that a further differentiation was not possible (e.g. JH0). After a RMU was defined, we tried to find an equivalent in the raw material collection of the Institute for Pre- and Protohistory in Erlangen. The raw material collection of the FAU is especially relevant in this regard, because most of the material results from systematic surveys conducted in the course of the analysis of the Middle Paleolithic layers of Sesselfelsgrotte (Weißmüller 1995; Richter 1997). It follows that the raw material collection contains most of the larger outcrops in the region of the Lower Altmühl Valley and, in first place, enables an estimation of the variability of the local to regional raw materials.

Data collection for lithic artifacts followed the type and attribute list published by B. Auffermann et al. (1990). Attributes were recorded for every artifact individually. Definitions of blanks were taken from J. Hahn (1982). Due to the fact that the methodology of B. Auffermann et al. (1990) was developed for sites from the Upper Paleolithic, we added categories for Middle Paleolithic blank- and tool types following G. Bosinski (1967) and E. Boëda (1994). All feature characteristics were stored and analyzed in an ACCESS-Database.

In a first step, the analysis of the lithic material from Felsenhäusl-Kellerhöhle aims at the distinction between broad chronological units on the level of periods; afterwards, more detailed analysis may lead to a further sub-division. The first examination of B. Kaulich and W. Weißmüller (2003) postulated a Middle- and a Upper Paleolithic component. Therefore, the first attempt of a chronological distinction between EUs is based on attributes that allow a classification of artifacts to one of these two periods. Despite the fact that the type list of Auffermann et al. (1990) is extensive, we restricted the number of artifact types used for a first elucidation of the time depth in the EUs as well as the overall assemblage to type fossils and technological marker pieces indicating concepts of retouch and raw material reduction with fixed chronological positions. Such a broad distinction is even more appropriate, as the role of several "type fossils" has become questionable in the last decades.

In fact, data from excavations conducted over the past 20 years have blurred the lines between the Middle and the Upper Paleolithic. Examples for the occurrence of comparably large quantities of blades and even bladelets, together with corresponding cores, in a Middle Paleolithic context are Tönchesberg (Conard 1992), Rheindahlen (Bosinski 2008) or Wallertheim (Conard & Adler 1997) during MIS 5, and chronologically younger, Balve IV (Pastoors & Tafelmaier 2010). Admittedly, also classical Upper Paleolithic tool types, such as endscrapers, borer or burins, appear in Middle Paleolithic contexts. However, at least in Middle Paleolithic assemblages of Bavaria, Upper Paleolithic tool types are usually made on flakes (Uthmeier 2004a), leading to the use of the scar pattern of blanks as an additional distinctive attribute. Our list of tool types and technological marker pieces supposed to indicate a production either in Middle Paleolithic or Upper Paleolithic is comparably short (Fig. 6) and influenced by the regional data set so far known from Southern Germany (Uthmeier 2004a; Richter 2016; Conard 2015), where transitional industries (in the sense the Châtelperronian or the Initial Upper Paleolithic, see Hublin 2015) are still missing. In this regard it is important to mention that we counted leafpoints, which are sometimes classified as belonging to a transitional industry, as Middle Paleolithic (for an extended discussion see Uthmeier 2004a; Richter 2009).

A differentiation based on the color of the patina or the state of preservation is viewed critical and therefore was not applied. Several examples have shown that both variables not necessarily correlate to the age of the corresponding artifacts (Rottländer 1989), but may be observed on artifacts from the same layer or even on the same piece (Hahn 1988).

	Diagnostic	Undiagnostic
Upper Paleolithic		
Upper Paleolithic Tool Types (typical)	Endscrapers, Burins, Borer and Backed Tools on diagnostic blanks	Retouched blades/bladelets on undiagnostic blanks
Upper Paleolithic Tool Types (atypical)	/	Endscrapers, burins and borer on undiagnostic blanks
Blanks	Blades/bladelets ≥/= 3 negatives in and/or opposite direction of the flaking	Blades/bladelets ≤/= 2 negatives in and/or opposite direction of the flaking
Cores	Blades/Bladelets ≥/= 3 negatives in and/or opposite direction of the flaking	Blades/bladelets ≤/= 2 negatives in and/or opposite direction of the flaking
Middle Paleolithic		
Middle Paleolithic Tool Types (typical)	Side scrapers and bifacial tools on diagnostic blanks	Retouched flakes on undiagnostic blanks
Middle Paleolithic Tool Types (atypical)	/	Side scrapers on undiagnostic blanks
Blanks	Levallois target flakes, Pseudo-Levallois points, wide flakes with natural or technological back	Simple flakes
Cores	Levallois cores, Quina cores, discoidal cores	Simple flake cores

Fig. 6. Felsenhäusl-Kellerhöhle. Diagnostic and undiagnostic artifacts applied for an attribution to the Middle or the Upper Paleolithic.

Abb. 6. *Felsenhäusl-Kellerhöhle. Auflistung der Artefakte, die für eine Zuweisung zum Mittel- oder Jungpaläolithikum als diagnostisch bzw. undiagnostisch angesehen wurden.*

Results

Geological sequence

Section West

In the section located underneath the western opening, we documented a sediment (GL 1a, Fig. 7) down to a depth of 24 cm, which exhibits unsorted, fine to coarse, triaxial, sub-angular, fresh (white) limestone gravel (80 %) embedded in dark grey (7.5 YR 4/1) to very dark grey (7.5 YR 3/1) silty matrix (20 %). Down to 35 to 40 cm of depth, we distinguished a separate and distinct deposit (GL 1b, Fig. 7) showing less abundant (40 %), unsorted, fine to medium, triaxial, subangular, possibly more weathered (yellower) limestone gravel in dark grey (7.5 YR 4/1) to very dark grey (7.5 YR 3/1) sandy silt (60 %). Both GL 1a and GL 1b appeared loose and intensively bioturbated by large roots from a tree which grew on the external slope in the proximity of the western opening. Contacts at the base of each of these layers were clear to diffuse and wavy.

Below GL 1b and down to a depth of about 60 cm, we reported sorted, 1 to 2 cm-sized, subangular to subrounded, triaxial to equiaxial, possibly weathered (yellowish) limestone fragments (40 %) in a reddish brown (5 YR 4/3) clayey silt (60 %) (GL 2a, Fig. 7). This

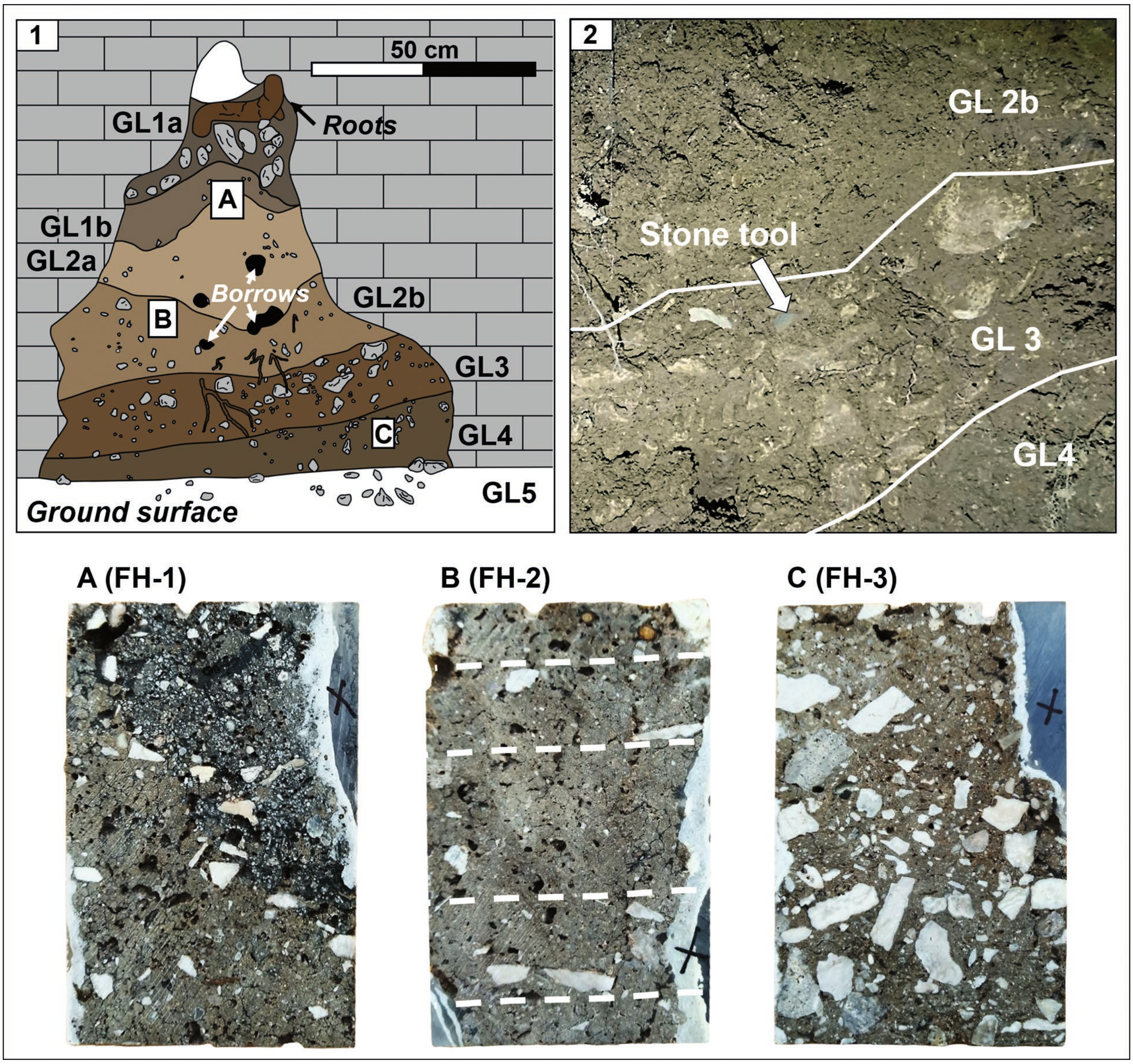


Fig. 7. Felsenhäusl-Kellerhöhle. Section West: Detail 1 depicts the geological layers (GLs) discussed in the text and the location of micromorphological samples (A, B, C). Sample FH-1 (A) was collected at the contact between GL 1b and GL 2a, FH-2 (B) is from GL 2b, and FH-3 (C) comes from GL 4. Dashed lines show the weak bedding of FH-2. Micromorphological samples measure 6x9 cm. Detail 2 shows the contact between GL 2b, GL 3 and GL 4 as it appeared in the field.

Abb. 7. *Felsenhäusl-Kellerhöhle. Abschnitt West: Detail 1 zeigt die geologischen Schichten (GLs), die im Text diskutiert werden und die Position der mikromorphologischen Proben (A, B, C). Probe FH-1 (A) stammt aus dem Kontaktbereich zwischen GL 1b und GL 2a, FH-2 (B) stammt aus GL 2b und FH-3 (C) kommt aus GL 4. Gestrichelte Linien zeigen die schwache Schichtung von FH-2. Die mikromorphologischen Proben messen 6x9 cm. Detail 2 zeigt den Kontakt zwischen GL 2b, GL 3 und GL 4 wie er in der Höhle beobachtet wurde.*

sediment appeared more compact than the above GL 1a and GL 1b, although it was bioturbated by plant roots and potential animal borrows. The contact separating GL 2a from the below sediment (GL 2b) appeared smooth and clear. Although similar to the above layer, GL 2b (Fig. 7) seemed to display some weak bedding, which appeared more visible in the micromorphological block we collected from this unit. More in detail, the chip from GL 2b exhibited 2 to 3 cm thick layers rich (>70 %) in brown (7.5 YR 4/2) clayey silt alternating with 1 to 2 cm thick beds richer (40 to 60 %) in moderately sorted, angular to subrounded, oblate to triaxial, fine to medium, poorly weathered (few yellow, but more white) fragments of limestone (Fig. 7). Within these beds, oblate, angular, fresh gravel fragments seemed to lie sub-horizontal, possibly delimiting depositional surfaces. Despite the presence of these sedimentary structures, GL 2b exhibited multiple animal and possibly insect borrows measuring 2 to 5 cm in diameter. We traced GL 2b down to a depth of 65 cm towards North and 80 cm towards South. The contact with the lower sediment (GL 3) appeared sharp and smooth.

GL 3 (Fig. 7) exhibited higher amounts (80 %) of unsorted, fine to coarse, subangular to subrounded, triaxial, weathered to fresh (yellow to white, rough to polished) limestone fragments in a yellowish brown (10 YR 5/4) silty clay/clayey silty matrix (20 %). Few centimeters below the contact we identified an undiagnostic lithic artifact (Detail 2 in figure 7). Plant roots from the above layers were present throughout GL 3. The contact with the lower layer could be traced between 80 and 90 cm below the top of the section (GL 4, Fig. 7), it appeared clear and smooth.

GL 4 was made from moderately sorted (mostly <2 cm), subrounded to subangular, triaxial to equiaxial, moderately weathered (white to yellow, rough to polish) fragments of limestone, speleothems, and snail shells in a yellowish brown silty clay/clayey silty matrix (10 YR 4/4). In contrast with the above GL 2b, the micromorphological block from GL 4 revealed that these gravel-sized components exhibit random apparent orientation. In this layer, as in the above sediments, we identified numerous plant roots.

We documented Section West down to a maximum depth of 100 cm. At this depth, outcropping from the ground surface, we observed a loose sediment (GL 5, Fig. 7), which was composed of unsorted, subangular to subrounded, fine to coarse, triaxial to equiaxial limestone fragments embedded in a yellowish brown to dark gray silty clay/clayey silt. The whole sequence of Section West is summarized below in a table (Fig. 8) trying to correlate observed natural layers with artificial "layers" as defined by the excavator.

GL		Lower boundary at depth below surface	Description	Color of fine grained matrix (Munsell color chart)	Assumed artificial "layer" as defined by the excavator
1	1a	-24 cm	unsorted, fine to coarse, triaxial, sub-angular, fresh limestone gravel embedded in silty matrix	dark grey (7.5 YR 4/1) to very dark grey (7.5 YR 3/1)	0-30 cm: corresponding to EU. 1
	1b	-35 to 45 cm	less abundant, unsorted, fine to medium, triaxial, subangular, possibly more weathered limestone gravel in sandy silt	dark grey (7.5 YR 4/1) to very dark grey (7.5 YR 3/1)	30-60 cm: corresponding to EU. 2
2	2a	-60 cm	1 to 2 cm-sized, subangular to subrounded, triaxial to equiaxial, possibly weathered lime-stone fragments in clayey silt (60 %)	reddish brown (5 YR 4/3)	
	2b	-65 cm	weak bedding of micromorphological layers rich in clayey silt alternating with beds richer in poorly sorted, angular to subrounded, oblate to triaxial, fine to medium, poorly weathered fragments of limestone	brown (7.5 YR 4/2)	60-90 cm: corresponding to EU. 3
3		-80 to -90	higher amounts of unsorted, fine to coarse, subangular to subrounded, triaxial, weathered to fresh limestone fragments in silty clay/clayey silty matrix	yellowish brown (10 YR 5/4)	
4		-?	moderately sorted subrounded to subangular, triaxial to equiaxial, moderately weathered fragments of limestone, speleothems, and snail shells in silty clay/clayey silty matrix	yellowish brown (10 YR 4/4)	
5		In front of the base of the section	Backdirt		
Not possible to correlate with our data, because the cave was likely partly refilled					90-120 cm: corresponding to EU. 4

Fig. 8. Felsenhäusl-Kellerhöhle. Stratigraphical sequence of Section West summarized.

Abb. 8. *Felsenhäusl-Kellerhöhle. Stratigraphische Abfolge von Abschnitt West zusammengefasst.*

Section East

About 200 cm from the southern opening we documented a section which we named "Section East" (Fig. 9). Given the existence of a 20 to 30 cm gap between the top of this outcrop and the bottom of the calcium carbonate pillars present in this portion of the cave (Fig. 10, details 3 & 4), we argue that the sequence preserved in Section East is truncated. The sediments exposed in Section East are likely trapped within a depression of the bedrock, which outcrops at the bottom and south from the exposure and is carved by one gully sloping westwards (Figs. 9 & 10). From the uppermost 3 cm of Section East we reported unit GL 6, which is composed of 2 mm thick layers exhibiting grey (7.5 YR 4/1) to very dark grey (7.5 YR 3/1) silt alternating with 2 to 5 mm thick yellowish brown (10 YR 5/4) silty clay laminations. In the field these laminations appeared capped by a calcite crust, measuring about 1 cm in thickness. Such feature, however, appeared not recognizable in our micromorphological sample. The contact with the below GL 7 appeared smooth, wavy and generally sharp, although

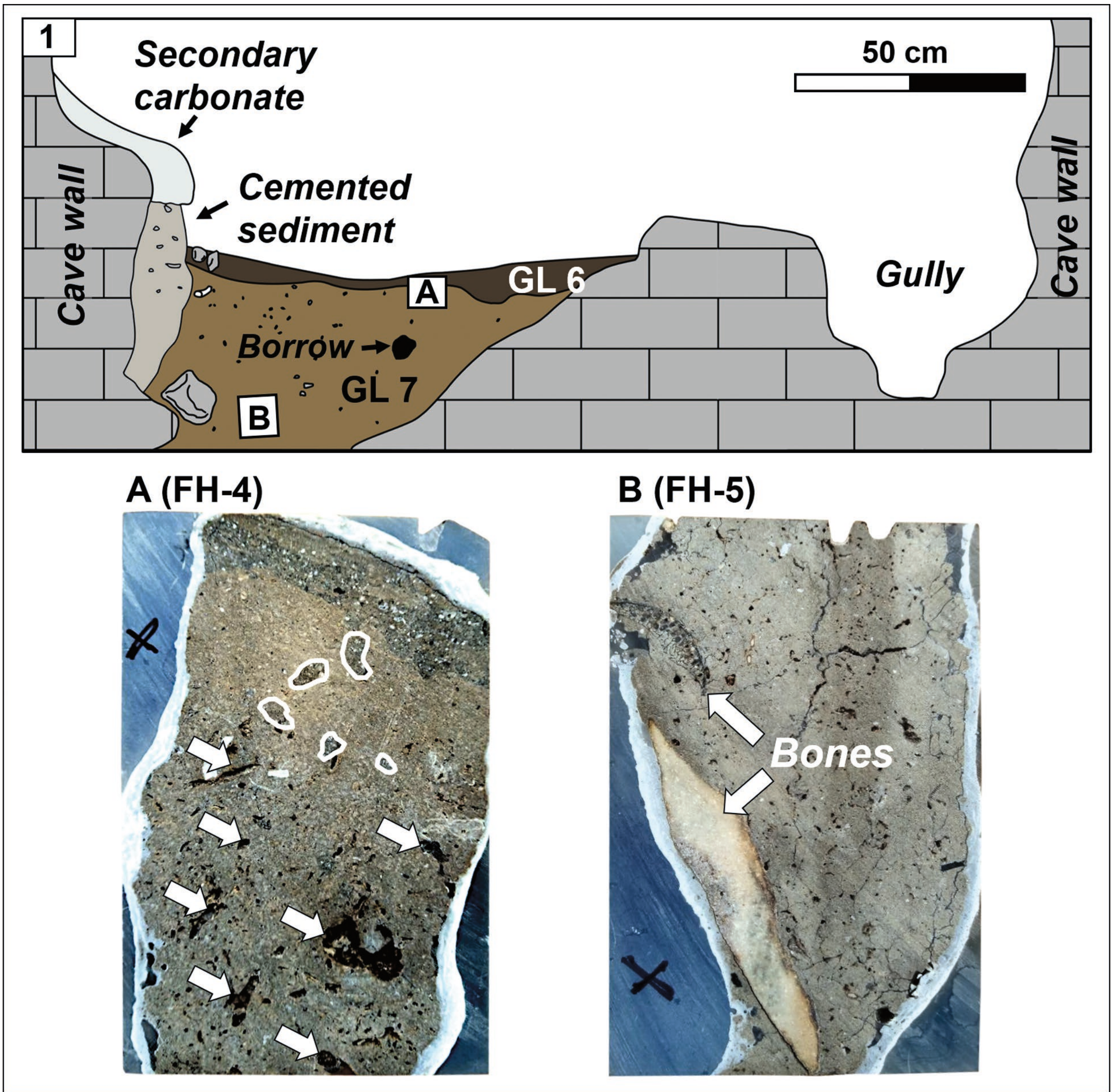


Fig. 9. Felsenhäusl-Kellerhöhle. Section East: Detail 1 depicts the geological layers (GLs) discussed in the text and the location of micromorphological samples (A, B). Sample FH-4 (A) was collected at the contact between GLs 6 and 7. This sample appears fairly bioturbated as shown by the downwards translocation of sediment from the upper darker laminations (white circles) and the frequent channels and chambers produced by borrowing fauna (white arrows). On the opposite FH-5, which was recovered from the bottom of GL 7, appears less disturbed and exhibits gravel-sized fragments of bones. Micromorphological samples measure 6x9 cm.

Abb. 9. *Felsenhäusl-Kellerhöhle. Abschnitt Ost: Detail 1 zeigt die geologischen Schichten (GLs), die im Text diskutiert werden und die Position der mikromorphologischen Proben (A, B). Probe FH-4 (A) stammt aus dem Kontaktbereich zwischen GLs 6 und 7. Diese Probe ist von Bioturbation betroffen. Kontrastierend ist Probe FH-5, die aus dem unteren Bereich von GL 7 stammt, davon weniger betroffen und beinhaltet kiesgroße Knochenfragmente. Die mikromorphologischen Proben messen 6x9 cm.*

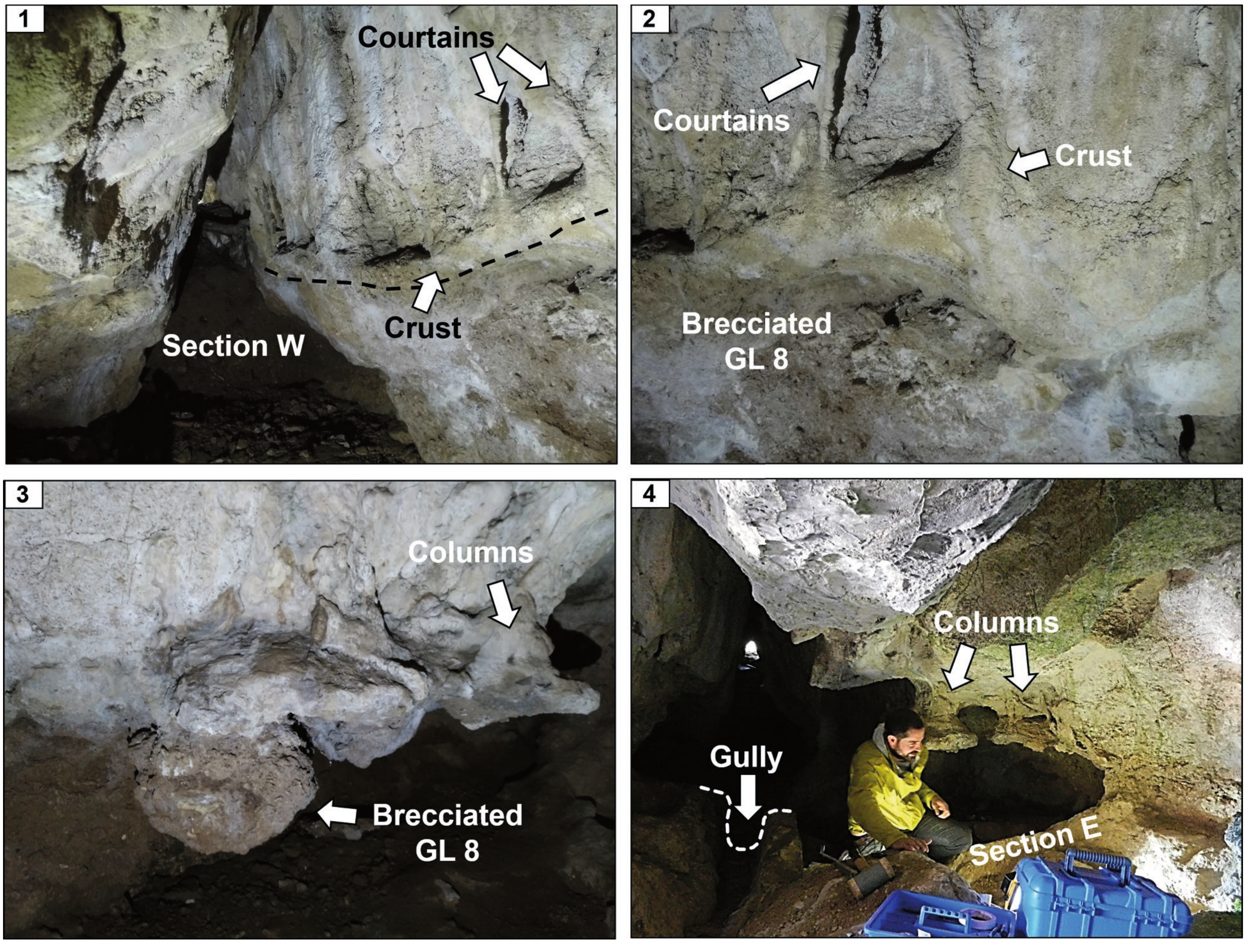


Fig. 10. Felsenhäusl-Kellerhöhle. Secondary carbonate and brecciated sediment along the Northern rock wall.
Abb. 10. *Felsenhäusl-Kellerhöhle. Sekundäres Karbonat und brekziiertes Sediment an der nördlichen Felswand.*

locally bioturbated. GL 7 (Fig. 9) was made from a massive, very compact, yellowish brown (10 YR 5/4) silty clay/clayey silt (90 %). Gravel in GL 7 was rare (10 %) and composed of subangular, triaxial, fine to medium gravel sized fragments of limestone, bone and chert (possibly artifact?) displaying downward coarsening. GL 7 exhibited evidence of bioturbation as shown by the occurrence of a 5x5 cm borrow. Along the cave wall this unit appeared cemented and covered with secondary carbonate (Fig. 9).

Sediments along the Northern wall

Along the northern wall of Felsenhäusl-Kellerhöhle, between 30 and ca. 100 cm East from Section West, we identified weakly developed, up to 25 cm long curtains made from calcium carbonate, which covered a laterally continuous, 5 to 10 cm thick calcium carbonate crust (Fig. 10, details 1 & 2). The latter appeared to slope westward, nearly reaching the bottom of GL 1a (Fig. 10, details 1 & 2). Below these speleothems, we observed brecciated remnants of a sediment made from rare subangular, triaxial, fine to medium gravel-sized fragments of limestone (40 %) embedded in a brown to yellowish brown clayey silt (GL 8, Fig. 10). Between 1 m and 1.5 m from Section West, the northern bedrock wall of Felsenhäusl-Kellerhöhle widens into a niche (Fig. 2; Fig. 10, details 3 & 4). There, these sediment remnants were covered and cemented by calcium carbonate columns measuring up to 40 cm in diameter and 40 cm in height (Fig. 10, detail 3).

Lithic artifacts

The first part of the lithic analysis is devoted to the search for chronologically homogeneous assemblages by typo-technological considerations unaware of the corresponding raw material ("basic assemblages"). In a second step, the identification of RMUs exclusively used in the Middle or Upper Paleolithic is applied to enlarge the data base, resulting in "expanded assemblages". Both the basic assemblages and the expanded assemblages are tested for their correlation with the excavation depths expressed by the respective EU. Finally, the expanded assemblages are analyzed for their typo-technological features and for the possibility of further subdivisions.

Typo-technological analysis

In terms of preservation, artifacts from all EUs are very similar. The proportion of artifacts with rounded edges and/or scars, indicating an exposure to running (karstic) water, is low. Conversely, each EU contains high proportions of artifact fragments that are best explained by post-depositional fracturing and/or non-rigorous excavation methods. Given the poor documentation, the precise process behind the fractures is difficult to access. However, facing the general richness in limestone debris of the sediments, it is plausible to assume that part of the breakages was favored by post-depositional site formation processes.

The number of diagnostic artifacts securely dated to the Middle Paleolithic on the one hand, and to the Upper Paleolithic on the other, is low. All in all, typo-technologically significant artifacts comprise 4.5 % of the overall assemblage only (Fig. 11). From these, 32 (1.2 %) are tool and blank types typical for the Middle Paleolithic, whereas 90 items (3.3 %) represent artifacts characteristic for the Upper Paleolithic. It follows that the majority of artifacts did not allow a secure attribution to one period or industry. All in all, 2 619 (95.6 %) pieces belong to the group of chronologically indifferent artifacts.

The absolute and relative frequencies of type fossils and technological markers in the EUs are given in figure 12. EUs of Group 1 allow a comparison between the typo-technological characteristics and the excavation depths. A first general observation of the frequencies in EUs of Group 1 is an increase of artifact numbers with increasing excavation depth (Fig. 4). With the exception of EU. 1 with only one chronologically significant artifact dated to the Upper Paleolithic, all EUs are characterized by a mixture of Middle and Upper Paleolithic artifacts. Even more so, the relation between Middle Paleolithic artifacts, Upper Paleolithic artifacts and indifferent pieces in EUs of Group 1 is similar. The relative frequency of Middle Paleolithic items does not exceed 1 %, and for Upper Paleolithic ones it varies between 1 % and 3 %. The ratio between Middle and Upper Paleolithic artifacts in each EU of Group 1 is between 1:2 and 1:3. Further, the composition of every EU of Group 1 is near to the one of EU 5.2, which is known to have been excavated without any control of the excavation depth. The fact that not only the majority of secure Middle Paleolithic artifacts, but also most of the Upper Paleolithic ones were found in the lowermost spit speaks for a constant and evenly distributed mixing of chronologically distant objects in all EUs.

To crosscheck results obtained from the inspection of the tables, we conducted a cluster-analysis which also included the arbitrary EUs 5.1. and 5.2 of Group 2 and sorted the EUs according to the degree of similarity between the typo-technological compositions. The resulting dendrogram (Fig. 13) shows that

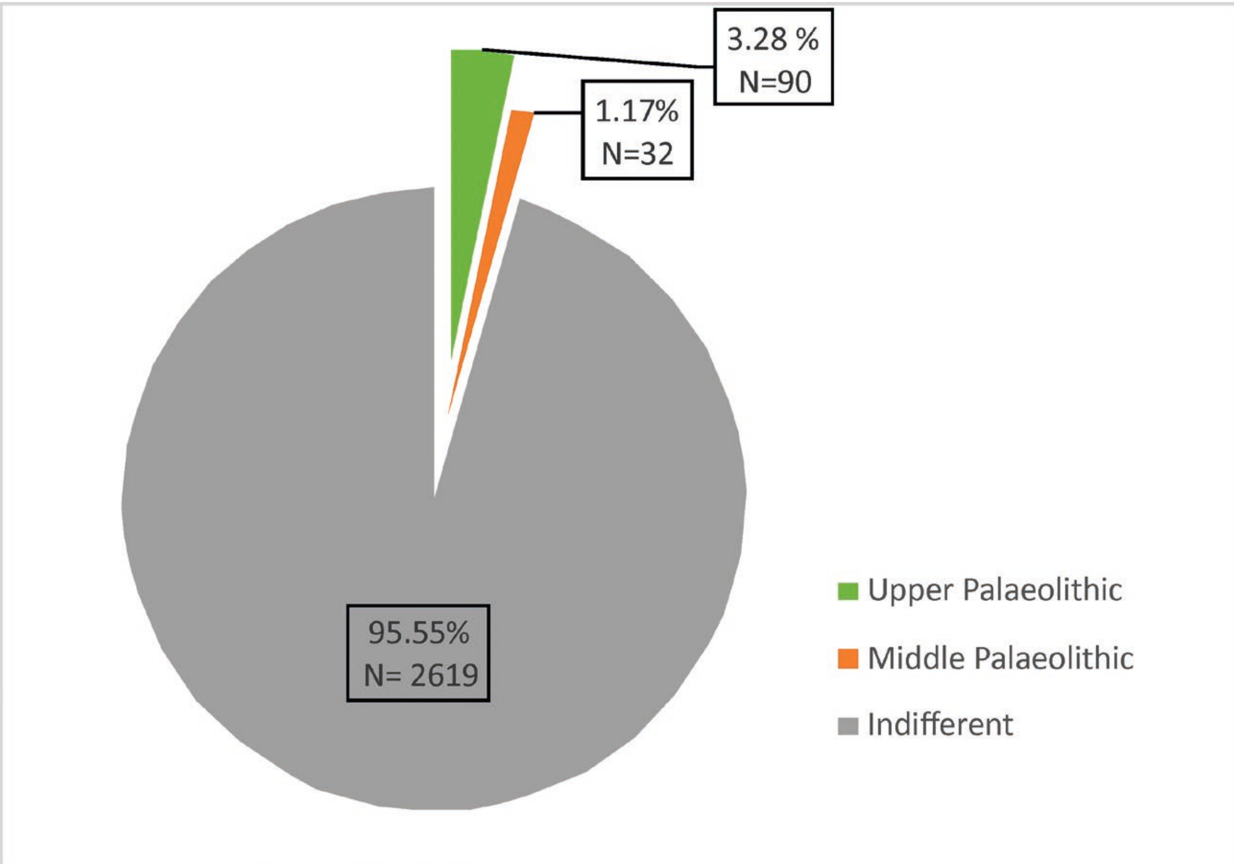


Fig. 11. Felsenhäusl-Kellerhöhle. Relative frequency of pieces diagnostic for the Middle and the Upper Paleolithic in the overall assemblage (N = 2 741).

Abb. 11. *Felsenhäusl-Kellerhöhle. Anteile diagnostischer Stücke des Mittel- und Jungpaläolithikums am Gesamtbestand (N = 2 741).*

		Upper Paleolithic type fossils and technological markers		Middle Paleolithic type fossils and technological markers		indifferent artifact types and forms		total		ratio UP/MP
		N	%	N	%	N	%	N	%	
Group 1	EU. 1 (0 to -30cm)	1	*1.3*	0	*0.0*	75	*98.7*	**76**	***100***	-
	EU. 2 (-30 to -60 cm)	9	*2.7*	3	*0.9*	318	*96.4*	**330**	***100***	3.0
	EU. 3 (-60 to -90 cm)	10	*1.3*	5	*0.7*	737	*98.0*	**752**	***100***	2.0
	EU. 4 (-90 to -120 cm)	16	*2.2*	7	*1.0*	704	*96.8*	**727**	***100***	2.3
Group 2	EU. 5.1	43	*11.3*	11	*2.9*	327	*85.8*	**381**	***100***	3.9
	EU. 5.2	11	*2.3*	6	*1.3*	458	*96.4*	**475**	***100***	1.8
	total	**90**	***3.3***	**32**	***1.2***	**2 619**	***95.6***	**2 741**	***100***	**2.8**

Fig. 12. Felsenhäusl-Kellerhöhle. Comparison of the different EUs according to their typo-technological spectra.

Abb. 12. *Felsenhäusl-Kellerhöhle. Vergleich der verschiedenen EUs basierend auf deren typo-technologischen Spektren.*

EU. 5.1 represents a distinct sub-cluster due to the relatively high proportion of diagnostic pieces, which results from the post-excavation selection made by the excavator. EU. 5.2 forms a cluster with EU. 4 and EU. 2, showing the similarity of assemblages from different excavation depths on the one hand, and the mixed assemblage of EU. 5.2. Assemblages from EU. 3 and EU. 1 form another sub-cluster; again, the sorting does not result in a cluster that brings together spits of subsequent depths. Instead, the results of the cluster analysis corroborates the assumption that EUs are affected by heavy stratigraphic mixing.

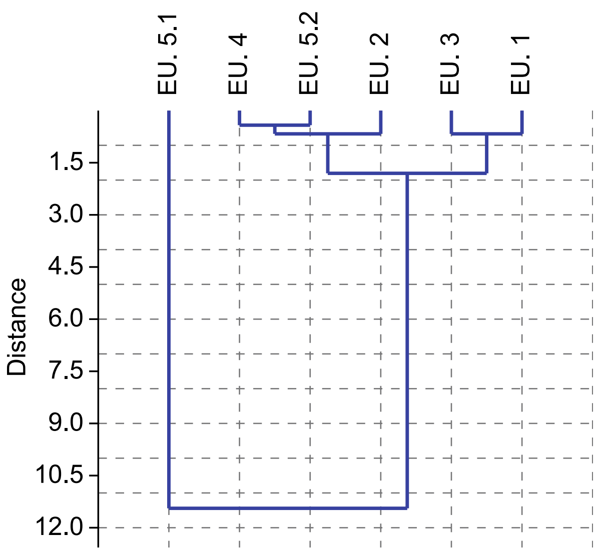


Fig. 13. Felsenhäusl-Kellerhöhle. Cluster-Analysis based on typo-technological considerations using relative quantities of diagnostic pieces (Upper/Middle Paleolithic) for every EU (given in figure 12) as variable.

Abb. 13. *Felsenhäusl-Kellerhöhle. Cluster-Analyse basierend auf typo-technologischen Einordnungen. Als Variable wurden die relativen Häufigkeiten (Jung/Mittelpaläolithikum) diagnostischer Stücke für jede Auswertungseinheit (angegeben in Abbildung 12) verwendet.*

Raw material analysis

The analysis of raw material attributes resulted in the identification of 17 RMUs. Figure 14 gives an abbreviated description of each RMU. A comparison with raw material samples stored in the lithothek of the Institute for Pre- and Protohistory at the Friedrich-Alexander-University Erlangen-Nürnberg showed that the majority of the RMUs are of local to regional provenance. Many RMUs recall raw materials found in the Paleolithic occupations of Sesselfelsgrotte (Weißmüller 1995; Richter 1997). The large number of RMUs classified as Jurassic and Cretaceous hornstones is mainly based on differences in basic features such as color, inclusions and raw volume. Therefore, these units seem to represent different geological raw material sources rather than different work pieces.

In general, Jurassic hornstone is predominant in nearly every EU, totaling up to a maximum of 336 individual pieces in EU. 3. In EU. 2, both Jurassic and Cretaceous hornstones are dominant in equal measure, with 140 individual pieces each. Quartz and lydite are rare in EU. 1 and EU. 2 (both not exceeding 20 pieces), while quartz is significantly more frequent in EU. 3 and EU. 4 (150 pieces in average). EU. 5.1 and EU. 5.2 follow this trend, while the amount of lydite stays rather low not exceeding 15 pieces. The dominance of Jurassic hornstone becomes even more apparent in the summed up relative frequencies of RMUs from the same geological formation within the EUs (Fig. 15). At the same time, the overall raw material composition of the EUs does not differ essentially; except for EU. 2, all EUs are dominated by Jurassic hornstones, followed by Cretaceous hornstones, quartz and lydite.

Even on the more detailed level of resolution, the RMUs, which are expected to allow the identification of chronologically different patterns of raw material acquisition in the different EUs, show the same trend. First and foremost, almost every RMU is represented in the different excavations depths, albeit in some cases in different amounts. A comparison of the relative frequencies of RMUs in EUs of Group 1, which represent excavation spits

Jurassic hornstone (round nodules)	JH 1	JH 2	JH 3
source	secondary	primary	secondary
description	Dark grey with red punctiform inclusions, homogeneous, rough texture	light gray with darker dots, homogeneous structure, plain texture	Dark gray with matt parts, lustrous, homogeneous, plain texture
Jurassic hornstone (round nodules)	JH 4	JH 5	JH 6
source	indifferent	primary	primary
description	Different colors, banded throughout, homogeneous, plain texture	Brown, partly banded, homogeneous, rough texture	Very dark grey with blackish parts, in parts fissured, heterogeneous, rough texture
Jurassic hornstone (plaquettes)	JH 7	JH 8	JH 9
source	secondary	secondary	secondary
description	black to dark green, lustrous, homogeneous, plain texture	Blueish to grey, banded troughout, in parts matt, homogeneous, plain texture	Greyish-green to brown, in parts with black punctiform inclusions, homogeneous, plain texture
Cretaceous hornstone	KH 1	KH 2	KH 3
source	secondary	primary	indifferent
description	Yellow to brown, reflection of light ("glittering"), heterogeneous, rough texture	White to grey, reflection of light ("glittering"), heterogeneous, very rough texture	Red to orange, reflection of light ("glittering"), heterogeneous, rough texture
quartz	Qz 1	Qz 2	Lt 1
source	primary	indifferent	primary
description	Grey to brown, in parts numerous fissures, heterogeneous, rough texture	Grey, crystalline structure, heterogeneous, rough texture	Black, in parts lustrous, homogeneous, plain texture
„lydite"/dolomite	Lt 2	Dt 1	
source	secondary	indifferent	
description	Red to green, in parts lustrous, homogeneous, plain texture	Grey to white, very crystalline structure, very rough texture	
Indifferent	e.g. single pieces with individual raw material attributes		

Fig. 14. Felsenhäusl-Kellerhöhle. Description of identified raw material units (RMUs).

Abb. 14. *Felsenhäusl-Kellerhöhle. Kurzbeschreibung der unterschiedenen Rohmaterialeinheiten (RMUs).*

(Fig. 16), underlines this as it shows no tendency that could be interpreted chronologically. Except for EU. 1, which has a slightly different representation of the frequencies of RMUs from Jurassic hornstone, all other EUs are suspiciously similar. If the EUs would indeed represent different phases of human occupation, this distribution would be rather implausible, as it not only indicates the diachronic procurement of the same outcrops, but also with similar intensities.

To test this further, we conducted a cluster analysis comparing all EUs according to their raw material spectrum (Fig. 17). As a result, EU. 1 is organized in its own sub-cluster, due to the different quantitative composition in the Jurassic hornstones. This is most likely the result of its low statistical relevance as EU. 1 is by far the smallest unit in terms of the absolute number of individual finds. EU. 3 is almost identical to EU. 4, which was already indicated by the comparison of the EUs of Group 1. The fact that EU. 2 is closer to EU. 5.1, which includes a large random sample, than to its stratigraphical neighbors (e.g. EU. 1 and EU. 3) again underlines the lack of correlation between the composition in RMUs and excavation depth.

Enlarging the data basis by exclusively used RMUs

Based on the lacking correlation between the frequency of different RMUs and depth, we considered typo-technologically indifferent pieces as part of dated assemblages if they were manufactured from RMUs exclusively found either among the Upper or the Middle Paleolithic diagnostic pieces. To identify those units, we applied a simple cross table with the presence/absence of chronologically indicative pieces in all RMUs. The resulting table (Fig. 18) shows that from all 17 RMUs we differentiated only five were certainly used in both periods. RMUs exclusively used during the Middle Paleolithic cover a variety of raw material types, e.g. Jurassic hornstone, Cretaceous hornstone and lydite. In contrast, RMUs exclusively used during the Upper Paleolithic comprise different types of Jurassic hornstone only. This preference of Jurassic hornstone in Upper Paleolithic context recalls general trends previously observed for example by H. Floss (1994).

The inclusion of otherwise undiagnostic artifacts from RMUs, which were exclusively used during the

Raw Material Unit	EU. 1		EU. 2		EU. 3		EU. 4		EU. 5.1		EU. 5.2	
JH 1	1.3		5.2		6.1		3.2		4.5		6.3	
JH 2	25		8.8		5.2		6.7		8.1		6.7	
JH 3	1.3		3.9		2.5		1.0		3.9		2.7	
JH 4	11.8		5.2		5.5		3.7		6.0		5.5	
JH 5	4.0	67.1	7.9	42.4	5.5	44.7	6.6	41.3	10.0	45.9	4.6	35.4
JH 6	15.8		4.6		4.1		5		2.1		1.9	
JH 7	6.6		2.1		9.2		9.5		4.7		5.5	
JH 8	1.3		0.9		0.3		-		3.4		0.4	
JH 9	-		3.3		4.8		3.2		1.8		-	
JH 0	-		0.6		1.6		2.5		1.3		1.7	
KH 1	10.5		21.8		16.8		17.1		20.5		20.0	
KH 2	10.5	21.1	19.1	42.4	10.6	28.3	11.4	30.8	11.6	35.7	5.7	27.2
KH 3	-		-		0.3		0.1		0.5		-	
KH 0	-		1.5		0.7		2.2		3.2		1.5	
Qz 1	7.9		3.0		16.1		14.3		9.7		24.8	
Qz 2	-	9.2	1.2	4.5	5.9	21.9	3.3	19.3	-	10.0	0.4	26.3
Qz 0	1.3		0.3		-		1.7		0.3		1.1	
Lt 1	-		0.6		0.1		0.4		0.3		-	
Lt 2	1.3	1.3	2.1	2.7	1.6	1.7	1.7	2.1	1.8	2.1	1.1	1.1
Lt 0	-		-		-		-		-		-	
Dt 1	-	-	-	-	-	-	0.1	0.1	0.3	0.3	-	-
In-different	1.3	1.3	7.9	7.9	3.3	3.3	5.9	5.9	6.0	6.0	10.1	10.1
Total	100	100	100	100	100	100	100	100	100	100	100	100

Fig. 15. Felsenhäusl-Kellerhöhle. Comparison of the different EUs according to their raw material spectra (given in percent).

Abb. 15. *Felsenhäusl-Kellerhöhle. Vergleich der verschiedenen EUs basierend auf deren Rohmaterialspektren (angegeben in Prozent).*

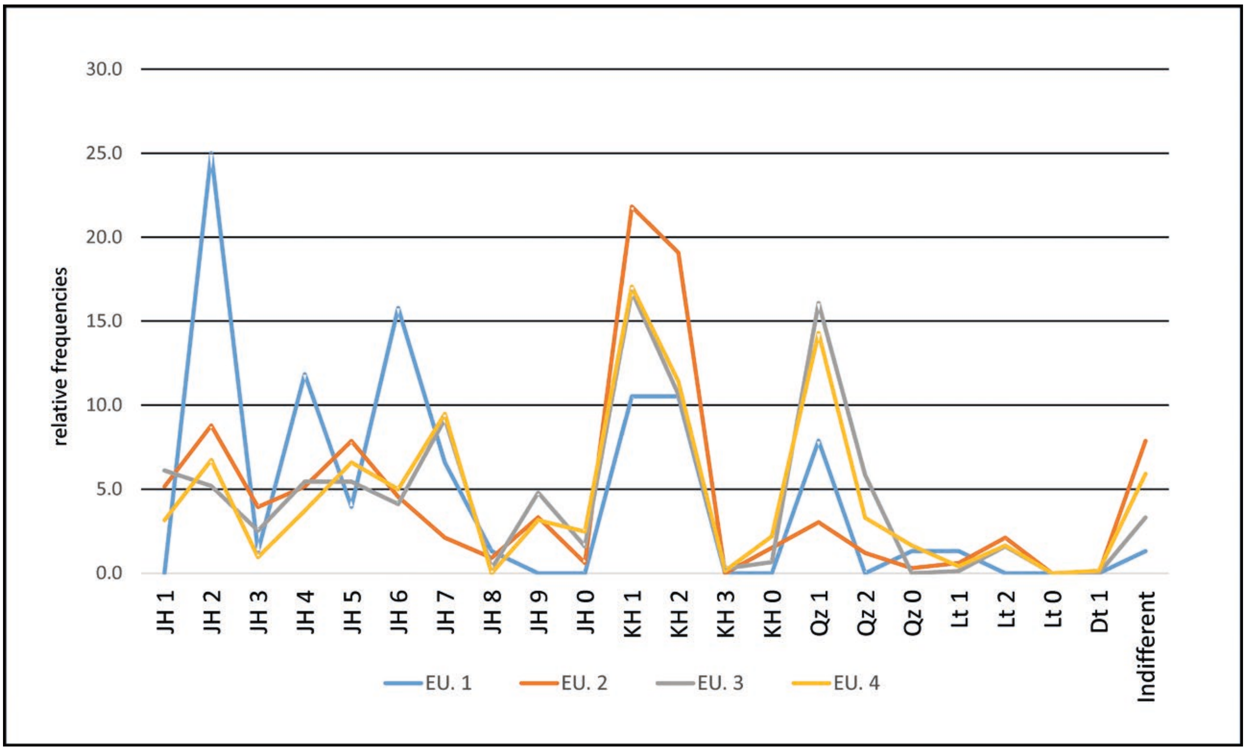


Fig. 16. Felsenhäusl-Kellerhöhle. Comparison of the relative frequencies of raw material units (RMUs) in EUs correlating to excavation depth (note: EU. 1 is the uppermost, EU. 4 the lowermost).

Abb. 16. *Felsenhäusl-Kellerhöhle. Vergleich der relativen Häufigkeiten von Rohmaterialeinheiten (RMUs) in Auswertungseinheiten mit Information zur Grabungstiefe (zur Beachtung: EU. 1 ist die hangende, EU. 4 die liegende Einheit).*

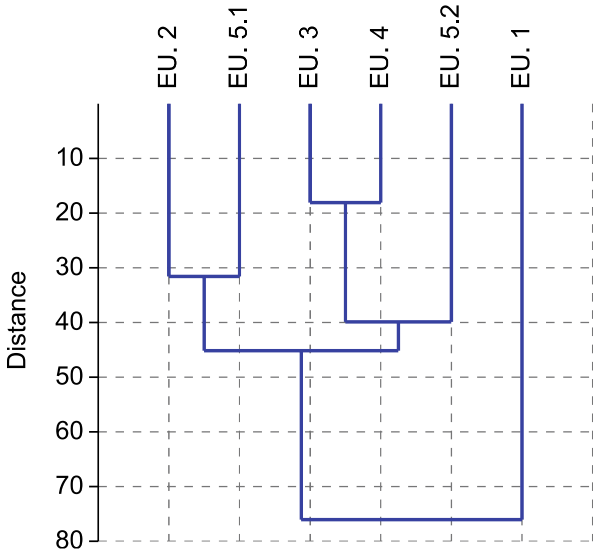


Fig. 17. Felsenhäusl-Kellerhöhle. Cluster-Analysis based on raw material spectrum within every EU using the relative quantities given in figure 16 for every RMU (e.g. JH1) individually.

Abb. 17. *Felsenhäusl-Kellerhöhle. Cluster-Analyse basierend auf dem Rohmaterialspektrum in jeder Auswertungseinheit. Als Variable wurden die relativen Häufigkeiten jeder RMU (z.B. JH1), die in Abbildung 16 angegeben sind, verwendet.*

Middle or the Upper Paleolithic, enlarged the total number of items in the respective assemblage significantly (Fig. 19). If compared to the relatively few diagnostic pieces in the "basic assemblages" (90 for the Upper Paleolithic and 32 for the Middle Paleolithic), the "expanded assemblages" now contain 536 Upper Paleolithic and 502 Middle Paleolithic artifacts, respectively.

Did the increase of chronologically sensitive artifacts lead to a better correlation between excavation spits and the find depth of Middle and Upper Paleolithic artifacts? Figure 20, which depicts the overall frequencies of dated artifacts from the expanded assemblages, shows that this is still not the case. Both Middle and Upper Paleolithic artifacts appear from the uppermost to the lowermost excavation unit. However, changes in EU. 1 and in EU. 2 deserve special attention. After expansion, it becomes apparent that there is also a considerable number of Middle Paleolithic artifacts in EU. 1 too. In EU. 2, the proportions have changed, so that Middle Paleolithic artifacts are now more numerous than Upper Paleolithic ones.

In sum, the following conclusion can be drawn from the analysis of the typo-technological structure and the raw material spectra of the EUs:

1. The total amount of lithic finds as well as the number of chronologically indicative items is increasing with excavation depth. This applies for both Middle and Upper Paleolithic artifacts.
2. Middle and Upper Paleolithic artifacts are found in every spit, e.g. from top to bottom.
3. Middle Paleolithic artifacts are not only numerous in the uppermost spit, but even outnumber Upper Paleolithic artifacts in the second spit. To the contrary, in the lowermost spits Upper Paleolithic artifacts are almost as numerous as Middle Paleolithic ones.

RMU	Diagnostic pieces: Middle Paleolithic	Diagnostic pieces: Upper Paleolithic	Result
JH 5	+		Raw material units exclusively used during the Middle Paleolithic
KH 2	+		
Lt 1	+		
JH 7	+	+	Raw material units used during the Middle- and the Upper Paleolithic
JH 1	+	+	
JH 9	+	+	
KH 1	+	+	
Qz 1	+	+	
JH 2		+	Raw material units exclusively used during the Upper Paleolithic
JH 3		+	
JH 4		+	
JH 6		+	
JH 8	Absence of diagnostic pieces		No correlation possible
KH 3			
Qz 2			
Lt 2			
Dt 1			

Fig. 18. Felsenhäusl-Kellerhöhle. Presence/absence cross table of the raw material units (RMUs) and diagnostic pieces (in red: Middle Paleolithic raw material exclusivities, in green: Upper Paleolithic raw material exclusivities).

Abb. 18. *Felsenhäusl-Kellerhöhle. Kreuztabelle für die An- und Abwesenheit von diagnostischen Artefakttypen in den Rohmaterialeinheiten (rot: Rohmaterialexklusivitäten für das Mittelpaläolithikum, grün: Rohmaterialexklusivitäten für das Jungpaläolithikum).*

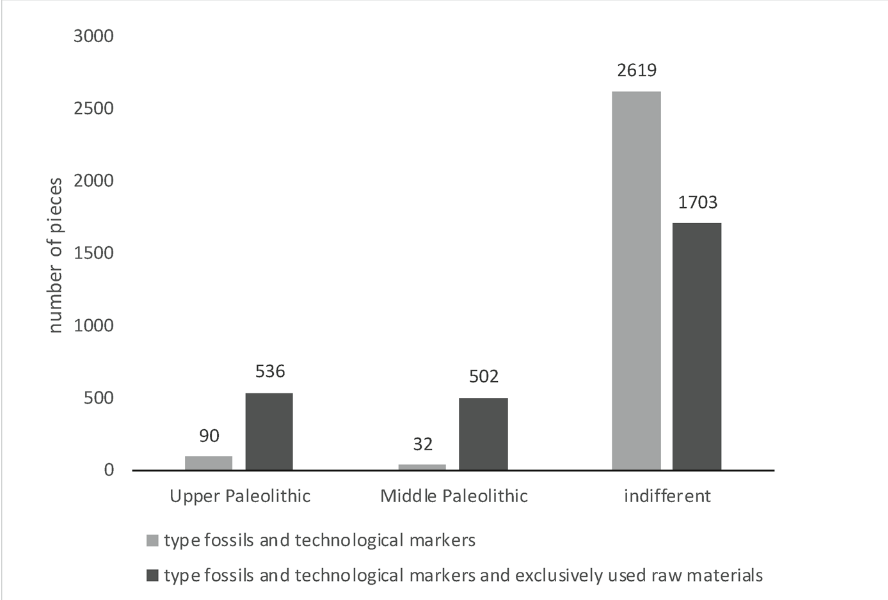


Fig. 19. Felsenhäusl-Kellerhöhle. Comparison between the artifact frequencies in basic assemblages and expanded assemblages of the Middle and Upper Paleolithic, and the frequencies of indifferent artifacts.

Abb. 19. *Felsenhäusl-Kellerhöhle. Vergleich der Artefakt-Häufigkeiten zwischen „Basis-Inventaren" und „Erweiterten Inventaren" sowie die Häufigkeit von Artefakten, die keinem der beiden Inventare zugeordnet werden konnten.*

4. The number of diagnostic pieces does not correspond to some kind of chronological sequence, but simply correlates with the growing number of finds.

All of these observations allow us to reject the hypothesis that the excavation spits reflect a chronological order. In consequence, the artifacts have to be treated analogous to a mixed collection.

Description of the Middle/Upper Paleolithic assemblage

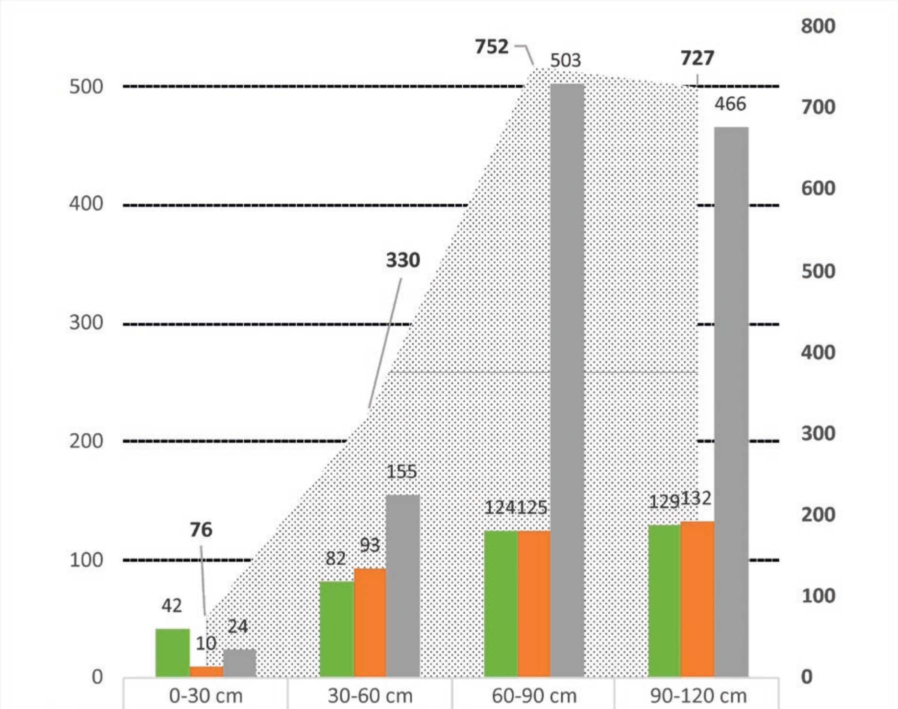
By separating all artifacts of clear chronological origin, we were able to distinguish three assemblages: the Upper Paleolithic assemblage 1, the Middle Paleolithic assemblage 2 , and a third assemblage with artifacts undiagnostic with regard to both typo-technological and raw material aspects. In the following section, we will focus on a typo-technological description of assemblage 1 and assemblage 2. Unless otherwise stated, the sections below refer to both the "basic assemblages" and the "expanded assemblages".

Assemblage 1 (Upper Paleolithic) is composed of 90 diagnostic artifacts from the basic assemblage, plus 446 artifacts attributed to it via raw material exclusivities. In sum, the expanded assemblage 1 accounts for 536 artifacts. In the basic assemblage Jurassic hornstone is with 72 individual pieces by far most numerous, followed by Cretaceous hornstone with 13 and quartz with 4 (Fig. 21).

The classification as Upper Paleolithic is based on the combination of backed pieces, endscrapers, burins and unipolar as well as bipolar blade cores (Figs. 22, 23 & 24). There are three backed bladelets (Fig. 23: 5-7), which all have an abrupt lateral retouch with an angle of almost 90° ("total backing" according to L. Moreau 2009), and one backed point (Fig. 23: 8). endscraper (Fig. 23: 11 & 12) are outnumbered by different types of burins (Fig. 23: 1-4). Among the burins, five dihedral burins (Fig. 23: 2 & 3) dominate over one burin on truncation (Fig. 23: 1) and one burin on breakage (Fig. 23: 4). Most endscrapers are on blades, while one piece is thick and exhibits an almost carinated retouch (Fig. 23: 12). Furthermore, there are three pieces with a lateral retouch, which do not allow further classification and were included due to their corresponding raw material.

In total, seven cores belong to assemblage 1 (Fig. 24: 1-5). In general, cores exhibit no cortex and were carefully prepared by adjusting the distal angles before starting the detachment of blades. One of the cores reaches a length of 15 cm and is best described as almost "flat-like" (Fig. 24: 1). The unipolar flaking surface is narrow and opposite to an equally narrow back, whereas the sides of the core are relatively wide. The remaining cores are much smaller and prismatic in form (Fig. 24: 5). Whereas the bulk of them is again unidirectional, there is one fragmented semi-prismatic core that has the only bidirectional flaking surface among the assemblage (Fig. 24: 4).

The main features of the flaking process, as evidenced by the attribute analysis of blades and cores, can be summarized as follows: the flaking aimed at the production of long and regular blades with primarily unipolar dorsal scar patterns (Fig. 24: 7 & 8). The bulbs of percussion are generally small. Bulbar scars are very rare and often accompanied by lips. In sum these technological features indicate direct



	0-30 cm	30-60 cm	60-90 cm	90-120 cm
total	76	330	752	727
UP	42	82	124	129
MP	10	93	125	132
ind.	24	155	503	466

Fig. 20. Felsenhäusl-Kellerhöhle. Absolute frequencies of artifacts in the expanded assemblages of the Middle Paleolithic (red) and the Upper Paleolithic (green), and the frequency of chronologically indifferent artifacts (grey), in EUs with information about the excavation depth (from left to right: EU. 1 to EU. 4); as a control variable, the frequency of all artifacts per EU is given (second Y-axis on the right).

Abb. 20. *Felsenhäusl-Kellerhöhle. Absolute Artefakt-Häufigkeiten in den Erweiterten Inventaren des Mittelpaläolithikums (rot) und des Jungpaläolithikums (grün) sowie die Häufigkeit von chronologisch indifferenten Artefakten (grau) in Grabungseinheiten mit Informationen zur Grabungstiefe (von links nach rechts: EU. 1 bis EU. 4); als Kontrollvariable wurde die absolute Anzahl an Artefakten je Auswertungseinheit auf der zweiten Y-Achse (rechts) aufgetragen).*

percussion, using soft stones and/or antler, for the blade production (Pelegrin 2000). Knapping angles were not calculated exactly due to the very small amount of artifacts which have their proximal end preserved. With the exception of one dihedral burin, modified pieces are exclusively made from Jurassic hornstone. The same applies for the blades and bladelets, which were also primarily made from Jurassic hornstone. Flakes were produced from both Cretaceous and Jurassic hornstone. However, several blade cores were produced from Cretaceous hornstone (e.g. Fig. 24: 1-2), underlining the possibility that the number of blades made from this raw material originally may have been higher. The fact that part of the production of backed tools was conducted on-site is proven by the presence of two microburins (Fig. 23: 9 & 10).

Assemblage 2 (Middle Paleolithic) is composed of 32 diagnostic artifacts of the basic assemblage. Another 470 otherwise indifferent artifacts where identified by their raw material as belonging to it, too. In sum, 502 artifacts account for the expanded assemblage. In the basic assemblage Cretaceous and Jurassic hornstone is nearly equally distributed with 14 and 12 individual pieces, respectively. Quartz (3 individual pieces) and lydite (1 individual piece) are far less frequent (Fig. 25).

Among the side scrapers, twelve simple side scrapers (Fig. 27: 5-7) are most numerous. Furthermore, we documented two convergent scrapers (Fig. 27: 8), one double scraper (Fig. 27: 9) and one denticulated piece (Fig. 27: 10). Three simple laterally retouched flakes were sorted into the assemblage by their raw material attributes.

The blank production is characterized by the Levallois and Quina concept, indicated by several technological flakes, respectively (Fig. 28). However, the classification of the only core belonging to this assemblage to the Levallois concept remains questionable (Fig. 28: 1). Flakes often have a prominent bulb of percussion accompanied by bulbar scars, indicating hard hammer detachment. Concerning the

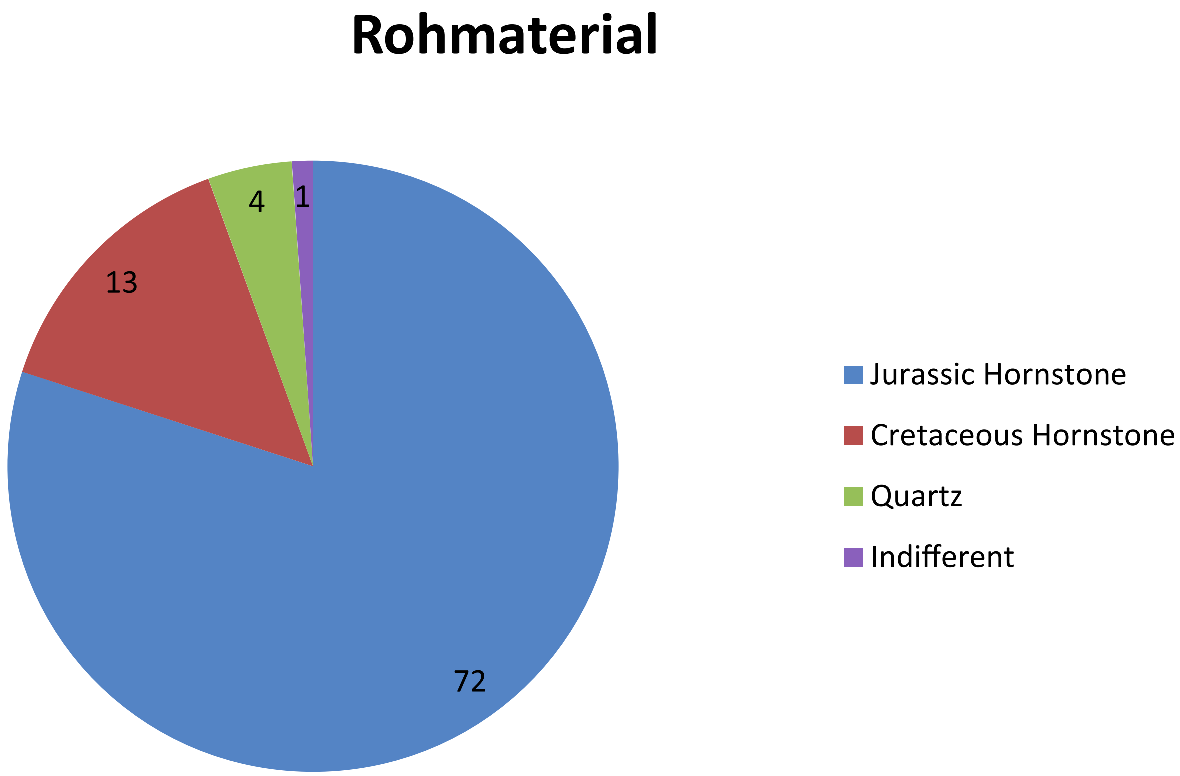


Fig. 21. Raw material spectrum of Assemblage 1. In the following the absolute quantities for the different RMUs (basic assemblage) are given: JH 1 = 5, JH 2 = 10, JH 3 = 6, JH 4 = 21, JH 6 = 9, JH 7 = 13, JH 9 = 4, JH 0 = 4, KH 1 = 12, KH 0 = 1, Qz = 4, 00 = 1. N = 90.

Abb. 21. *Rohmaterialspektrum in Inventar 1. Im Folgenden sind die absoluten Quantitäten der verschiedenen RMUs (Basis-Inventar) angegeben: JH 1 = 5, JH 2 = 10, JH 3 = 6, JH 4 = 21, JH 6 = 9, JH 7 = 13, JH 9 = 4, JH 0 = 4, KH 1 = 12, KH 0 = 1, Qz = 4, 00 = 1. N = 90.*

raw material use, it can be summarized that tools are often made from Cretaceous hornstone, while bifacial tools are more often produced from Jurassic hornstone, amongst which plaquettes were the preferred raw volume.

In combination with the Levallois and Quina concept of core reduction, the presence of 4 bifacial tools (Figs. 26, 27 & 28) allows a secure classification as Middle Paleolithic, even when taking into consideration that the fragmented preservation of the bifacial tools (Fig. 27: 1-3) did not allow the secure the identification of lithic type fossils, e.g. *Keilmesser*, large handaxes, *Fäustel* or *Blattspitzen* (Bosinski 1967; Uthmeier 2004a; Richter 1997).

Rank	Tool class	Basic assemblage (N)	Identified by raw material exclusivities (N)	Expanded assemblage (N)	Proportion (%)
1	dihedral burin	5	-	5	*26.3*
2	backed bladelet	3	-	3	*15.8*
3	endscraper	2	1	3	*15.8*
4	lateral retouch	1	2	3	*15.8*
5	microburin	2	-	2	*10.5*
6	burin on truncation	1	-	1	*5.3*
7	burin on breakage	1	-	1	*5.3*
8	backed point	1	-	1	*5.3*
	Total	**16**	**3**	**19**	***100***

Fig. 22. Felsenhäusl-Kellerhöhle. Absolute frequencies of tool classes in assemblage 1 (Upper Paleolithic), differentiated in basic assemblage, pieces identified by raw material exclusivities, and expanded assemblage, sorted by their rank calculated from the relative frequencies of the expanded assemblage.

Abb. 22. *Felsenhäusl-Kellerhöhle. Absolute Werkzeugklassen-Häufigkeiten in Inventar 1 (Jungpaläolithikum), unterschieden nach Basis-Inventar, anhand von Rohmaterialexlusivitäten datierten Artefakten und erweitertem Inventar. Anhand der relativen Häufigkeiten des erweiterten Inventars wurde eine Rangfolge ermittelt.*

Fig. 23. Felsenhäusl-Kellerhöhle. Tools from Assemblage 1: 1 burin on truncation, 2 & 3 dihedral burin, 4 burin on breakage, 5-7 backed bladelet, 8 backed point, 9 & 10 microburin, 11 & 12 endscraper.

Abb. 23. *Felsenhäusl-Kellerhöhle. Zur Beachtung: Werkzeuge aus Inventar 1: 1 Stichel an Endretusche, 2 & 3 Mehrschlagstichel, Stichel an Bruch, 5-7 Rückenmesser, 8 Rückenspitze, 9 & 10 Kerbrest, 11 & 12 Kratzer.*

Fig. 24. Felsenhäusl-Kellerhöhle. Cores and blanks from Assemblage 1: 1-5 blade cores, 6 crested blade, 7-8 unretouched blades.

Abb. 24. *Felsenhäusl-Kellerhöhle. Zur Beachtung: Kerne und Grundformen aus Inventar 1: 1-5 Klingenkerne, 6 primäre Kernkantenklinge, 7-8 unretuschierte Klingen.*

Discussion

Geoarchaeological analysis

The sequence we described in Section West (Fig. 7) correlates well with the uppermost part of the profile published by B. Kaulich and W. Weißmüller (2003). However, in comparison with that profile, our section is shallower and does not exhibit a sediment comparable for depth and composition to the lowermost geological unit (5) described by B. Kaulich and W. Weißmüller (2003). Such discrepancy might indicate that since the early 2000s the back of Felsenhäusl-Kellerhöle has been partly (re)filled. This hypothesis is further supported by the deposit we observed at the base of Section West (GL 5), which exhibits compaction and mixed composition compatible with back dirt and/or collapse from the exposed section. Although they reported the occurrence of other sediment remnants inside Felsenhäusl-Kellerhöle, B. Kaulich and W. Weißmüller (2003) did not mention explicitly the

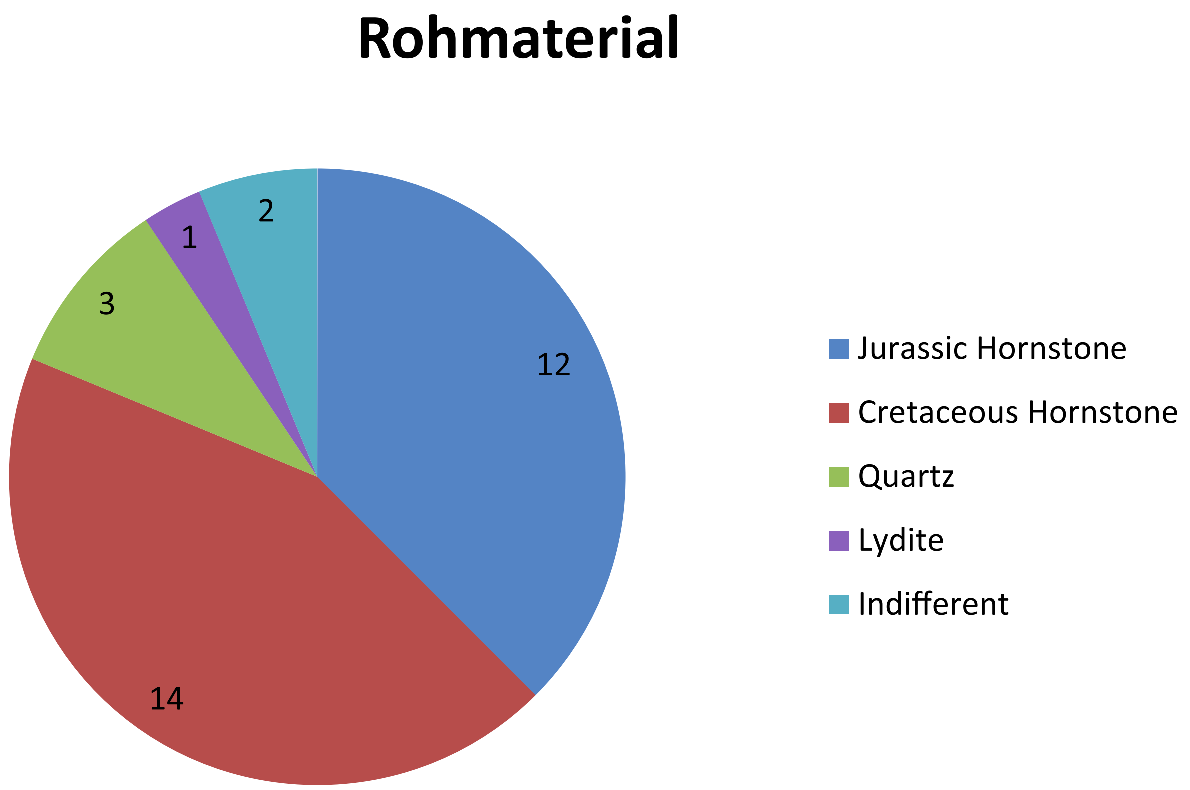


Fig. 25. Raw material spectrum in Assemblage 2. In the following the absolute quantities for the different RMUs (basic assemblage) are given: JH 1 = 1, JH 5 = 3, JH 7 = 3, JH 9 = 2, JH 0 = 2, KH 1 = 12, KH 2 = 1, KH 0 = 1, Qz 1 = 3, Lt 1 = 1, 00 = 2. N = 32.

Abb. 25. *Rohmaterialspektrum in Inventar 2. Im Folgenden sind die absoluten Häufigkeiten der verschiedenen RMUs (Basis-Inventar) angegeben: JH 1 = 1, JH 5 = 3, JH 7 = 3, JH 9 = 2, JH 0 = 2, KH 1 = 12, KH 2 = 1, KH 0 = 1, Qz 1 = 3, Lt 1 = 1, 00 = 2. N = 32.*

occurrence of an exposure comparable to our Section East. Such discrepancy further suggests Section East might have been exposed in recent years.

Although the analysis of micromorphological samples has not been completed, the lithological data presented in this paper are enough to put forward preliminary hypotheses concerning formation processes at Felsenhäusl-Kellerhöle. From the lower part of Section West we reported two distinct sediments (GL 4 and GL 3, Fig. 7), in which coarse-sized fragments appear triaxial to equiaxial, randomly oriented, rough to polished, and exhibit higher rounding in comparison with the above deposits. These characteristics might be resulting from a combination of sedimentary processes, such as mass-wasting (Bertran & Texier 1999), and post-depositional processes, such as calcium carbonate dissolution. We reject the hypothesis that chaotic arrangement of

Rank	Tool class	Basic assemblage (N)	Identified by raw material exclusivities (N)	Expanded assemblage (N)	Proportion (%)
1	simple scraper	12	-	12	*50.00*
2	bifacial retouch	4	-	4	*16.67*
3	convergent scraper	2	-	2	*8.33*
4	lateral retouch	-	3	3	*12.50*
5	bifacial retouch (edge)	1	-	1	*4.17*
6	double scraper	1	-	1	*4.17*
7	denticulated piece	1	-	1	*4.17*
	Total	**21**	**3**	**24**	***100.00***

Fig. 26. Felsenhäusl-Kellerhöhle. Absolute frequencies of tool classes in assemblage 2 (Middle Paleolithic), differentiated in basic assemblage, pieces identified by raw material exclusivities, and expanded assemblage, sorted by their rank calculated from the relative frequencies of the expanded assemblage.

Abb. 26. *Felsenhäusl-Kellerhöhle. Absolute Werkzeugklassen-Häufigkeiten in Inventar 2 (Mittelpaläolithikum), unterschieden nach Basisinventar, anhand von Rohmaterialexlusivitäten datierten Artefakten und erweitertem Inventar. Anhand der relativen Häufigkeiten des erweiterten Inventars wurde eine Rangfolge ermittelt.*

Fig. 27. Felsenhäusl-Kellerhöhle. Tools from Assemblage 2: 1-3 fragment of bifacial tool, 4 scraper with ventral thinning, 5-7 simple scraper, 8 convergent scraper, 9 double scraper, 10 denticulated piece.

Abb. 27. *Felsenhäusl-Kellerhöhle. Werkzeuge aus Assemblage 2: 1-3 Fragmente bifazieller Werkzeuge, 4 Schaber mit ventraler Verdünnung, 5-7 Einfacher Schaber, 8 Spitzschaber, 9 Doppelschaber, 10 Gezähntes Stück.*

components within these layers might be resulting (solely) from bioturbation, because GL 3 and GL 4 exhibit less borrows and roots in comparison with GL 2b, which despite the bioturbation shows evidence of bedding. The lack of deposits similar to GL 3 and GL 4 closer to the southern entrance suggests that either these sediments entered the cave only from the western opening (which seems unlikely) or have been removed from the rest of the cave before GL 1a, 1b, 2a, 2b, 5, 6, 7, and 8 accumulated (e.g. because areas near to the cave opening are more affected by erosion).

In Section West above GL 3 and GL 4 we distinguished GL 2, which is rich in brown silty clay/clayey silty (Fig. 7). The fine fraction of this layer exhibits color and grain size similar to GL 7 and GL 8, which we documented in Section East and along the northern cave wall (Figs. 9 & 29). Deposits with comparable lithology are widely reported from caves and valleys of the Jura mountain range, they mostly date to the Late Glacial Maximum/Late Glacial and are usually regarded as the result of sedimentary rework and chemical weathering of loess (Riek 1957; Gwinner

Fig. 28. Felsenhäusl-Kellerhöhle. Core and blanks from assemblage 2: 1 Levallois Core, 2-4 Levallois flakes, 5 and 6 Quina flakes.

Abb. 28. *Felsenhäusl-Kellerhöhle. Kern und Grundformen aus Inventar 2: 1 Levallois-Kern, 2-4 Levallois-Abschläge, 5 und 6 Quina-Abschläge.*

1989; Schall 2002; Goldberg et al. 2003; Miller 2015; Barbieri & Miller 2019; Barbieri 2019). The lower part of GL 2, GL 2b, contains few, bedded, moderately sorted (less than 2 cm in size) angular, oblate, poorly weathered fragments of limestone (Fig. 7). This type of gravel is common in Swabian and Frankonian Jura, and in the local literature it is referred to as "*Bergkies*" (Krajcarz et al. 2016; Wolff 1962; Riek 1973; Barbieri 2019). This sediment type is usually interpreted as the result of frost-induced brakeage of exposed limestone bedrock, during intensive freezing and thawing cycles (Riek 1957; Wolff 1962; Riek 1973; Campen 1990, 1995; Freund 1998; Barbieri 2019). *Bergkies* is commonly reported from deposits dating to the end of the Pleistocene (Schmidt 1912; Riek 1934; Riek 1935; Riek 1957; Riek 1973, Wetzel & Bosinski 1969; Kind 1987; Campen 1990; Barbieri et al. 2018, 2019), also at the nearby site of Sesselfelsgrotte (Freund 1998). On the opposite, gravel-sized fragments appear rarer in the reworked loess deposit preserved in Section East (GL 7). They are coarser and randomly oriented, even in the lowermost and less bioturbated part of GL 7 (Fig. 9). Such lithological data seem to suggest a rapid and more turbulent deposition of reworked loess in this part of the cave. Given that GL 7 rests on top of gullies carving the bedrock and sloping westwards (Figs. 9 & 10), we hypothesized that reworked loess in Section East might have been deposited by mass-wasting processes moving from the southern entrance towards the back of Felsenhäusl-Kellerhöhle. In the back of the cave loess deposition alternated with the accumulation of *Bergkies* (GL 2b). Water infiltrating through the rock fissures was probably more intensive in this part of the cave, due to proximity to the western opening, and resulted in a more intensive breakage of the limestone wall during freezing periods. In comparison with GL 2b, the upper part of GL 2 (GL 2a in figure 7)

Section West			Northern Wall	Section East	Proposed datation	Amount of artifacts		
Depth in cm	layer	comment				few	med.	max.
-24	GL 1a	Anthropogenic sediments similar to dark laminations in GL 7. Humans cut into the Pleistocene sequence and lighted fires (?) in the cave	Not present (removal by anthropogenic processes)	GL 6	Holocene			
-45	GL 1b							
Intensive precipitation of secondary carbonate					Early Holocene/ Late Pleistocene			
-60	GL 2a	Reworked loess mixed with other sediments by colluviation (?) and bioturbation.	GL 7 covering bedrock in this part	GL 8 covering bedrock in this part	Late Pleistocene			
-65	GL 2b	During cold and dry periods reworked loess moved from the southern entrance to the back. During more intensive freezing and thrawing Bergkies accumulated			Late Pleistocene			
?	GL 3	Colluvation possibly followed by cryoturbation and limestone dissolution	Removed by geogenic processes		MIS 3 (?)			
?	GL 4	Colluvation possibly followed by cryoturbation and limestone dissolution						
-120	Not exhibited in the documented sequence		Bedrock					
?								
?	GL 5	Backdirt						

Fig. 29. Felsenhäusl-Kellerhöhle. Summary of the preliminary results of geoarchaeological investigation in the remaining sediments; the amount of artifacts is schematic (med. = medium. max. = maximum).

Abb. 29. *Felsenhäusl-Kellerhöhle. Zusammenfassung der vorläufigen Ergebnisse der geoarchäologischen Untersuchungen an den erhaltenen Sedimentresten; die Fundhäufigkeiten sind schematisch (med. = mittlere Häufigkeit, max. = maximale Häufigkeit).*

exhibits no sorting, no recognizable mesoscopic sedimentary structures, frequent and large plant roots and borrows. We regard all these features as indicative of intensive bioturbation.

The upper contact of GL 2 and GL 7, although bioturbated, is sharp and was possibly shaped by erosional processes (Figs. 7 & 9). Above this potential erosional surface, GL 1 (in Section West) and GL 6 (in Section East) contain charcoals and other fresh organic materials of likely Holocene age. In GL 6 laminations rich in organics alternate with silty clay layers, that are similar to the underlying reworked loess (GL 7, Fig. 9). Such bedding suggests that (probably during the Holocene) humans removed Pleistocene sediment from the entrance to the cave and lighted fires (and possibly stored goods). Holocene humans probably dug into the cave sequence leaving some of it exposed, along the cave walls and towards the back of the cave. This resulted in some of the reworked loess to be periodically eroded away from the sediment exposures and deposited on top of the anthropogenic sediments.

Although it was not visible in our micromorphological samples, in the field we observed a 1 cm-thick layer of calcium carbonate coating the upperpart of GL 6. Similarly, speleothems formed along the Northern wall of the cave appears to merge into the upper part of GL 1 (Fig. 10). These data show changing cave environment (likely higher rate of water dripping). Increasing formation of secondary carbonate features has also been reported from the entrance of Hohlenstein-Stadel, in the Lone Valley (Swabian Jura), in sediments dating to the end of the Pleistocene and to the early Holocene (Barbieri et al. 2018; Barbieri 2019). The geometry of the carbonate features inside Felsenhäusl-Kellerhöhle shows that, when they formed, the cave was filled at the back but partly empty at the entrance.

In sum, our lithological data show that:

1. The sediment exposures within Felsenhäusl-Kellerhöhle are composed of distinguishable layers, thus the hypothesis that the entire filling of the cave is mixed can be rejected.
2. Deposits preserved within the cave can be regarded as the result of diverse formation processes and changing environments.
3. Within the cave, sedimentary and diagenetical processes exhibit a significant lateral variability.

On first look, there is a profound contradiction between the results of the lithological analysis, which documented an *in-situ* sequence of the Pleistocene sediments, and the analysis of the lithic artifacts, which clearly showed a complete mixing of artifacts in all excavations depths. There are a number of equally plausible, and therefore intertwined, explanations for this:

- The cave filling was divided in a back part without mixing, and an entrance part with mixing.
  In theory, this is well possible due to the fact that almost all cavities experienced a Holocene use, and that these often were connected to building activities (flattening of the surface etc.). Some of the most probable potential functions, such as a stable for animals and/or a facility for storage, are already indicated by the name "Kellerhöhle". Due to the restricted head room in the back part of the cave, this would be more or less confined to the southern (entrance) part of the cave.
- The mixing of artifacts resulted from site formation processes that (during the Late Pleistocene: GL 2a, 2b, 6 and 7) brought in sediments with already mixed lithic assemblages.
  In theory, this would be possible if, for example, erosion cut a side upslope, with a stratigraphy containing Middle and Upper Paleolithic artifacts. Given the almost non-existing platform in front of the cave and the almost vertical cliffs above the entrances, this can be excluded, unless the landscape in the close surroundings of the cave was profoundly different during the Pleistocene.
- The mixing of Middle and Upper Paleolithic artifacts resulted from pronounced bioturbation. Numerous roots and borrows were documented and indicate the presence of pronounced biogenic activities that have altered the original cave filling to an extend that would allow for a mixing of also larger pieces. This could explain the decrease of artifact frequencies from the bottom towards the top spits. On the other hand, the fact that we observed intact bedding alongside with bioturbation features (for instance in GL 6 and GL 2b) suggests that bioturbation should have not erased the original archaeological stratigraphy.
- The mixing results from a complex sedimentological sequence excavated in horizontal spits.

The inclination and/or the patchy presence of layers can be in part reconstructed by our geoarcheological investigations. In any case, the natural site formation process was, despite the small size of the cave, complex. This is mainly due to the configuration of the curved, but short cavity with one comparably large and one small entrance on roughly the same elevation and, in addition, the rippled structure of the bedrock forming numerous sediment traps. The many speleothems, crusts and *Bergkies* point to penetrating water as another factor of the site formation process. The insufficient excavation methods would not only lead to a mixing of sediments and archaeological levels, but would also be in agreement with the fact that the lower spits had more artifacts (given that find-bearing layers were originally found more near to bed rock in most parts of the cave).

Lithic Assemblages

Separating all artifacts of clear chronological origin, we were able to establish two assemblages, which differ on the scale of Paleolithic periods. The resulting units are still broad ones and almost securely do not correspond to single occupations. Given the many problems of the excavation techniques and the fact that refits have not been found, the identification of single occupations is excluded for Felsenhäusl-Kellerhöhle. This is even more so, as palimpsests are the prevailing situation even under very good preservation conditions such as *in-situ* occupation surfaces; in many cases, they have proven to nevertheless result from different occupations (see Romagnoli & Vaquero 2016.; Patou-Mathis & Chabai 2003; Uthmeier & Chabai 2018). It follows that we have to be very careful when it comes to the attribution of the assemblages to a specific industry due to different reasons. First of all, a large part of the material is typo-technologically indifferent and cannot be assigned to the Middle or the Upper Paleolithic. This holds true even after the expansion via exclusively used raw material units, which in itself is not without uncertainties due to the fact that the overall number of diagnostic artifacts with clear chronological origin is very low. Therefore, the classification of the undiagnostic tools might have been, in parts, erroneous. In sum, we suggest to use only the presence and absence of specific tool types or technologies as an argument for a more detailed classification of the material from Felsenhäusl-Kellerhöhle to a specific industry.

The relatively numerous fragments of comparably massive bifacial tools, combined with side scrapers and flakes from Levallois and Quina cores, argues for a classification of assemblage 2 to a Mousterian with Micoquian-Option (MMO)/*Keilmessergruppen* (Richter 1997; 2016; Jöris 2004). The outline of the bifacial tools and the use of plaquettes as raw piece resembles assemblages from other sites of the MMO/*Keilmessergruppen* located in the Lower Altmühl Valley, such as Sesselfelsgrotte, "G-Complex" (Richter 1997), Obernederhöhle (Freund 1987), Klausennische (Bosinski 1967) or Abri am Schulerloch (Böhner 2008). Besides the bifacial tools and side scrapers, denticulated pieces are another typical component of these sites. The "G-Complex" (Richter 1997) of the nearby Sesselfelsgrotte is geographically the closest analogy to assemblage 2. From a technological point of view, the MMO assemblages from Felsenhäusl-Kellerhöhle and Sesselfelsgrotte both exhibit Levallois as well as Quina flaking methods, while these concepts seem to be absent in the Middle Paleolithic of Obernederhöhle (Freund 1987). J. Richter (1997) subdivided the MMO of the Sesselfelsgrotte into an older phase with both the Quina and the Levallois concept ("MMO-A"), and a younger phase without Quina concept, but a prevalence of different Levallois methods, amongst which those with parallel target flakes gain more importance ("MMO-B") (Richter, 1997, 2016). Due to the fact that the application of the Levallois concept is not restricted to one of the two phases, two hypotheses about the chronological position of assemblage 2 within the MMO are possible: first, artifacts of assemblage 2 were discarded in the cause of one or more occupations belonging to the MMO-A, and thus represent a shorter time period within the Bavarian Late Middle Paleolithic, or second, assemblage 2 represents several occupations that cover both the period of the MMO-A and the MMO-B. The fact that the Levallois recurrent method with parallel Levallois flakes and blades could not be identified in assemblage 2 may speak for occupations primarily during the MMO-A. However, a secure classification of concepts and methods of raw material reduction should not only rely on blanks, but also on the presence of cores; the absence of Levallois methods with parallel target blanks therefore remains somewhat weak.

In the regional context of Upper Paleolithic of Southern Germany (Freund 1963; Hahn 1982; Uthmeier 2004a; Conard 2015; Weißmüller 1987), the presence of backed tools in assemblage 1 argues for a classification as Gravettian or Magdalenian. This is reinforced by the documentation of microburins, which are an important chronological marker, because their existence is not confirmed before the Gravettian (see e.g. Moreau 2009 or Bolus 2012). From a technological point of view, assemblage 1 exhibits features traditionally associated with both the Gravettian and the Magdalenian. Semi-circumferential cores with a bidirectional flaking surface typically occur in the Gravettian and are (in this context) classified as belonging to the Corbiac method (Bordes 1967, 1970; Weißmüller 1987). However, technologically similar cores with two opposed striking platforms also appear at Bavarian Magdelenian sites, such as the Kaufertsberg/Hexenküche, lower level (Kaulich 1983, Fig. 27, 2) or Barbing A (Reisch 1974, Fig. 8, 1-2). Generally the assemblages from the C-Layers of Sesselfelsgrotte (Dirian 2003) seem to be from both a technological and a typological point of view the best analogies to assemblage 1. The similarities apply for the presence of tools, especially microburins and endcrapers, of analogous morphological appearance (Dirian 2003, Pl. 3, 4 & 11); while endscrapers and microburins seem to be absent in Abri Schmidt, the only site commonly attributed to the Gravettian in Lower Altmühl Valley (Prufer 1961; Otte 1981).

To conclude, it cannot be decided if each of the two assemblages from Felsenhäusl-Kellerhöhle represents several shorter occupations (possibly across different industries; e.g. it cannot be excluded that assemblage 1 might correspond to occupations belonging to the Magdalenian and the Gravettian) or one longer stay. However, given the comparably low sedimentation rate, a number of shorter stays seems much more plausible. The fact that both assemblages contain evidence for on-site blank and tool production points to a use of Felsenhäusl-Kellerhöhle not only for ephemeral stays, e.g. for hunting purposes, but also for basic activities. Additionally we documented a few crested blades, decortication flakes and plaquettes of Jurassic hornstone as well as one core which could not be assigned to the Upper- or Middle Paleolithic assemblage. However the size of the cave seems to exclude longer stays with the character of a base camp. But we have to keep in mind that there is no direct correlation between the size of a cavity and the duration of stays within. Examples from the Lower Altmühl Valley as the aforementioned Sesselfelsgrotte contained several different occupations (e.g. Richter 1997; Weißmüller 1995; Dirian 2003) with evidences for rather long stays while the nearby Abri Schmidt, despite being larger, was seemingly not used as intensive (Freund 1998; Prufer 1961).

Conclusions

Results of the typo-technological considerations of lithic assemblage from Felsenhäusl-Kellerhöhle on the one hand, and geoarchaeological samples taken from the profile in the back of the cave on the other, at first glance seem to contradict each other. While the analysis of the artifacts showed a mixture of Middle and Upper Paleolithic artifacts in every horizontal spit, analysis of the remaining sections of sediment proved the existence of an intact stratigraphy at least in parts of the cave. A number of equally plausible (partly intertwined) explanations can be imagined, but the insufficient excavation methods certainly lead (or further added) to a mixing of sediments and archaeological levels. Therefore, the reconstructed assemblages have to be treated analogous to mixed collections. Without absolute dates, we were only able to estimate the ages of the still intact sediments. Sediments below the Holocene most probably date to the Late Pleistocene and overlie geological layers, which - much less secure and only based on the analogy of the Middle Paleolithic finds to the MMO of Sesselfelsgrotte (belonging to MIS 3). We distinguished two chronologically homogeneous assemblages, one attributed probably to the Magdalenian and the other one to the MMO/*Keilmessergruppen*. Due to the weakness of the stratigraphical information, any further interpretation is difficult and remains, to a large extend, speculative. What can be stated with some security is the fact that the size of the Felsenhäusl-Kellerhöhle as well as its topographical position near to the river recalls the neighboring Sesselfelsgrotte. The latter is a little larger and has a more spacious platform, but still both sites are small if compared to other caves and rock shelters in the Lower Altmühl valley. Both caves open to the South and are thus exposed to the warmth of the sunlight. Although any precise functional interpretation of the assemblages from Felsenhäusl-Kellerhöhle is speculative, it can still be said that the stays were not only dedicated to the discard of imported lithic resources, but also experienced the discard of artifacts of different parts of the reduction sequence, such as cores, microburins and crested blades. However, the size of the cave almost excludes longer stays with a character of a base camp. In fact, a function as toss zone of discard must be taken into consideration for the back part of the cave. The initially stated research questions regarding the Paleolithic occupation of Felsenhäusl-Kellerhöhle and the cavity's stratigraphy can be answered as follows:

- Integrity of the stratigraphical sequence
  Our results strongly suggest that an intact stratigraphical sequence had been apparent; at least in parts of the cave.
- Integrity of the artificial spits
  Our results strongly suggest that the artificial spits applied by the excavator are of no scientific value; therefore we have to treat assemblages analogous to a mixed collection.
- Classification and dating of the lithic assemblage(s)

We were able to distinguish two chronologically homogeneous assemblages: assemblage 1 should probably be attributed to the Magdalenian. Assemblage 2 should be attributed to the MMO/*Keilmesser-gruppen*. Any further interpretation is difficult and remains, to a large extend, speculative.

Despite the loss of information due to inappropriate excavation methods applied, the Felsenhäusl-Kellerhöhle still enlarges the data set of sites in the regional context of the Lower Altmühl Valley. Seeing that further excavations are excluded (the already excavated backdirt is not accessible anymore), we still hope that limited future investigations such as the analysis of the faunal remains and OSL-dates of the small portion of intact sediments will help to gain a better understanding of the Paleolithic occupation of the Felsenhäusl-Kellerhöhle.

After the data collection was finished, additional artifacts from Felsenhäusl-Kellerhöhle were found among the collection of the owner of the cave. A survey of the all in all 490 pieces showed that these include only chronologically indifferent pieces of no additional informative value. Therefore, they were not analyzed. Another 412 pieces could not be securely assigned to Felsenhäusl-Kellerhöhle and were also excluded from our studies.

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