The functional analysis of the Mousterian and Micoquian assemblages of Sesselfelsgrotte, Germany: Aspects of tool use and hafting in the European Late Middle Palaeolithic

Funktionsanalysen der Moustérien- und Micoquien-Inventare der Sesselfelsgrotte, Deutschland: Ein Beitrag zu Werkzeuggebrauch und Schäftung im späten Mittelpaläolithikum Europas

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Abstract - Presented here are the results of a functional analysis of the lithic material from the G-complex at Sesselfelsgrotte. Different tool uses were attested as well as different prehensile modes. Several artefacts, amongst which are percussion tools and projectiles, proved to have been used while hafted and various hafting arrangements could be reconstructed. Neanderthals at Sesselfelsgrotte prove to have been able to anticipate tool use. Their hafting of tools for which hafting is not a precondition for use is considered to be an important indicator for their cognitive abilities.

***Zusammenfassung -** Anhand umfangreicher experimenteller Testserien und mikroskopischer Gebrauchsspurenanalysen konnten neue Erkenntnisse zum Einsatz von Steinwerkzeugen aus dem G-Komplex der Sesselfelsgrotte gewonnen werden. Dabei wurde ein methodisches Verfahren entwickelt, dass es ermöglicht Schäftungsspuren auf Steinwerkzeugen zu identifizieren. Es konnte festgestellt werden, dass Steinwerkzeuge aus der Sesselfelsgrotte systematisch geschäftet wurden. Dabei handelt es sich hauptsächlich um Werkzeuge für deren sinnvollen Einsatz eine Schäftung unbedingt erforderlich ist wie Waffenspitzen oder keilartig Werkzeuge. Aber auch andere Werkzeuge wie Messer oder Schaber, bei denen eine Schäftung die Handhabung zwar verbesserte jedoch nicht zwingend erforderlich war, wurden geschäftet. Die untersuchten Werkzeuge wurden hauptsächlich bei der Verarbeitung der Jagdbeute und zur Instandhaltung und Konfektionierung anderer Gerätschaften – belegt ist z.B. Holzbearbeitung - eingesetzt. Eine weit vorausschauende Planung bei der Geräteherstellung ist dokumentiert. Denn bereits bei der Grundproduktion einiger Werkzeuge wurde deren spätere Schäftung berücksichtigt. Die hohen kognitiven Fähigkeiten der Neanderthaler aus der Sesselfelsgrotte können durch diesen Planungsprozess überzeugend nachgewiesen werden.*

Keywords - microwear, use, hafting, Neanderthals
Gebrauchsspurenanalyse, Werkzeuggebrauch, Schäften, Neanderthaler

Introduction

Research at Sesselfelsgrotte

The Sesselfelsgrotte cave is situated in the valley of the lower Altmühl River, a tributary of the Danube (Bavaria, Germany). The site has a unique sequence of 22 Middle Palaeolithic occupations and several Upper Palaeolithic occupations (Richter 2001). Excavations by the University of Erlangen were mainly carried out in the 1960s and 1970s (Freund 1968, 1998). Research at Sesselfelsgrotte has been quite detailed up to now, as witnessed by the four volumes that have already appeared on the subject (Weissmüller 1995; Richter 1997; Freund 1998; Dirian 2004) and one currently due to be published (Böhner in press).

The lowest part of the stratigraphy (Fig. 1) is referred to as the *"Untere Schichten"* and consists of eight occupation units (Weissmüller 1995; Richter 1997; 2001) assigned an early Weichselian age and corresponding with oxygen isotope sub stages 5c and 5a. Typologically and technologically these industries are comparable to contemporaneous western European Mousterian industries. About 10 000 artefacts were recovered. On top of these levels are layers L, K and I, which correspond with the first glacial maximum of the Weichselian glaciation (OIS 4) and do not contain archaeological material. Layer I, together with layers H, G and F, forms part of the so-called "G-complex", which consists of thirteen Mousterian

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and Micoquian assemblages postdating the first glacial maximum of the last cold stage (ca. 65 ka BP) (Jöris 2002). Layer G itself consists of up to six overlying horizons, which represent actual living floors with several fireplaces, many burnt faunal remains and abundant stone artefacts. About 85 000 stone artefacts and numerous animal remains (mainly mammoth, reindeer and horse) were recovered, as were remains of a hominin foetus/neonate (from Horizon G5: Rathgeber in press, after Street et al. 2006). The underlying layers H and I, and the overlying layer F are sterile. The G-Complex is overlain by a late Middle Palaeolithic horizon (layer E3). This is succeeded by loessic deposits of the last glacial maximum of the last cold stage (ca. 24 ka BP) (Jöris 2002) and two archaeological horizons with several late Upper Palaeolithic and Final Palaeolithic assemblages. More details concerning the stratigraphy can be found in the original publications (Weissmüller 1995; Richter 1997; Freund 1998).

Characteristic of the Middle Palaeolithic assemblages at Sesselfelsgrotte is the relatively low percentage of bifacial pieces within a Mousterian industry. This resulted in the use of the term "Mousterian of Micoquian tradition" (Freund 1968). The Micoquian as defined by Bosinski (Bosinski 1967) consists of four form groups (*"Formengruppen"*), which are partially linked to the stratigraphy of the cave site Balver Höhle (Günther 1964). Recently, the Central European Micoquian assemblages have been referred to as the *"Keilmessergruppen"*, named after the very typical bifacial *"Keilmesser"* tool form (Jöris 2002). Chronologically, Sesselfelsgrotte is placed into the last phase (phase C) of these *Keilmessergruppen* industries (Jöris 2002).

Based on a raw material spectrum analysis, Richter divides the G-complex into four cycles, each one ideally including a more explorative initial short occupation (represented by an *"Initialinventar"*) and a subsequent more intensive, longer occupation (producing a *"Konsekutivinventar"*) (Richter 1997). Each of these occupations may comprise more than one inventory. Based on his results, Richter concludes

Stratigraphy	Archaeological Unit	Attribution	Details	Oxygen Isotope Stages	Approximate ages BP (after Richter 2001) or C14 dates (after Richter 1997)
Layer A		Middle Ages		OIS 1	
Layer B		Late Palaeolithic			ca. 11 ka
Layer C		Upper Palaeolithic		OIS 2	ca. 18 ka
Layer D		2nd Glacial Maximum			ca. 24 ka
Layer E3		late Middle Palaeolithic			37 000 ± 1 000 (GrN-7153)
Layer F	sterile				
Layer G1	A01	Mousterian & Micoquian	Late Micoquian	OIS 3	
Layer G1/G2	A02				
	A03				
Layer G2	A04				36 600 ± 875 (GrN-6180) on bone; 41 840 + 1 170/-1 020 (GrN-6848) on charcoal
	A05				
	A06				
Layer G3	A07				ca. 41 ka
Layer G4	A08		Early Micoquian		46 600 + 980/- 880 (5114/5024/5026 – preliminary date) on bone
	A09				
Layer G4a/G5	A10				ca. 48ka
	A11				
Layer H	sterile/A12				
Layer I	sterile/A13				ca. 61ka
Layers K, L	no material	1st Glacial Maximum		OIS 4	ca. 65ka
Layer N					> 45 900 (GrN-7033) on charcoal
„Untere Schichten"	A01-A03	Mousterian	Typical Mousterian	OIS 5a	
	A04		Charentian/Quina	&	
	A05 & A06		Charentian/Ferrassie	OIS 5c	
	A07 & A08		Mousterian with microlithic tools		

Fig. 1. Overview of the stratigraphical situation at Sesselfelsgrotte based on Richter (1997, 2001).
Abb. 1. *Überblick über die stratigraphische Sequenz der Sesselfelsgrotte nach Richter (1997, 2001).*

that in the G-Complex, the Mousterian and Micoquian are not true "form groups" or cultural units; instead, the occupation duration and its position within the occupation cycle determine whether an inventory has a more Mousterian or a more Micoquian character (Richter 1997). The Mousterian and the Micoquian are parts of the same system, but initial assemblages are more Mousterian, while secondary assemblages are more Micoquian. Consequently, Richter proposes the term "Mousterian with Micoquian option" (M.M.O) within which the "Micoquian-option" becomes more visible when the use duration of the site increases (Richter 1997). Moreover, Richter distinguishes an early (M.M.O.-A) and a later Micoquian (M.M.O.-B), the early Micoquian being characterised by the use of Quina or other non-Levallois methods, while Levallois methods are in use during the later Micoquian.

Based on Richter's raw material analysis, the material from the G-complex is divided into thirteen inventories, some of which are contemporaneous, with three additional inventories of material found out of context. The inventory of the initial phase (*"Initial-inventar"*) is characterised by few notched and denticulate pieces, few bifacial tools and low intensity of retouch. The tools are predominantly locally fabricated specimens (single side scrapers, notched and denticulate pieces). Tools imported as finished items, such as multiple side scrapers, points and "microliths" are present in only limited numbers. This is explained as a result of an occupation of short duration with high regional mobility, during which the area is explored and tested for raw materials resulting in a larger diversity in raw material usage (Richter 1997).

The inventory of the second phase (*"Konsekutiv-inventar"*) is characterised by lower raw material diversity, more bifacial tools, more notched and denticulate pieces and a higher intensity of retouch. Imported finished pieces are more important. This pattern is explained by a lower regional mobility and more important duration of occupation. More expert knowledge about the availability of raw materials results in a preference for the highest quality leading to lower raw material variety (Richter 1997).

A use-wear analysis was carried out on the microliths (Richter 1997), which are comparable to pieces described as *"raclettes"* by Bordes (Bordes 1961). The flakes are never larger than about 2 cm and often have all-round retouch. A total of 202 microlithic pieces from archaeological unit A01 up to A06 was examined microscopically. Forty-three specimens showed microwear traces, mainly polishes, determined as being caused by working soft, sometimes wood-like plant materials (Lass 1994).

Methods

Selection procedure

Based on the information provided by Freund (Freund 1998) and Richter (Richter 1997; 2001), it was decided to first focus on two archaeological units, A06 and A08, corresponding to excavation layers G2 and G4 respectively, which were described as living floors with several fireplaces. Unit A08 belongs to the Early Micoquian or cycle 2 of the sequence (Richter 1997). The unit consists of 223 tools, including seven points (Richter 1997). Unit A06 belongs to a Late Micoquian and cycle 3 according to Richter. The unit consists of 321 tools including six points (Richter 1997). Both A08 and A06 are referred to so-called *"Konsekutiv-inventare"*, the second phase of a cycle, A08 within cycle 2 and A06 (together with A05) within cycle 3. In the case of cycle 2 there is no initial assemblage, while the initial inventory within cycle 3 is unit A07. Pieces from these units were examined macroscopically for potential signs of functional wear, starting with pieces which were selected by J. Richter as representative of the assemblage on typological grounds. Pieces with potential wear were examined under low power magnification and the most promising pieces were selected for more detailed analysis in the laboratory in Leuven, under low and high power magnification.

In a second stage, attention was also devoted to archaeological units A02 and A10, mainly the pieces selected by J. Richter (for A02). Unit A10 corresponds to excavation layer G5/G4a and represents the oldest phase of the sequence (cycle 1). A fireplace was recovered in association with this assemblage (Richter 1997). Unit A02 corresponds with excavation layer G/G1 and represents a younger phase (cycle 4). A fireplace was again recovered in association with the material (Richter 1997). The pieces from these units were examined macroscopically and under low power, but they were not subjected to more detailed analysis at Leuven.

Aside from this selection procedure, special attention was devoted to the bifacial pieces. These pieces were curated separately in the collection at Erlangen, which facilitated a quick macroscopic screening for signs of wear, independent of their archaeological unit. Due to this procedure, some pieces from unit X03 were also analysed. This unit contains pieces from an unknown stratigraphical position (e.g. during profile cleaning), which makes such pieces less suitable for a functional analysis. They originally seem to have been mainly part of units A01, A05 and A09 (Richter 1997).

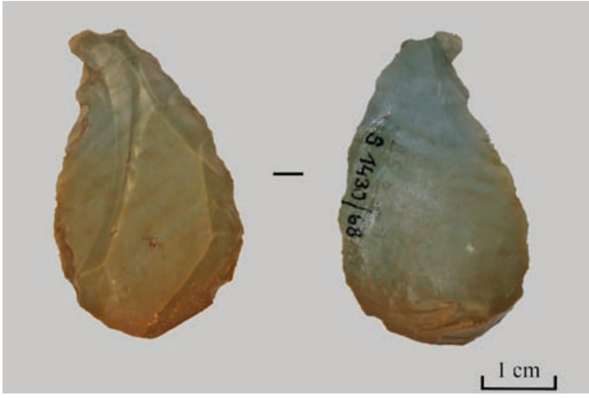
An important factor influencing tool morphology is the raw material that was predominantly used, a variety of Jurassic chert (*Jurahornstein Typ Baiersdorf*) (Richter 2001). This occurs in thin slabs, which means that mainly thin products are generally produced, often with both dorsal and ventral cortex remaining. Consequently, it is not surprising that many bifacial products were manufactured out of this material.

Experimental basis

The presented research relies on an extensive experimental referential basis that was created with a view to understanding hafting traces (Rots 2002a) and on additional reference collections produced within the research group earlier with a view to understanding use-wear traces.

The "hafting referential basis" includes about 400 experimental tools used for various activities (wood-working, hide-working, etc.) with variable prehensile modes (hand-held, with a wrapping, or in various hafting arrangements). Different hafting materials (e.g. bone, antler, wood) and haft types (e.g. male, male split, juxtaposed) were tested. The research involved the development of a method (Rots 2002a; 2002b; 2003; 2004; Rots et al. 2001) that would allow a reliable interpretation of hafting traces on archaeological assemblages (Rots 2005; Rots & Van Peer 2006). The impact of several variables on the formation process of hafting traces was examined (e.g. Rots & Vermeersch 2004) and the potential and reliability of the method were controlled in a number of blind tests (Rots 2002a; Rots et al. 2006). A distinction was made between different levels of interpretation, a first being the distinction between hand-held and hafted tools (e.g. Rots 2004) and a second the distinction between different hafting arrangements (Rots 2002a).

While the experimental reference collection on hafting is itself representative for use-wear, additional use-wear reference collections containing some 300 experimental tools were also available during this study (i.e. reference collections produced by Symens, Gysels and Caspar (Caspar 1988) and others).



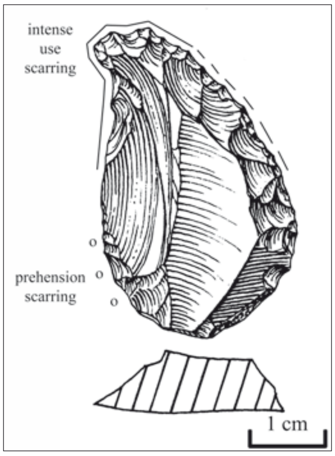


Fig. 2. Hand-held scraper (S1430/68) (oblique, convex side scraper on pointed flake, cf. Richter 1997).

Abb. 2. *Schaber ohne Schäftung (S1430/68) (schräger, konvexer Schaber an spitzem Abschlag, cf. Richter 1997)*

Analytical Procedure

Analytical procedures differ for the material that was examined at the University of Erlangen and for the material that was studied at Leuven. At Erlangen we only had access to a stereoscopic binocular microscope (magnifications up to 80x), so only macroscopic (with the naked eye) and low magnification examinations were possible. For the material examined at Leuven, a high magnification analysis with an Olympus metallurgical microscope (magnifications 50 - 500x) was performed, together with a detailed low magnification analysis using a Wild stereoscopic binocular microscope (magnifications up to 100x).

The state of preservation of the Sesselfelsgrotte material is acceptable and adequate for a reliable analysis, in particular at a low power level. In several cases, light or moderate post-depositional polishing hinders high power observations (e.g. S1430/68, S1479/68: Figs. 2 & 3). Scarring evidence is, however, well preserved and few post-depositional scars were observed. Scarring therefore formed the main focus of this study. Quite reliable interpretations could be made, even though interpretations are not always exact (e.g. relative material hardness instead of exact worked material) or pushed to the interpretation limit (e.g. generally no interpretation of haft material) for reasons of reliability (e.g. polish preservation issues).

During analysis, artefacts were cleaned with alcohol or occasionally with acetone. No chemical cleaning was necessary. The post-excavation procedure for cleaning the artefacts apparently involved the use of acids, which may be destructive for polishes, but it is unclear to what extent this was done. This may explain the sometimes poor presence of polish in contrast to distinct scarring evidence.

Photographs of the wear traces were only possible for the exported material as no adapted photographing equipment for microscopes was available at Erlangen.

Regarding the terminology used, it is important to note the distinction between type names (e.g. "side scraper", *"Keilmesser"*) and names used in a functional sense (e.g. "adze", "scraper"). In the latter case, no particular typology is referred to and diverse morphologies may have been used for the function in question. Attention should therefore be paid to the exact context in which the names are used. Generally, it is mentioned whether typology or function is referred to.

Of the 400 pieces that were quickly analysed and not considered relevant for a more detailed study, most pieces did not show any functionally relevant wear or wear that could be recognised as such (Fig. 4). Only a few pieces therefore deserve mentioning. These pieces include three end scrapers with

Fig. 3. Hafted scraper/rabot (S1479/68) (side scraper).

Abb. 3. *Geschäfteter Schaber (S1479/68) (Schaber).*

potential use and hafting wear (one of which as hafted scraper/*rabot,* cf. infra), one bifacial tip fragment, possibly a projectile tip, and one transversal scraper that was potentially used and hafted (as a scraper/*rabot*).

The 292 pieces that were analysed more closely can be subdivided into four large typological categories as defined by Richter (Richter 2001): bifacial pieces, standard Mousterian tool types, Upper Palaeolithic tool types and microlithic tools (Figs. 5 & 6). The remaining pieces comprise retouched and unretouched pieces, cores, core renewals and tang fragments. The bifacial pieces, 339 in total, of which 94 were examined, can be subdivided into *Halbkeil, Keilmesser,* bifacial scrapers, bifacial tip fragments and the remaining bifacial pieces and fragments (cf. Fig. 5). The 95 examined standard Mousterian tool types (from a total of 1 053) consist of points, different forms of scrapers (e.g. side scrapers, transverse scrapers and *déjeté* scrapers), denticulates, notched pieces, backed knives etc. Nine out of 192 Upper Palaeolithic tool types were examined and these consist of end scrapers, perforators and drills. In addition, eight microlithic tools were examined, as well as 34 retouched pieces and 44 unretouched pieces.

Based on the number of pieces analysed per unit, it is calculated that about 28% of the bifacial pieces were examined for wear traces, 9% of the standard Mousterian tool types and 4.5% of the Upper Palaeolithic and Microlithic tool types (cf. Fig. 7). This adds up to about 4.5% of the total tool assemblage. If attention is focussed on unit A06 and A08 only, given their more intensive functional analysis, the percentages are as follows: about 44% of the bifacial tools from A06 and A08 were examined, next to 21% of the standard Mousterian ones and 19% of the Upper Palaeolithic and microlithic tool types (cf. Fig. 7). This adds up to about 26% of the total tool assemblage from A06 and A08.

Analytical approach	A01	A02	A05	A06	A08	A09	A10	X03	blank	Total
Quick macroscopic screening	0	0	0	289	111	0	0	0	0	400
Macroscopic & low magnification analysis	1	29	3	85	61	17	23	9	1	229
Macroscopic, low & high magnification analysis (examined at Leuven)	0	0	0	24	39	0	0	0	0	63
TOTAL	1	29	3	398	211	17	23	9	1	692

Fig. 4. Total number of examined pieces per archaeological unit and analytical approach used.

Abb. 4. *Anzahl der untersuchten Stücke pro archäologischer Einheit sowie der benutzen Untersuchungsmethoden.*

Results

The functional results are discussed per large typological category (cf. Figs. 8 - 12) and are subsequently summarised with more conclusive counts regarding tool use and prehensile modes (cf. Figs. 13 - 15). Based on our current knowledge regarding hafting, the following conceptual framework is proposed based on the degree of hafting practised.

1) No indications of hafting. If tasks for which tools need to be hafted were performed, they were performed with other tools than stone tools (e.g. pointed wooden spears)

2) Hafting is attested, but it is restricted to tools for which hafting is a precondition dictated by the tool's function, such as axes and projectiles. Other stone tools were used in the hand.

3) Hafting is attested and is not restricted to tools for which hafting is a necessity. Apart from the latter tools, tools were also mounted for which hafting facilitates tool use. This can be assumed to mainly affect tools that reflect a frequent or specialised activity (to be demonstrated).

4) Hafting is practiced on a large scale, for all kinds of tools, although this does not imply that all tools are necessarily hafted. Hafting is dealt with in a flexible way and especially for short tool use; tools may have been frequently hand-held. Task performance and social values (e.g. display) may play a role in the decision.

General typological category	A01	A02	A05	A06	A08	A09	A10	X03	Total
Bifacial pieces									**339**
Halbkeil	0	2	2	0	2	1	1	0	**8**
Keilmesser	8	4	2	10	12	10	6	3	**55**
Bifacial piece	23	21	15	22	27	12	4	20	**144**
Bifacial scraper	3	1	0	5	8	5	2	2	**26**
Bifacial tip fragment	1	0	0	3	1	0	1	0	**6**
Bifacial fragment	21	11	8	14	16	14	4	6	**94**
Lateral edge renewals		1	2	1	1	1	0	0	**6**
Standard Mousterian tools									**1'053**
Point	4	4	2	6	7	2	0	1	**26**
Convergent scraper	6	7	3	5	5	8	3	7	**44**
Side scraper	14	16	12	16	12	9	8	5	**92**
Convex side scraper	43	18	28	33	29	25	18	26	**220**
Concave side scraper	3	1	0	2	1	3	1	0	**11**
Double side scraper	4	5	4	14	1	7	0	2	**37**
Déjeté scraper	13	2	5	7	5	4	1	6	**43**
Transverse scraper	13	6	6	9	4	4	5	2	**49**
Scraper	12	11	4	11	8	6	7	13	**72**
Backed knife	4	1	0	2	0	2	0	0	**9**
Terminally retouched pieces	7	7	4	13	6	2	1	4	**44**
Denticulate	31	25	9	31	15	5	2	7	**125**
Notched piece	56	24	32	59	47	34	12	17	**281**
Upper Palaeolithic tools									**192**
End scraper	18	8	4	14	6	6	1	5	**62**
Burin	2	1	0	2	0	0	0	2	**7**
Perforator/drill/bec	26	9	14	42	10	7	1	14	**123**
Others									**1**
Pebble tool	0	0	0	0	0	0	0	1	**1**
GrandTotal	**312**	**185**	**156**	**321**	**223**	**167**	**78**	**143**	**1'585**

Fig. 5. Total number of tools per inventory according to Richter (1997).

Abb. 5. *Anzahl der Werkzeuge pro Inventar nach Richter (1997).*

Apart from these degrees of hafting intensity, which do not necessarily have chronological implications, many variations are possible, according to the degree up to which hafting is integrated in the production context of tools, the degree of specialisation in tool production, social values etc. Hafting appears to be a very instructive variable for the reconstruction of past ways of life when confronted and integrated with other site data (e.g. tool use, technology and spatial data). It bears witness to a degree of planning and anticipation of tool use and a certain complexity in human behaviour.

Bifacial pieces

The functional results obtained for the bifacial tools are summarised in figure 7. A feature that is immediately clear is the lack of correspondence between a tool type and a particular tool function, even for quite intensively worked tool types such as hand-axes, *"Halbkeil"* or *"Keilmesser"*.

The Halbkeil are most specific in function, given that some form of percussive activity tends to be associated with them, and with the exception of one specimen they seem to have been used for woodworking tasks. The piece identified as a scraper/chopper (cf. Fig. 8) is a small *Halbkeil*, which might be explained by a use in lighter woodworking tasks. Only the *Halbkeil* interpreted as having been "used & hafted" was possibly used on another material, perhaps for scraping hides, but this interpretation remains uncertain (S4595/70; cf. Fig. 16). The piece was re-sharpened and not used afterwards, leaving little wear evidence to attain a reliable use interpretation. The hafting-wear interpretation is reliable given that hafting-wear is not affected by resharpening (only the used edge is); on the contrary, resharpening may even increase the amount of hafting wear as a result of the pressure exerted by the hammer during resharpening (Rots 2002a).

One of the hand-axes proved to have been used as a hafted knife (S0261/74, Fig. 17). The irregular retouch on the left edge with zones of intense abrasion at first gave the impression that this piece was a production failure. However, closer examination provided sufficient indications of use in the form of bifacial scarring and abrasion on the tip, edge scarring and a small distal ventrally initiated oblique fracture. The hafting evidence consists of superimposed abrupt scarring and crushing around the potential haft limit,

General typological category	A01	A02	A05	A06	A08	A09	A10	X03	(blank)	Number of tools
Bifacial pieces										**94**
hand-axe					1	1	2			4
Halbkeil		2			1		1			4
Keilmesser		1		4	3	3	2	1		14
Bifacial piece		1		4	11	1	2	3		22
Bifacial scraper				5	1	4		2		12
Bifacial tip fragment				3	1		1			5
Bifacial fragment		3	2	6	14	4	3	1		33
Standard Mousterian tools										**97**
Side scraper		10	1	21	22	2	1	1	1	59
Point				8	6	1				15
Transverse scraper		3		3	4					10
Déjeté scraper				1	2					3
Scraper				1						1
Scraper fragment				2						2
Unifacially worked fragment							1			1
Knife				1						1
Denticulate		1			2					3
Notched piece		1								1
Tip fragment					1					1
Upper Palaeolithic tools										**9**
End scraper		1		1	1					3
Small end scraper		2		2						4
Perforator/drill				1	1					2
Microlithic tools										**8**
Microlithic scraper				1	1					2
Microlithic denticulated flake					1					1
Microlithic retouched flake					1					1
Microlithic flake					2					2
Microlith					1					1
Microlith fragment					1					1
Retouched pieces										**32**
Retouched flake				13	5		1			19
Retouched flake fragment				6						6
Retouched blade				3			1			4
Retouched blade fragment				1	2					3
Unretouched pieces										**44**
Flake				3	4		3			10
Flake fragment				7	4		3	1		15
Blade				2	1		1			4
Blade fragment		2		3			1			6
Irregular piece					4					4
Levallois flake		2		3						5
Others										**8**
Core	1				1					2
Lateral edge renewals					1	1				2
Overshot				1						1
Tang fragment				3						3
Grand Total	**1**	**29**	**3**	**109**	**100**	**17**	**23**	**9**	**1**	**292**

Fig. 6. Microscopically analysed pieces per unit according to large typological categories and groups of Richter (Richter 2001).

Abb. 6. *Anzahl der mikroskopisch untersuchten Stücke pro Einheit sortiert nach groben typologischen Kategorien (Richter 2001).*

large ventral scars and superimposed hinge-into-feather and hinge-terminating scars. A small triangular hand axe with cortex remains showed evidence of use as a projectile (S8802/73, Fig. 18). The evidence on the tip consists of a ventral large step-terminating impact scar, associated with other abruptly terminating impact scars and scarring on the adjacent lateral edges. In addition, there is scarring around a potential haft limit, characterised by curved initiations, hinge or step-terminating scars, crushing and bifacial scarring. The piece is fractured proximally in an oblique, ventrally initiated fracture with a lot of associated scarring, which supports the interpretation that this fracture occurred under impact. A third hand-axe also proved to have been used while hafted, but the exact use was not clear (S8500/73). It is a fragment of an irregular small hand-axe with remains of cortex and an intentionally removed tip (Richter 1997), but actually resembles a bifacial, coarse yet thin end scraper. Given the high relative number of hafted hand axes, one has

General typological category	Total number of tools	*% analysed*	*% analysed of A06 & A08*
Bifacial pieces	339	*28.0*	*44.3*
Standard Mousterian tools	1'053	*9.0*	*20.7*
Upper Palaeolithic & „Microlithic" tools	192	*4.7*	*18.9*
Others	1		
Grand Total	**1'585**	***5.4***	***25.9***

Fig. 7. Analysed tool percentages.

Abb. 7. *Prozentzahlen der untersuchten Werkzeuge.*

Bifacial pieces	Functional interpretation	A01	A02	A05	A06	A08	A09	A10	X03	(blank)	Number of tools
Hand-axe	uncertain					1					1
	used & hafted						1				1
	hafted knife							1			1
	hafted projectile							1			1
subtotal						1	1	2			**4**
Halbkeil	used & hafted					1					1
	hafted scraper, rabot							1			1
	hafted scraper, chopper		1								1
	hafted adze		1								1
subtotal			2			1		1			**4**
	uncertain				1						1
Keilmesser	production failure				1						1
	unfinished								1		1
	unfinished or hand-held knife							2			2
	used						1				1
	used & hafted		1			1					2
	knife					1	2				3
	hand-held knife				1						1
	hafted projectile					1					1
	hafted scraper, rabot				1						1
subtotal			1		4	3	3	2	1		**14**
Bifacial pieces & fragments	uncertain		1	1	1	7	4		1		15
	production failure				3	7		1			11
	hafted extremity or production failure					1					1
	unused				1	1					2
	possibly used			1	2	3	1		1		8
	used & hafted		1								1
	perforator				1						1
	hafted axe / adze					2		1	2		5
	hafted knife					1					1
	hafted projectile		1		3	3		3			10
	hafted scraper, rabot				1	1					2
	hafted fragment		1		1			1			3
subtotal			4	2	13	26	5	6	4		**60**
Bifacial scraper	unfinished						3		2		5
	possibly used				1						1
	used & hafted				1						1
	hafted axe						1				1
	knife				1						1
	hafted scraper, rabot				1	1					2
	projectile				1						1
subtotal					5	1	4		2		**12**
Total number of tools			**7**	**2**	**22**	**32**	**13**	**11**	**7**		**94**

Fig. 8. Functional interpretation of bifacial tools.
Abb. 8. *Funktionale Interpretation der bifaziellen Werkzeuge.*

to recognize that they are systematically thin specimens (cf. Figs. 17 & 18).

Among the *Keilmesser,* a large variety of tool uses was identified, even though knives tend to dominate, especially when unfinished or unspecific objects are not taken into account. The hand-held knife is a kind of backed (bifacial) knife. The pieces identified as a hafted scraper/*rabot* show triangular morphology, highly similar to the side scrapers identified as having served for the same function (cf. infra). The non-interpreted piece is a base fragment of a *Keilmesser*. One of the "used & hafted" *Keilmesser* was used for percussion, but no more details could be derived. Another was possibly used as scraper/*rabot*; this *Keilmesser* also has a scraper edge (cf. Richter 1997: Pl. 26, 1: S3222/69 – [wrong numbering]). The identified projectile shows impact damage (spin-offs), some associated with bright spots, pseudo-burin spalls on the edges and a distinct haft limit can be identified (S1477/68, Fig. 19).

Several production failures were recognised among the bifacial pieces and fragments (cf. Fig. 8), showing manufacturing problems, such as the inability to reduce an edge or surface (e.g. remove a central thicker zone) and unintentional fractures. Such problems are recognized on the basis of comparisons with finalised end products (which allows the identification of the goal of the manufacturing process) and

Standard Mousterian tools	Functional interpretation	A01	A02	A05	A06	A08	A09	A10	X03	(blank)	Number of tools
Side scraper	uncertain				1	1	1	1		1	5
	production failure					2			1		3
	unused		1		2	1					4
	possibly used			1	5	3	1				10
	used & hafted		1		1	2					4
	hand-held knife		2		2	3					7
	hand-held perforator		1								1
	hand-held scraper				1	2					3
	hafted groover				1						1
	hafted scraper		1		2	2					5
	hafted scraper, rabot		1		3	2					6
	hafted chopper, scraper					1					1
	hafted axe/adze		2		1	2					5
	hafted projectile				2	1					3
	hafted extremity		1								1
Point	unused					1					1
	possibly used				1						1
	used & hafted						1				1
	perforator				2						2
	hand-held scraper				1						1
	hafted scraper					1					1
	hafted scraper, rabot				1	1					2
	hafted projectile				2	3					5
	projectile tip					1					1
	hafted extremity				1						1
Transverse scraper	used & hafted		1			2					3
	hand-held knife		1								1
	hafted scraper		1		2	1					4
	hafted scraper, rabot				1						1
	hafted projectile					1					1
Déjeté scraper	uncertain				1						1
	hafted fragment					1					1
	hafted scraper					1					1
Scraper & scraper fragments	possibly used				1						1
	hafted scraper				2						2
Unifacially worked fragment	production failure							1			1
Knife	uncertain				1						1
Denticulates/notched piece	possibly used					1					1
	hafted perforator					1					1
	hafted adze		1								1
	hafted adze/axe		1								1
Total number of tools			**15**	**1**	**37**	**37**	**3**	**2**	**1**	**1**	**97**

Fig. 9. Functional interpretation of Mousterian tools.

Abb. 9. *Funktionale Interpretation der Moustérien-Werkzeuge.*

knowledge of knapping problems related to the manufacture of bifacial products obtained by experimental knapping. While more problems may occur during the manufacture of bifacial products in comparison to flaked pieces, many production failures of the latter category may go unnoticed in an assemblage when unretouched pieces or fragments are concerned. Among the used items, projectiles clearly dominate, next to hafted axes/adzes. Aside from these groups, hafted scrapers/*rabots*, a hafted knife and a perforator were also identified. Three hafted fragments were identified. Possibly these are remains of an impact tool such as a projectile or hafted axe/adze given the easily recognisable hafting wear produced by such uses, but traces were not sufficiently distinctive to infer this with any certainty.

Of the 12 bifacial scrapers, many seemed unfinished and did not show use-wear traces. A hafted axe, a projectile, two hafted scrapers/*rabots* and a knife were nevertheless identified.

It is clear from this analysis that there is no strict link between typology and function, even for very

Upper Palaeolithic tools	Functional interpretation	A02	A06	A08	Number of tools
	uncertain	1			1
Endscraper	hafted end scraper (scraping or chopping)			1	1
	hafted adze		1		1
Small end scraper	possibly used & hafted		1		1
	possible hafted scraper/chopper	1			1
	hafted scraper	1	1		2
Perforator/drill	unused			1	1
	possible perforator		1		1
Total number of tools		**3**	**4**	**2**	**9**

Fig. 10. Functional interpretation of Upper Palaeolithic tools.

Abb. 10. *Funktionale Interpretation der jungpaläolithischen Werkzeuge.*

Microlithic tools	Functional interpretation	A06	A08	Number of tools
Microlithic scraper	uncertain	1		1
	unused		1	1
Microlithic denticulated flake	possibly used & hafted		1	1
Microlithic retouched flake	possibly used		1	1
Microlithic flake	unused		2	2
Microlith	possible hafted scraper		1	1
Microlith fragment	uncertain		1	1
Total number of tools		1	7	8

Fig. 11. Functional interpretation of microlithic tools.

Abb. 11. *Funktionale Interpretation der mikrolithischen Werkzeuge.*

specific bifacial types, but this is not a new observation (e.g. Odell 2001). However, morphological similarities frequently exist among pieces with the same function, other than the morphological parameters used in a typological sense.

In total, thirteen projectiles were identified among the bifacial tools, among which we find (typologically speaking) a hand-axe, a *Keilmesser* (S1477/68, Fig. 19) and a bifacial scraper. Projectiles are of necessity hafted. Tips were identified, as well as hafted fragments and fragments of which their position is not clear. As a result of the significant impact during use, hafting wear is generally abundant (Fig. 20a). In several cases, a tip fracture occurred, which can result in intense scarring on the fracture edge (P5580/S65, Fig. 21). At least one of the projectiles, S1477/68 (cf. Fig. 19) shows different retouching on the used and hafted portion. The non-hafted edges show fine, parallel and intrusive retouching resulting in a very regular edge, and the hafted edges are coarsely retouched resulting in a more irregular edge. A concavity resulting from bifacial retouch forms the limit between both; it also corresponds with the haft limit. Very similar observations were made on a Middle Stone Age foliate specimen from Taramsa-8, Egypt (Van Peer et al. 2008) and, as in the case of that foliate, the point of the Sesselfelsgrotte piece possibly received its final shaping while hafted. This is a

General typological category	Functional interpretation	A01	A02	A05	A06	A08	A09	A10	X03	(blank)	Number of tools
Retouched pieces											
Retouched flake & flake fragments	uncertain				8	1					9
	unused				3	1					4
	possibly used					1					1
	hand-held use				1						1
	hand-held knife					1		1			2
	perforator				3	1					4
	hafted percussion tool				1						1
	hafted axe/adze				2						2
	hafted extremity				1						1
Retouched blade & blade fragments	not interpretable							1			1
	possibly used				1						1
	perforator				1						1
	hafted perforator				1						1
	hafted fragment				1	2					3
subtotal					**23**	**7**		**2**			**32**
Unretouched pieces											
Flake & flake fragments	uncertain				2	2		2			6
	unused					4		2			6
	possibly used				1	1		1	1		4
	used & hafted				1						1
	hafted scraper, rabot				2	1					3
	knife				1						1
	projectile							1			1
	projectile base				1						1
	hafted extremity				2						2
Blade & blade fragments	uncertain				2			1			3
	unused					1		1			2
	possibly used				1						1
	perforator				1						1
	projectile										1
	hafted extremity				1						2
Levallois flake	unused				3						5
Irregular piece	uncertain					4					4
subtotal					**18**	**13**		**8**			**44**
Others											
Core	production waste	1									1
	unused					1					1
Lateral edge renewals	burnt						1				1
	unused					1					1
Overshot	uncertain				1						1
Tang fragment	uncertain				1						1
	production failure				1						1
	hafted fragment				1						1
subtotal		**1**			**4**	**2**	**1**				**8**
Total number		**1**	**4**	**0**	**45**	**22**	**1**	**10**	**1**	**0**	**84**

Fig. 12. Functional interpretation of remaining pieces.

Abb. 12. *Funktionale Interpretation der restlichen Stücke.*

strategy that allows lining up the edges with the edges of the hafting arrangement, which reduces resistance when the tool is thrown.

Eight axes or adzes were identified (among them two *Halbkeile*, including one used for lighter chopping), most of which seem to have been used for woodworking. These kinds of tools need to be hafted to allow use (percussion). The seven hafted scrapers/*rabots* were also used for woodworking tasks. Eight knives were identified; most were used for butchering and had variable prehensile modes. Only one perforator was identified, for which the prehensile mode could not be determined.

Most of the bifacial implements proved to have been hafted for use. Given that many pieces remained unused, this means that 39 out of the 57 used bifacial pieces showed evidence of hafting. This is partially a consequence of tool use, including functions as projectiles and adzes/axes for which hafting is obligatory. Apart from such pieces, a number of other tools proved to have been used while hafted, in particular the very specific category of pieces used as a kind of scraper/*rabot*. Based on the use-wear traces (e.g. location, initiation and morphology of the scarring), it was determined that these pieces were used in a whittling motion (away from the user), mostly on wood. One can imagine that this kind of use is also largely facilitated by a haft. The activity is quite recurrent throughout the assemblage and therefore represents an important task: for the bifacial tools six examples were identified, but other examples were identified among the Mousterian tool types. The exact task this tool was set to cannot be defined, but in view of the production of wooden tools and hafts (e.g. projectile shaft, axe/adze haft) whittling wood seems likely. A final tool use that proved to have been performed in some circumstances while hafted is cutting: two out of eight knives proved to have been used hafted (S4594/70, Fig. 22) and one possibly hafted (P2964/S65, Fig. 23). There is, however, no apparent distinction on the level of the worked material; most knives seem to be related to a butchering activity. For a knife,

Functional Interpretation	A01	A02	A05	A06	A08	A09	A10	X03	(blank)	Total
Production failures - total										**24**
production failure/waste	1			5	8					14
shaping fracture							1			1
unfinished					1	3	1	4		9
Unused - total										**32**
unused		3		10	16		3			32
Used - total										**37**
used						2				2
possibly used		1	1	16	9	5	1	2		35
Hafted Tools -total										**110**
***projectiles - total**										**28**
hafted thrusting point					2					2
hafted projectile		2		6	5		2			15
projectile tip				2	3		2			7
projectile base				1	1		2			4
***percussion tools - total**										**24**
hafted adze		1			2					3
hafted axe						1	1	2		4
hafted axe/adze		4		4	3					11
tip of hafted axe					1					1
fragment of hafted adze				1						1
hafted scraper, chopper		2			2					4
***others - total**										**58**
hafted scraper, rabot		2		10	6		1			19
hafted scraper		4		6	9					19
hafted perforator				1	1					2
hafted butchering knife					1		1			2
hafted knife					1					1
hafted groover				1						1
hafted extremity		3		8	3					14
Hand-held Tools - total										**19**
hand-held scraper				2	1					3
hand-held perforator		1			1					2
hand-held butchering knife		2		2	2					6
hand-held knife		1		2	2		3			8
Other Tools - total										**23**
scraper			1		1					2
perforator				10	1					11
butchering knife					1					1
knife		1		3	1	2	1		1	9
Uncertain - total										**47**
uncertain				9	6		1			16
not interpretable/-ed		2	1	8	10	6	3	1		31
GrandTotal	**1**	**29**	**3**	**109**	**100**	**17**	**23**	**9**	**1**	**292**

Fig. 13. Summary of functional interpretations per archaeological unit.

Abb. 13. *Zusammenfassung der funktionalen Interpretationen pro archäologischer Einheit.*

Functional Interpretation		Worked material	Prehensile mode			Total	Summ. Total
			Hand-held	Hafted	Unknown/None		
Percussion	axe/adze	unknown	0	1	0	1	20
		(possibly) wood	0	17	0	17	
	axe tip	wood	0	1	0	1	
	adze fragment	possibly wood	0	1	0	1	
Projectile	thrusting point	meat and bone	0	2	0	2	28
	projectile	meat and bone	0	15	0	15	
	projectile tip	meat and bone	0	7	0	7	
	projectile base	none	0	4	0	4	
Scraping	scraper, chopper	possibly wood	0	4	0	4	47
	whittling	unknown	0	10	0	10	
		(possibly) wood	0	9	0	9	
	scraper	unknown	2	9	1	12	
		soft to medium-hard	0	1	0	1	
		medium-hard	1	3	0	4	
		medium-hard / hard	0	3	0	3	
		(possibly) hide	0	4	0	4	
Perforating	perforator	unknown	0	1	4	5	15
		moderate to hard	0	0	1	1	
		hard material	2	1	6	9	
Cutting	butchering knife	meat and bone	6	2	1	9	27
	knife	unknown	6	0	8	14	
		soft to medium-hard	1	0	0	1	
		medium-hard / hard	1	1	1	3	
Grooving	grooving	hard material	0	1	0	1	1
Hafted extremity	use unknown	unknown	0	11	0	11	14
	possibly used	unknown	0	1	0	1	
	impact use	unknown	0	2	0	2	
Used		unknown	1	0	1	2	37
Possibly used		unknown	0	9	25	34	
		possibly hide	0	0	1	1	
Unused		none	-	-	32	32	32
Other	uncertain	unknown	0	0	16	16	71
	not interpretable/-ed	unknown	0	0	27	27	
	(burnt)	unknown	0	0	4	4	
	production failure/waste	none	-	-	14	14	
	shaping fracture	none	-	-	1	1	
	unfinished	none	-	-	9	9	
Grand Total			**20**	**120**	**152**	**292**	**292**

Fig. 14. Summary of worked materials and actions.

Abb. 14. *Zusammenfassung der bearbeiteten Materialien und der Tätigkeiten.*

hafting is definitely not necessary but can in certain conditions facilitate tool use. There is as yet no valid explanation for the occurrence of both hand-held and hafted knives; it may be personal choice, a certain prehensile mode may have advantages for a particular stage in the butchering process, there may be a distinction between curated knives and others prepared on-the-spot and so on.

It was possible to identify some pieces as having been used while hafted even though their exact use is not entirely clear. The use and hafting traces are, however, sufficiently distinctive from other potential wear on the tool.

The only tools that were identified with certainty as hand-held implements were knives (in a functional sense). Other than that, hand-held use could not be identified among the bifacial tools, even though it may have existed; no prehensile mode could be determined with certainty for the perforator or for some other pieces and such pieces may very well have been used in the hand, given that hand-held use leaves less explicit and recognisable prehensile wear than hafted use.

Mousterian tool types

The most represented function among the Mousterian tools is some form of scraping (cf. Fig. 9).

Prehensile wear interpretation	Cycle 4: A01-02	%	Cycle 3: A05-06	%	Cycle 2: A08-09	%	Cycle 1: A10	%	disturbed	Number of tools
unknown	2		21		24		5		2	54
none	4		14		26		5		4	53
used but prehensile mode unknown		*0*	26	*33.8*	17	*25.4*	1	*7.7*	2	46
hand-held	4	*16.7*	6	*7.8*	7	*10.4*	3	*23.1*		20
hafted	20	*83.3*	45	*58.4*	43	*64.2*	9	*69.2*	2	119
Total number	**30**		**112**		**117**		**23**		**10**	**292**

Fig. 15. Summary of prehensile wear interpretations per occupation cycle (Richter 1997).

Abb. 15. *Zusammenfassung der Schäftungsspuren pro Besiedlungszyklus (Richter 1997).*

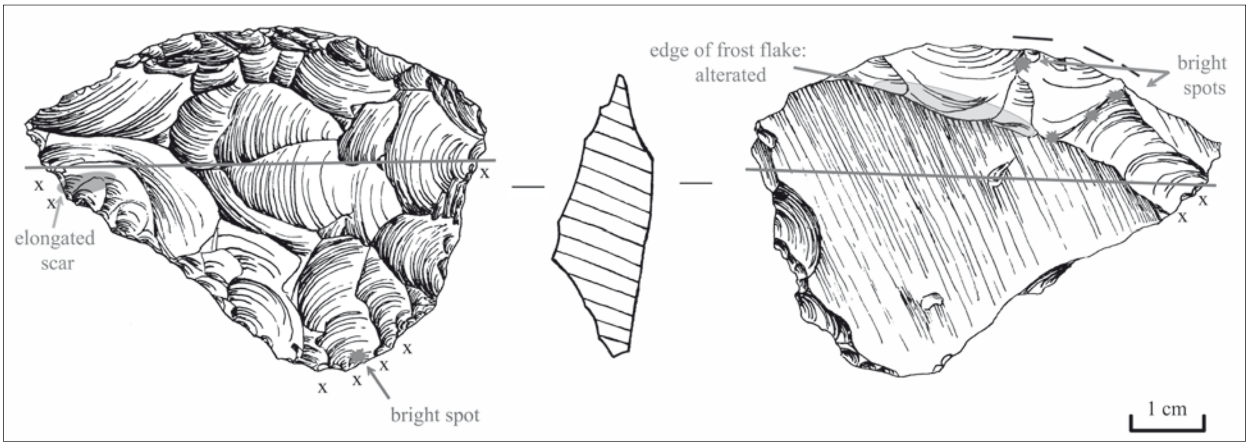


Fig. 16. Hafted hide scraper (S4595/70) (asymmetrical Halbkeil, ventral only partially retouched, on frost flake, cf. Richter 1997).

Abb. 16. *Geschäfteter Lederschaber (S4595/70) (asymmetrischer Halbkeil mit partieller ventraler Retusche and Frostabschlag. cf. Richter 1997).*

Fifteen scraping tools were identified, eleven of which proved hafted. One of these, S1322/68 (cf. Fig. 24), shows clear evidence of resharpening while hafted. The resharpening started from both lateral edges towards the centre, which is a procedure that is also observed among certain experimental knappers (Fig. 24: zones A). However, the resharpening resulted in intense bifacial damage in zone A' (Fig. 24). Given its proximity to the haft limit, this damage was difficult to correct and may have led to the tool's discard. The tool was not used after resharpening as demonstrated by the presence of use-wear in the central zone and its absence in the re-sharpened area. Concerning the exact tool use, the intense hafting wear may be suggestive of use in launched percussion instead of pure scraping, since high-pressure tasks result in far greater development of hafting wear (Rots 2002a, 2004; Rots & Vermeersch 2004).

Furthermore, nine scrapers/*rabots* were identified, all of them hafted. Projectiles proved to be important; ten were identified, including one tip fragment. At least two thrusting spear points were identified, which were typologically classified as a point and a transverse scraper. Seven hafted axes/adzes and one tool for lighter chopping represent the percussive tasks. One of the hafted axes/adzes (P4155/S65, Fig. 25) is highly similar morphologically to *"tranchets"* (Bordes 1961). It shows clear evidence of woodworking in the form of polish and scarring. While the left and most prominent part of the working edge (zone A, cf. Fig. 25) shows well developed wood use-wear, the wear pattern is interrupted in the right part (zone B, cf. Fig. 25). It seems that the latter zone was re-sharpened following the formation of a large use-impact scar, but this resharpening session was interrupted (possibly due to scarring around the haft limit, although this is uncertain) and the tool was discarded. Another hafted adze shows high morphological resemblance to the scrapers/*rabots*, but is a lot broader (S1713/68, Fig. 26, compare with S1428/68, Fig. 27, and P3049/S65, Fig. 28). Eight knives, all hand-held (e.g. P3043/S65, Fig. 29), four perforators with variable prehensile modes and one hafted grooving tool complete the list of identified tool uses. Three

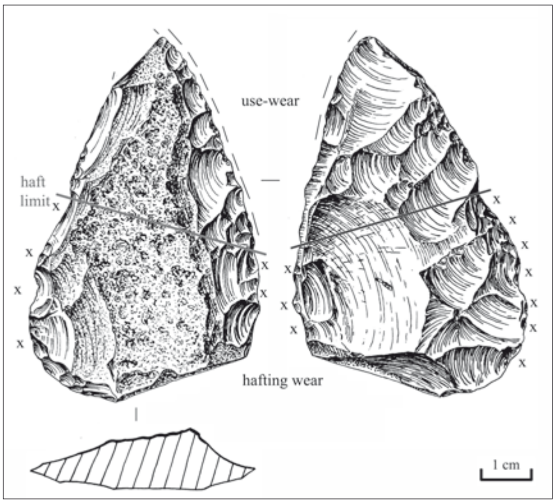


Fig. 17. Hafted knife (S0261/74) (triangular hand-axe with cortex remains, alternating retouch, cf. Richter 1997).

Abb. 17. *Geschäftetes Messer (S0261/74) (dreieckiger Faustkeil mit Kortex und alternierender Retusche, cf. Richter 1997).*

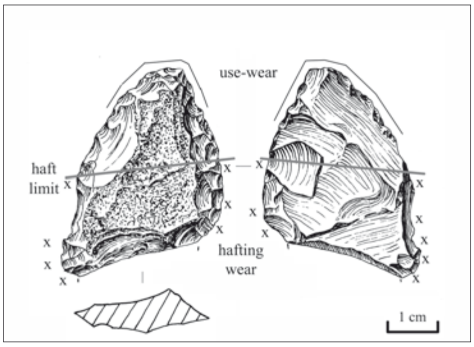


Fig. 18. Possible projectile tip (S8802/73) (small triangular hand-axe with cortex remains, cf. Richter 1997).

Abb. 18. *Mögliche Waffenspitze (S8802/73) (kleiner, dreieckiger Faustkeil mit Kortex; cf. Richter 1997).*

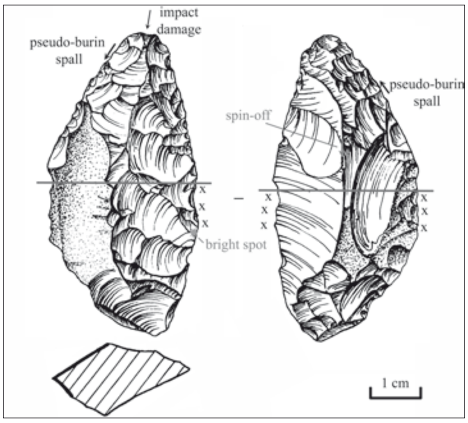


Fig. 19. Hafted projectile (S1477/68) (Keilmesser with angular working edge, thinned base, cf. Richter 1997).

Abb. 19. *Geschäftete Waffenspitze (S1477/68) (Keilmesser mit winkliger Arbeitskante und ausgedünnter Basis, cf. Richter 1997).*

hafted fragments of unidentifiable tools were also found, next to four production failures and four unused pieces.

Most pieces demonstrate hafted use. For a small number of tools the prehensile mode was not clear, alongside pieces whose overall interpretation was uncertain.

The important morphological variety among side scrapers (including single and double side scrapers) may explain the large variety of identified tool uses. Scraping is clearly the dominant activity (14) and includes pieces used in the aforementioned wood whittling activity. Seven pieces were used in some form of percussive activity, aside from seven hand-held knives, three projectiles (including one convergent side scraper), one perforator and one grooving tool.

The group of the points also includes pieces determined as convergent side scrapers, given their high morphological similarity. A function as a projectile (6) or perforator (2) is in line with their morphology; for scraping functions this is less so (4). Not all projectile determinations are entirely certain. The tip damage on one of the points can best be explained by impact, but it is not wholly convincing (P5773/S65, Figs. 20c & 30); the relatively thick and robust point may have reduced scarring. The hafting wear on the contrary is very explicit. The use-wear damage favours a use as thrusting spear instead of a thrown projectile. The point's morphology supports this interpretation given that robust tips increase the risk of a thrown projectile bouncing off on impact with the prey.

The analysed notched and denticulate pieces are comparable in function (i.e., percussion tool), but given that only four were analysed this remains a matter for further investigation.

Upper Palaeolithic tool types

The functional results for the Upper Palaeolithic tool types are summarised in figure 9. Few pieces were analysed. End scrapers proved to have been mainly used hafted in scraping or percussion activities. A haft limit was clearly marked by a scar and associated striation (Fig. 20c). A possible perforator was also found.

Microlithic tool types

A number of microlithic tools was analysed (cf. Fig. 11), but their use is generally uncertain. Three were identified as unused and for two pieces the interpretation was uncertain. Only two pieces were possibly used, one of which may have been hafted, and one may represent a possible hafted scraper.

Remaining pieces

Aside from standard tool types, a number of other (retouched) flakes, blades and fragments was selected and analysed (cf. Fig. 12). Tool uses are variable.
Use determination was impossible or uncertain for 26 pieces. There are two production failures, 19 unused pieces, seven possibly used specimens and two were used on a non-specified material. Perforators are quite frequent (7). Apart from that, there are three knives, three percussion tools, three projectiles, three hafted scrapers/*rabots* and nine hafted extremities (S3885/69, Fig. 31) or fragments.

Unretouched pieces proved to have been used particularly as knives or projectiles. This is not surprising as a cutting edge is very important for both functions and edges are preferentially left unretouched. One could compare this to Levallois points, which are regularly used as knives or projectile points (Shea 1988; Plisson & Beyries 1998; Shea et al. 1998). Among the unretouched pieces were found several hafted extremities. The morphology or function of the originally used portion is generally unknown, unless it can be determined on the basis of characteristic hafting wear traces and/or a characteristic fracture type, such as in high-impact motions like percussive tasks or use as a projectile (Rots 2002a).

Discussion

In the following discussion, results are summarised for all examined pieces and interpreted from a wider functional perspective, in particular relative to tool use and prehensile modes. The data on which this discussion relies can be found in figures 12, 13 and 14.

Tool use life & prehensile mode

As reproduced in figure 12, the individual tools were positioned in their life cycle based on the functional results. Some pieces proved to be discarded during the production stage, while others were discarded unused at the end of it. Although the latter items appear to represent finished products, no use-wear traces were observed. Several bifacial pieces were

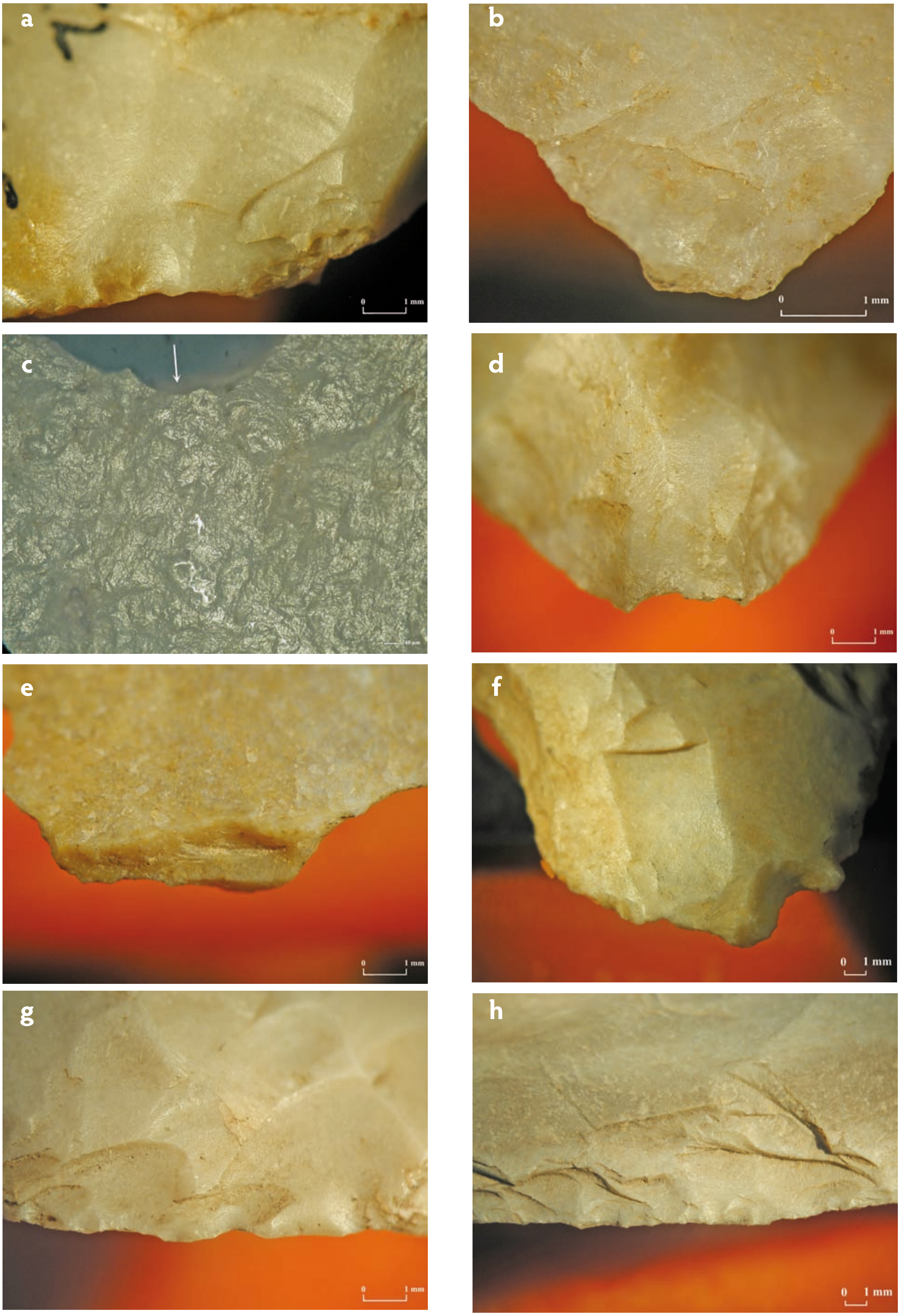
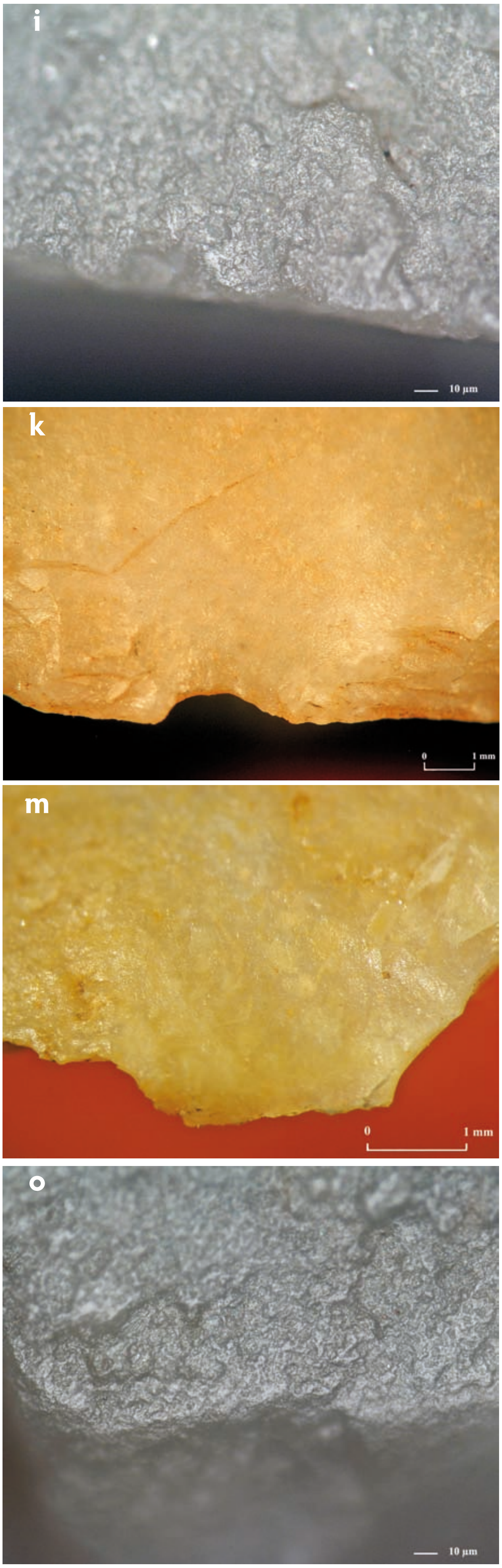
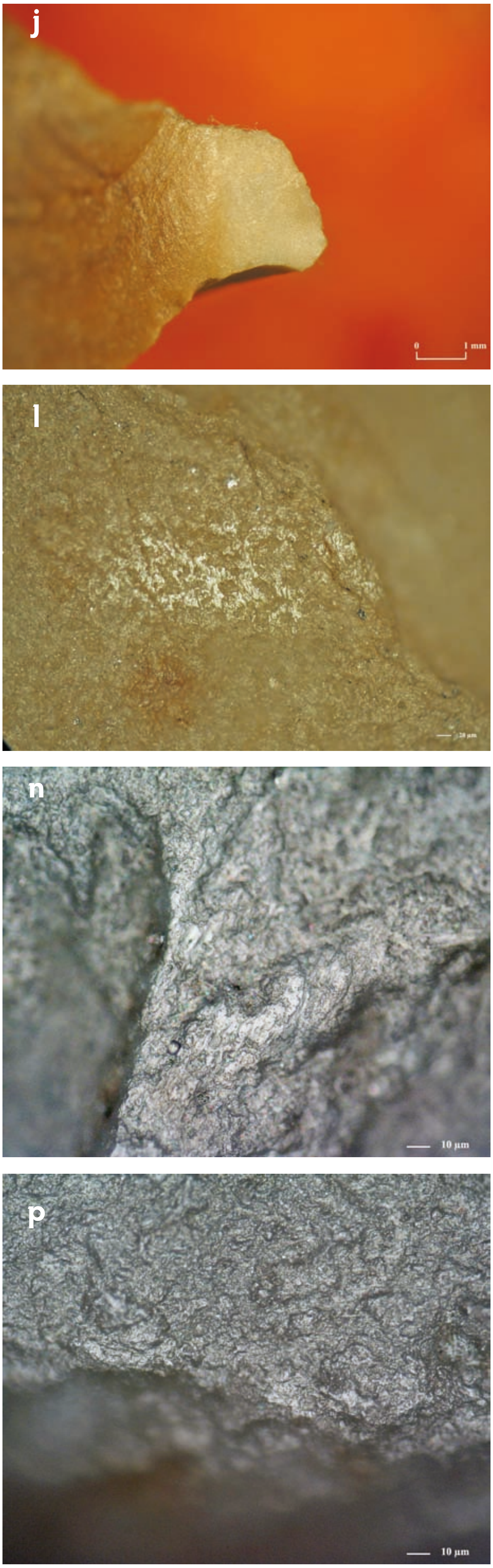


Fig. 20. (legend next pages - Abbildungslegende nächste Seiten)





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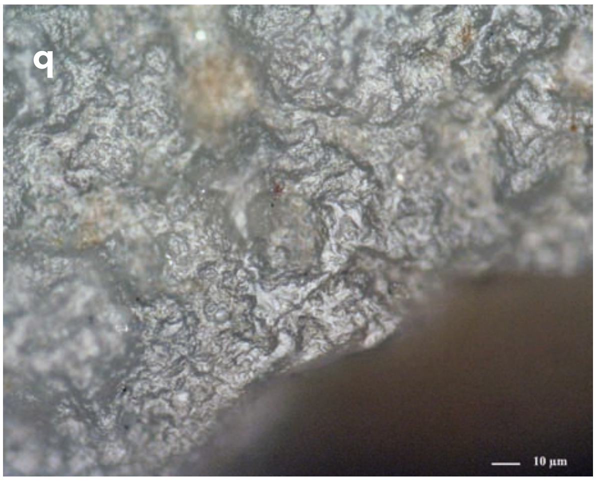

Fig. 20. Low and High Power microwear evidence (see different scales !!): a. Hafting damage on the ventral medial left edge of P5580/S65 (projectile) (12x); b. Possible impact damage on ventral tip of P5773/S65 (projectile) (25x); c. Hafting friction striation associated with negative of hafting scar around the haft limit on the ventral medial right edge of P5780/S65 (hafted scraper/chopper) (50x); d. Impact damage on dorsal tip of P5773/S65 (projectile) (12x); e. Possible impact fracture on S1321/68 (possible projectile) (12x); f. Impact damage on dorsal tip of S3947/69 (projectile) (6x); g. Use scarring on the dorsal left used edge of P4155 (axe/adze) (12x); h. Use scarring on the dorsal scraper-head of S1713/68 (probably wood chopping) (6x); i. Limited use polish on left distal extremity of P4155/S65 (axe/adze) (200x); j. Perforating use damage on distal tip of P5018/S65 (12x); k. Hafting scar from binding contact around the haft limit on the dorsal left medial edge of P5773/S65 (projectile) (12x); l. Hafting friction striation associated with hafting scarring around the haft limit on the ventral medial right edge of S3893/69 (knife) (100x); m. Hafting edge scarring on the ventral left haft limit of S1428/68 (scraper/rabot) (25x); n. Hafting edge scarring associated with a bright spot on the ventral medial left edge of S4595/70 (hide scraping) (200x); o. Hafting wood polish on the ventral medial ridge of P4155/S65 (axe/adze) (200x); p. Hafting wood polish on the ventral medial ridge of P4155/S65 (axe/adze) (200x); q. Hafting bright spot on the ventral right proximal edge of S1514/68 (associated with dorsal scarring) (hide scraping) (200x).

Abb. 20. *Mikroskopische Beispiele von Gebrauchsspuren in unterschiedlicher Auflösung (beachte unterschiedlicher Maßstab!!): a. ventral, mediale Schäftungsspuren an der linken Kante von P5580/S65 (Waffenspitze); b. Möglicher Auftreffschaden an der ventralen Spitze von P5773/S65 (Waffenspitze) (25-fach); c. Schäftungsrillen in Verbindung mit Schäftungsabsplitterungen an der Schäftungskante im ventral medialen Bereich der rechten Kante von P5780/S65 (geschäfteter Schaber) (50-fach); d. Auftreffschaden an dorsaler Spitze von P5773/S65 (Waffenspitze) (12-fach); e. Möglicher Auftreffschaden an S1321/68 (mögliche Waffenspitze) (12-fach); f. Auftreffschaden im Spitzenbereich dorsal bei S3947/69 (Waffenspitze) (6-fach); g. Gebrauchsspuren dorsal an der linken Arbeitskante von P4155 (Keil) (12-fach); h. Gebrauchsspuren dorsal auf Schaberkappe von S1713/68 (wahrscheinlich Holzbearbeitung) (6-fach); i. Partielle Gebrauchspolitur am linken, distalen Ende von P4155/S65 (Keil) (200-fach); j. Bohrspuren an distaler Spitze von P5018/S65 (12-fach); k. Schäftungsspuren durch Bindung im Bereich der Schaftgrenze dorsal, medial an linker Kante von P5773/S65 (Waffenspitze) (12-fach); l. Schäftungsrillen in Verbindung mit Schäftungsabsplitterungen an der Schaftgrenze ventral, medial an der rechten Kante von S3893/69 (Messer) (100-fach); m. Absplitterungen ventral an der linken Seite der Schaftgrenze von S1428/68 (Schaber) (25-fach); n. Aussplitterungen der Schäftungskante in Verbindung mit glänzendem Fleck ventral, medial an der linken Kante von S4595/70 (Lederbearbeitung) (200-fach); o. Schäftungspolitur durch Holzbearbeitung ventral medial bei P4155/S65 (Keil) (200-fach); p. Schäftungspolitur durch Holzbearbeitung ventral medial bei P4155/S65 (Keil) (200-fach); q. Schäftungsglanz ventral, proximal an rechter Kante von S1514/68 (in Verbindung mit dorsalen Absplitterungen) (Lederbearbeitung) (200-fach).*

discarded in this life cycle stage, no doubt as a result of the many possible problems encountered during their manufacture (in comparison to flaked implements). Other pieces were discarded during or at the end of their use cycle. On some, only non-diagnostic use-wear traces were observed, while for others a particular use could be identified. Several pieces proved to be exhausted, either due to the proximity of the used edge to the haft limit (minimum 7, e.g. P3049/S65, Fig. 28), a fracture (minimum 31; e.g. P4340/S65, Fig. 32), or an unsuccessful resharpening session (minimum 4, e.g. S1322/68, Fig. 24). Many of the hafted scrapers/*rabots* especially proved to have been used until exhaustion. The hafted extremities are also remains of exhausted products that fractured during use. The original use of the once-complete tools could not be determined, but the presence of hafting wear indicates that they were definitely used at one point on the evidence of experimental data (Rots 2002a). It is also worth noting that several used pieces also show evidence of production problems. However, the problems were overcome sufficiently to allow both use and hafting (e.g. P4155/S65, Fig. 25). This kind of observation was mainly made on hafted tools since hafting makes more demands on the morphological appearance of a piece (e.g. thickness, width) than prehension (Rots 2005).

Interestingly, there is a clear predominance of hafted tools in the assemblage. Partially, this is because hafting results in more explicit wear than prehension, making it easier to distinguish hafted tools. It is therefore likely that tools for which no prehensile mode could be identified (cf. Fig. 15) were used in the hand. If this should prove to be true, the predominance of hafted tools would be less clear. One also needs to note that hafted tools are likely to have been more intensively worked (e.g. to adapt them morphologically to fit a certain haft) making them more recognisable in an assemblage than hand-held tools. On the other hand, many unretouched pieces may have been used in the hand (e.g. for short tasks) and a large part of the hand-held tool set may thus be

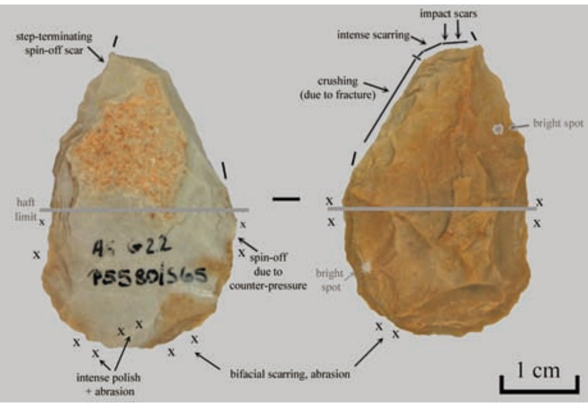

Fig. 21. Possible projectile (P5580/S65) (bifacial point).

Abb. 21. Mögliche Waffenspitze (P5580/S65) (bifazielle Spitze).

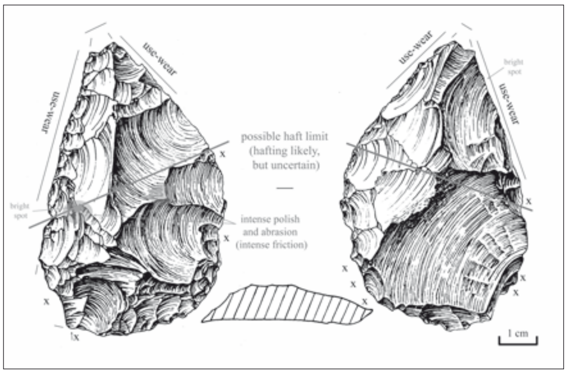

Fig. 23. Knife (P2964/S65) (bifacially worked convex side scraper on flake).

Abb. 23. Messer (P2964/S65) (bifazieller konvexer Schaber an Abschlag).

difficult to recognise in an assemblage. Nevertheless, when only tools (in a typological sense) are taken into account, hafting remains predominant and hafting was clearly a systematic practice at Sesselfelsgrotte, in sharp contrast with an expected absence of stone tool hafting among Neanderthals (e.g. Bisson 2001).

A closer look at the hafted tools shows that a large part represents items for which hafting is a necessity, such as projectiles and percussion tools. For the remaining pieces, no particular prehensile mode is vital for their use and the choice of a particular prehensile mode is guided by other factors. When attempting to discover potential factors influencing the choice for a particular prehensile mode, it is important to note that the majority of knives were used in the hand. Apparently, a haft was not considered to form a true advantage for their use. This contrasts with projectiles and percussion tools, which were – necessarily – systematically used while hafted. Scraping tools were also preferentially used in a haft, possibly as a way to increase the exerted pressure, while no clear patterns emerge for other tool uses, such as perforators. For many perforators, no prehensile mode could be determined, but given the absence of use-wear evidence for the use of a mechanical drill, hafting was definitely not necessary for their use. Perhaps the exact tool function or use context determined whether they were hafted or not, but this issue is difficult to evaluate based on this analysis alone. One can imagine that hand-held tool use may have taken place in a more incidental context with tools fabricated on the spot (or taken from a prepared stock), while hafted tools demand planning and may have been used for more systematic and frequently recurring tasks. Hafted tools were therefore more likely curated. On the other hand, one must also pay attention to other factors such as the speed with which tools become exhausted and the hafting arrangement itself. The exhaustion rate obviously differs according to the performed task; knives blunt easily and, given that retouched edges are not ideal for cutting tasks, resharpening is not always possible or attempted and the pieces may be quickly discarded. This could explain the dominance of hand-held knives over hafted ones. The chosen hafting

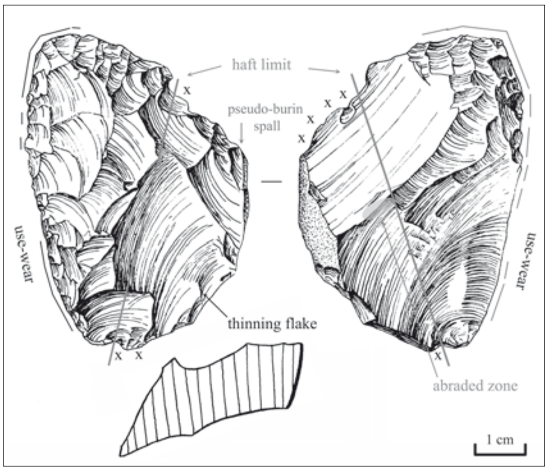

Fig. 22. Hafted knife (S4594/70) (leaf form side scraper on flake with cortical back, ventral only partial retouch, cf. Richter 1997).

Abb. 22. Geschäftetes Messer (S4594/70) (blattspitzenartiger Schaber an Abschlag mit Kortexrücken; ventral mit partieller Retusche, cf. Richter 1997).

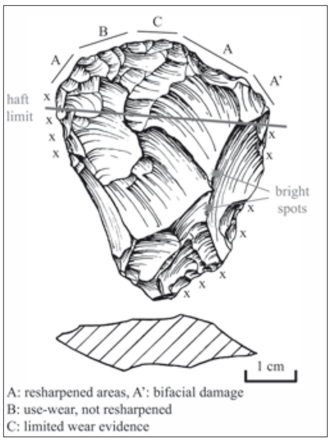

Fig. 24. Hafted scraper (S1322/68) (strongly convex transverse scraper on core edge flake, cf. Richter 1997).

Abb. 24. Geschäfteter Schaber (S1322/68) (stark konvexer Breitschaber an Kernkantenabschlag, cf. Richter 1997).

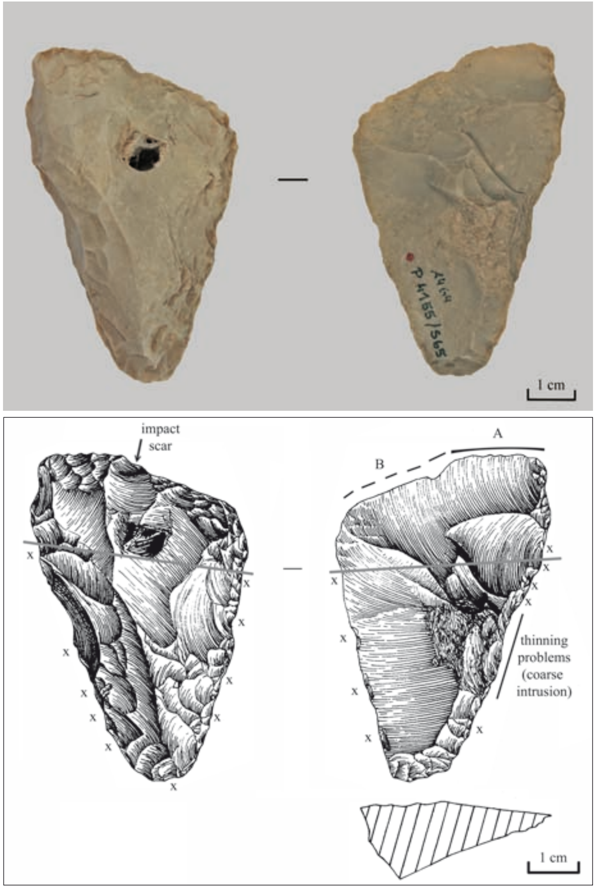

Fig. 25. Hafted axe/adze (cf. tranchet) (P4155/S65) (triangular, leaf-point-like scraper, one edge with La Quina- like steep retouch, cf. Richter 1997).

Abb. 25. *Geschäfteter Keil (cf. tranchet) (P4155/S65) (dreieckiger blattspitzenartiger Schaber an Kante mit Quina-artiger Steilretusche cf. Richter 1997).*

arrangement – which is also guided by the performed task – determines the ease of retooling. A hafting arrangement involving resin makes retooling more complicated in terms of location and duration (e.g. a hearth is necessary) than when a piece is fixed with bindings. In the latter arrangement, stone tools can be

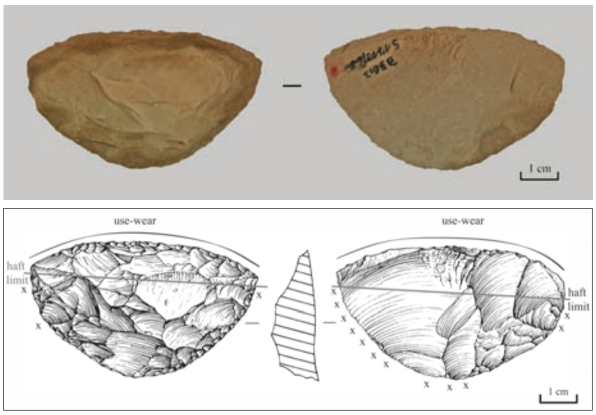

Fig. 26. Hafted adze (S1713/68) (leaf form transverse scraper on flake, ventral only partially retouched, cf. Richter 1997).

Abb. 26. *Geschäfteter Keil (S1713/68) (blattförmiger Transversalschaber an Abschlag, ventral partiell retuschiert, cf. Richter 1997).*

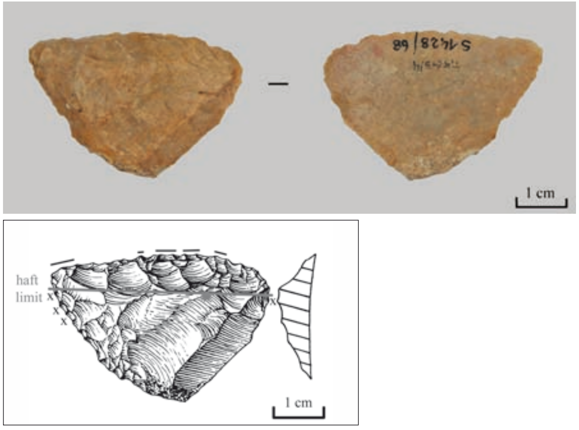

Fig. 27. Hafted scraper/rabot (S1428/68) (asymmetrical point on flake with some lateral cortex remains, cf. Richter 1997).

Abb. 27. *Geschäfteter Schaber (S1428/68) (asymmetrische Spitze an Abschlag mit lateraler Kortex, cf. Richter 1997).*

easily and quickly replaced, in any location, if a suitable stockpile is prepared in advance. The presence of unused, but finished items could suggest the existence of stockpiles, but these pieces remain a minority in the examined assemblage and do not include pieces with important morphological adjustments such as the hand axe, *Keilmesser* or *Halbkeil* (cf. Figs. 8 - 12). Consequently, there are no reliable indications at this moment and it in fact requires the analysis of the entire tool assemblage.

Fragments were identified both for the projectiles and the percussion tools (cf. Fig. 13). These fragments are a result of fracture during use. Given the significant impact to which these pieces were submitted, the fractured remains often show appreciable diagnostic wear, allowing a determination of their original function.

In addition, hafted fragments were identified for which the original tool use could not be determined

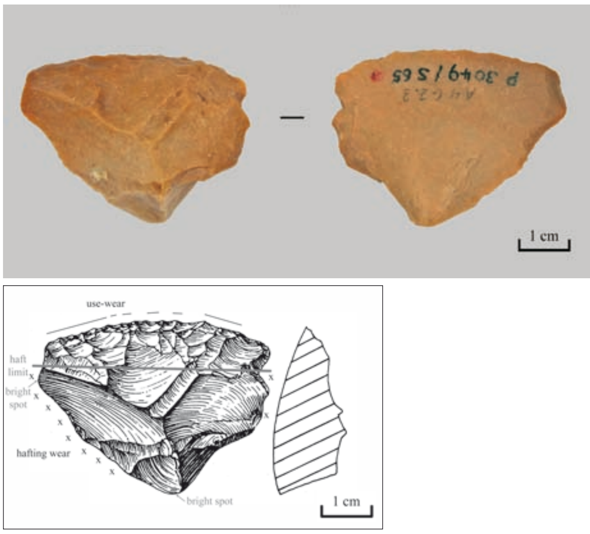

Fig. 28. Hafted scraper/rabot (P3049/S65) (transverse scraper on thick flake with Quina retouch, cf. Richter 1997).

Abb. 28. *Geschäfteter Schaber (P3049/S65) (transversaler Schaber an dickem Abschlag mit Quina-Retusche, cf. Richter 1997).*

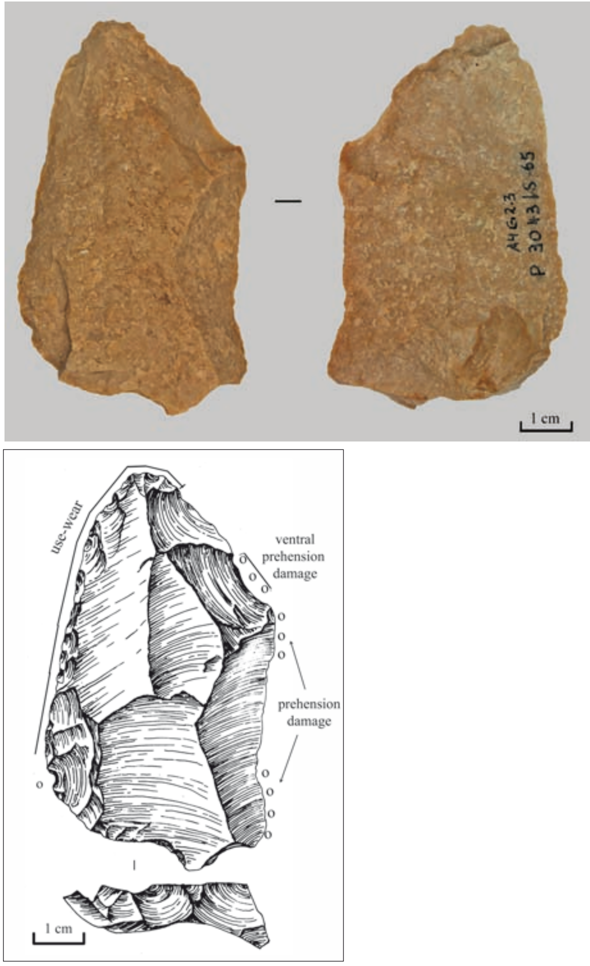

Fig. 29. Hand- held knife (P3043/S65) (convex side scraper on Levallois flake with core-edge remains, cf. Richter 1997).

Abb. 29. *Messer ohne Schäftung (P3043/S65) (konvexer Schaber an Levallois-Abschlag mit Kernkantenresten, cf. Richter 1997).*

with certainty. They definitely fractured during use, but given the absence of an important loaded impact, the wear traces on the fragments are less diagnostic and more difficult to attribute to a particular type of use. This group of pieces may also include some less diagnostic remains from projectiles or percussion tools. Generally speaking, fractures occur more frequently on hafted tools than on hand-held tools due to the differences in pressure exerted during use (Rots 2002a). Within the group of hafted tools, fracture frequency increases with the pressure exerted; the higher the impact or exerted pressure (e.g. percussion, projectiles), the higher the risk of fracturing. Also tool motion has an influence and hafted scraping tools will fracture more easily than hafted knives. In the former case, the haft works as a kind of lever, which increases the risk of transversal fractures of the stone tool around the haft limit. Stress is also put on the stone tool close to the haft limit during perforating motions. During cutting, on the contrary, the exerted pressure is parallel to the tool's edge and little stress is put on the stone tool itself. Pressure is in fact restricted to the bond between the stone tool and the hafting arrangement and the risk of

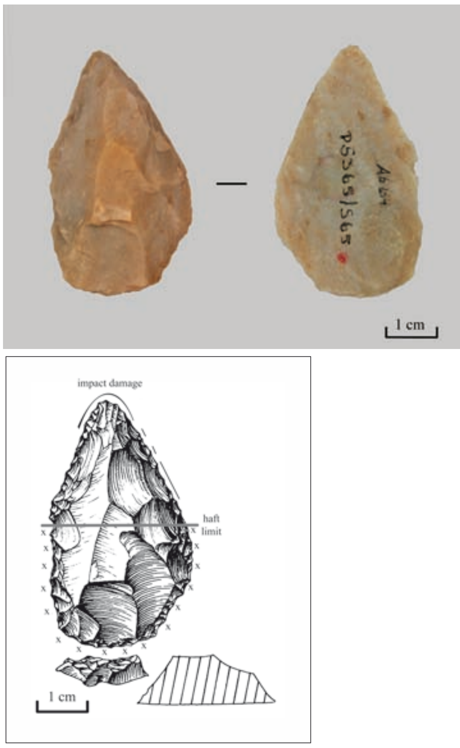

Fig. 30. Possible thrusting spear point (P5773/S65) (slightly asymmetrical point with dorsally thinned back on Levallois flake, cf. Richter 1997).

Abb. 30. *Mögliche Spitze eines Wurfspeeres (P5773/S65) (leicht asymmetrische Spitze mit dorsal ausgedünntem Rücken an Levallois-Abschlag, cf. Richter 1997).*

pieces falling out of their haft is therefore greater than that of their fracturing (Rots 2002a).

Up to now, limited evidence has been available for hafting in the Middle Palaeolithic, although a few early studies provided suggestive examples (e.g. Anderson-Gerfaud & Helmer 1987; Beyries 1987a; 1987b). The hafting (and use) of Levallois points has been a sensitive issue (Shea 1988; Plisson & Beyries 1998; Shea et al. 1998), in which the find of a Levallois point imbedded in the vertebra of a wild ass contributed significant evidence (Boëda et al. 1996; 1999). Further hafting evidence was observed on a variety of Middle

Fig. 31. Hafted extremity (S3885/69) (retouched proximal blade fragment).

Abb. 31. *Geschäftetes Ende (S3885/69) (retuschiertes, proximales Klingenfragment).*

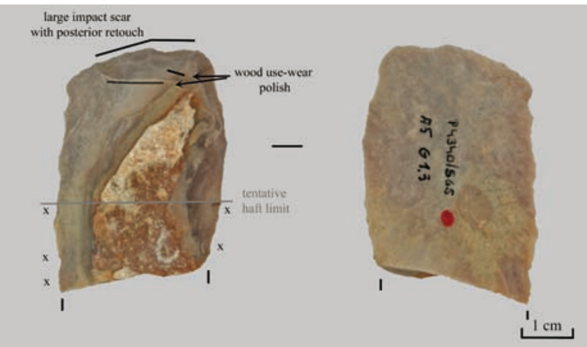

Fig. 32. Hafted wood adze, fractured (P4340/S65) (end scraper on fractured blade).

Abb. 32. *Geschäfteter Keil für Holzbearbeitung, gebrochen (P4340/S65) (Kratzer an Klingenfragment).*

Palaeolithic tools from Starosele and Buran Kaya III in the Crimea (Hardy 1999; Hardy & Kay 1999; Hardy et al. 2001), while hafting appears to have been absent at the French site La Quina (Hardy 2004). Interestingly, the evidence at Starosele includes scrapers and points, while the evidence of Buran Kaya III includes foliate points, a scraper, a scaled piece and a trapezoidal microlith (Hardy et al. 2001). This means that hafting was also practised for tools for which hafting was not dictated by the tool's use, similar to the situation observed for Sesselfelsgrotte.

Worked material & action

The identifications of the materials worked vary in accuracy due to the preservation of the artefact material and the analytical procedure (cf. Fig. 14). Generally speaking, only the relative hardness of the worked material can be determined on the basis of low power analysis. Only in some conditions can more specific worked materials be suggested. For pieces that were also analysed under high power and that were sufficiently well preserved, more detailed determinations of the worked material are possible. This explains the presence of relative and more exact worked material determinations in Figures 13 and 33. It is likely – although not certain – that at least part of the identified medium-hard contact materials are in fact wood, while at least part of the hard contact materials correspond to bone/antler. Therefore, the percentages for woodworking and animal processing in figure 33 are minimal values.

For interpretations concerning the performed motion, the analytical approach and preservation condition are less of an issue since many reliable interpretations are already possible at a low power level. After all, interpretation of the performed action is mainly based on the distribution of macro- and microscopic traces over the tool's edges, aspects that are clearly visible under lower magnifications.

Concerning the percussion tools (including axing, adzing and light chopping), the main worked material appears to be wood (Fig. 20g - i), even though not all determinations were made with certainty. On the whole, the angles of the used edges in question are suggestive of woodworking (woodworking tools ideally have edge angles between 35-45°: Caspar et al. 1998).

For projectiles, the worked material is evident, given that it is determined by impact in the prey (Fig. 20b, d - f). Interestingly, both thrusting points and projected points were observed, showing the existence of both thrusting and throwing spears. However, it must be added that it cannot be entirely excluded that the more general projectile point category contains one or two additional (because non-diagnostic) thrusting spear points. For base fragments, no specific hunting technique can be identified. Whether the throwing spear was hand-thrown or projected with a spear thrower cannot be determined on our current knowledge regarding impact wear and the available experimental datasets, but given the absence of evidence for the existence of spear throwers around this time period contrasted with its frequent occurrence in later periods, the spear was presumably hand-thrown. The combination of different hunting tools should not be surprising. A thrusting spear is often used to finish off prey (Frison 1978; 1989; Hughes 1998; Rots & Van Peer submitted), which is the kind of use that is supported by the microscopic wear evidence on the Sesselfelsgrotte thrusting spear points. There is evidence to support the existence of a close-range hunting technique among Neanderthals (Wynn & Coolidge 2004), even though Berger and Trinkaus (1995) define this as being performed with thrusting spears only. I believe that hand-thrown spears can also be classified among close-range hunting weapons since the average distance a spear can be thrown effectively by hand (in contrast to using a spear thrower) is relatively limited (about 10m: Hughes 1998), depending on its weight. Given that the weight of Neanderthal spears was probably significant, to judge by finds of wooden spears at Lehringen (Thieme & Veil 1985) and Schöningen (Thieme 1997), even though these are older than Sesselfelsgrotte, their effective distance may be well below 10m, meaning that they were in fact thrown at very close range. Besides, one can also question whether both techniques are truly different or whether the same hunting weapon may not have been used both for thrusting and for close-range throwing. A more flexible use of such spears should thus not be excluded, despite theoretical differences in weight and balance between the two kinds of spear and the evidence for morphological differences between thrusting and throwing spear points observed for MSA sites in Northeast Africa (Rots & Van Peer submitted) and, to a more limited degree, at Sesselfelsgrotte. Thrusting points are on average sturdier, slightly heavier and less intensively worked than thrown projectile points, resulting in an increased weight at the tip of thrusting spears. The more limited morphological differences between both sets of points at Sesselfelsgrotte by comparison with the MSA of Northeast Africa may in fact reflect the more interchangeable nature of both types of spears at Sesselfelsgrotte. The identification of throwing spears does not necessarily contradict the observations of Schmitt et al. (2003), since both hunting techniques – especially when used interchangeably – can be expected to have a similar effect on the human body and lead to potential asymmetries in the strength of the upper limbs.

For scraping tools, worked materials are far more variable and were not always easy to determine with certainty; wood and hide seem to be the recurring materials. Woodworking seems to be linked with whittling tools potentially used for de-cortication and straightening and shaping tasks etc. Interestingly, these tools ("scrapers/*rabots*") reveal a high morphological similarity, independent of their typological attribution, being generally triangular-shaped with tool use on the longest working edge (scraper edge) (e.g. Figs. 27 & 28). They seem to represent a quite specific or even specialised tool category. Typologically, these scrapers/*rabots* include side scrapers together with flakes, points, transverse scrapers and several bifacial implements. The amount of retouch needed to arrive at the given morphology thus differs significantly between them. Some pieces did not require retouch at all, which may suggest some – albeit limited – anticipation of the triangular morphology during blank production. Apart from the resemblance in general shape, all these pieces also share a similar working edge (i.e. shape and angle) that was intentionally arrived at through initial shaping or maintained through resharpening (many of these pieces are exhausted, cf. *supra*). Consequently, the morphology of these scrapers/*rabots* seems determined not only by the intended tool use (Dibble 1995; Bisson 2001), but also by the intent to haft the tool (Marks et al. 2001; Monnier 2006; 2007).

More standard scraping tools were used on a variety of worked materials of differing hardness, including hide (soft material). Possible medium-hard materials include wood (softwood and hardwood), but also soaked bone or antler. Perforating tools were generally used on hard materials (e.g. bone, antler, stone).

Knives were frequently used for butchering, but in many cases the exact worked material is difficult to infer. This is due to a combined range of factors; for instance meat cutting leaves little detectable wear when tool use times are relatively short. Meat polish forms slowly and scarring is generally limited if there is no bone contact. Determinations are further hampered by conditions of preservation and/or the analytical procedure (i.e. a low power analysis only). In the latter case, however, scarring remains observable. This implies that many of the knives for which no worked material was determined were potentially used for butchering or at least for cutting relatively soft materials. After all, the scarring intensity on butchering knives varies depending on the actual use the tool is set to, from penetrating the animal and cutting hide or meat without bone contact, to defleshing and on to disarticulating bones. While some tools may have been used throughout the butchering process, others may have been used only for particular stages. All this has consequences for the observed wear pattern and the ease and certainty with which a knife can be attributed to butchering (given the applied analytical procedure and preservation conditions). Further experimental work might highlight diagnostic criteria that allow further distinctions between these tools.

It is interesting to note that most subsistence-related activities seem to be related to the processing of animal resources (mainly hunting and butchering; a minimum of 41% of identified tool uses, cf. Fig. 33), while plant materials mainly seem to have been worked from a tool manufacturing perspective (e.g. production of wooden implements and hafts, with a minimum of 34% of identified tool uses, cf. Fig. 33). At first sight, this seems to contrast with the observations on the material from Starosele by Hardy and Kay, who observed more use evidence from plant materials than from working animal material (Hardy 1999; Hardy & Kay 1999; Hardy et al. 2001). However, upon closer examination, they do not offer much convincing evidence for the existence of elaborate plant working in the context of food procurement or processing. Most activities could equally well relate to the working of plant materials with a view to manufacturing tasks such as tool or binding manufacture. The same allies to the evidence from La Quina (France), where woodworking proved to be very important (Hardy 2004), Amud Cave (Israel; Madella et al. 2002) and many other Neanderthal sites (e.g. Beyries 1987a; Anderson-Gerfaud 1990; Hardy et al. 2001), including Sesselfelsgrotte. On the other hand, the functional results presented here indicate a strong reliance by Neanderthals on animal foods, as has been suggested by stable carbon and nitrogen analyses on Neanderthal bones (Bocherens et al. 1999; 2001; Richards et al. 2000). Nevertheless, it should be clear that plant-processing tasks in the context of food procurement can easily be performed without any implements or with non-stone (organic) implements, the existence of which is certainly due to the ample indications from Sesselfelsgrotte for plant processing related to manufacturing tasks.

Animal material was also processed from a manufacturing perspective, as attested by some evidence for hide scraping, bone/antler scraping and bone/antler perforating (Fig. 20j). These activities appear to have been more incidental and few of the tools show hafting evidence. There is no evidence of systematic or specialised hide or bone/antler working, in contrast with the dominance and relatively

Functional Interpretation	Used tools						Unknown/ unused		Total
	Wood	Animal matter	Soft/Medium hard	Medium hard	Medium hard/ Hard	Hard	Unknown	None	
All tools	32	38	2	4	7	10	143	56	**292**
% (of total analysed tools)	*11,0*	*13,0*	*0,7*	*1,4*	*2,4*	*3,4*	*49,0*	*19,2*	***100,0***
Used tools	32	38	2	4	7	10	-	-	**93**
% (of used tools with identified worked material)	*34,4*	*40,9*	*2,2*	*4,3*	*7,5*	*10,8*	-	-	***100,0***

Fig. 33. Percentages of worked materials compared to the total analysed assemblage and to the used tools with known relative or absolute worked material.

Abb. 33. *Anteile der bearbeiteten Materialien im Vergleich zur Gesamtheit des analysierten Materials und der gebrauchten Werkzeuge mit bekanntem gebrauchten Material.*

specialised nature of the wood-working tools. This demonstrates that hunting activities were above all aimed at food procurement. The 28 identified hunting tools reflect the existence of a variety of hunting techniques (i.e. thrusting and throwing spears) and, together with the high percentage of animal processing tools at Sesselfelsgrotte (providing a minimum of 41% of the number of used tools with identified contact materials, cf. Fig. 33), they confirm the evidence for routine hunting activities among Neanderthals at Salzgitter-Lebenstedt in Northern Germany (Gaudzinski & Roebroeks 2000) and other Neanderthal sites (Gaudzinski 1996).

Prehensile mode per occupation cycle

When the inferred prehensile mode is compared relative to the different occupation cycles defined by Richter (1997) at the Sesselfelsgrotte, few differences can be observed (Fig. 15). However, this must be viewed cautiously, given the non-random selection of the analysed pieces and the important differences in the number of analysed pieces between the different units. These things considered, most counts of identified hafted versus hand-held tools are comparable, in particular for the most intensively studied cycles 2 and 3. If the pieces for which no prehensile mode could be determined are taken into account and are considered as hand-held tools (which is possible, cf. *supra*, but entirely uncertain), the percentages of hand-held versus hafted tools become somewhat more balanced, in particular for cycle 3. Cycle 1 and 4 are exceptions, but this is because possibly only one tool was categorised among the non-determined ones. The percentages for cycle 4 (the youngest cycle) show the greatest difference: there appear to be more hafted tools in comparison with hand-held tools than observed in the other cycles, but obviously the analysed tool numbers are small. Aside from that, this is also a factor of the type of tools examined (cf. Fig. 6).

If one is to attach more meaning to these figures and examine potential chronological implications, a more or less equal number of tools should first be analysed for all cycles. In the case of the most intensively studied cycles 2 (Old Micoquian) and 3 (Young Micoquian), no fundamental differences in hafting intensity can be observed between them.

Another issue to be examined in this regard concerns J. Richter's ideas concerning "expert knowledge" as illustrated at Sesselfelsgrotte. According to Richter, the assemblages can be divided into primary *"Initialinventare"* and subsequent *"Konsekutivinventare"* based on their raw material use patterns (Richter 1997). The first set is characterised by the large variety of raw materials used, while the latter is characterized by the use of a more restricted number of high quality raw material sources. Richter attributes this to an increasing familiarity ("expert knowledge") of Neanderthals with the area and contained raw material sources following a more prolonged presence. Whether a similar pattern would emerge from the functional data is a very interesting question for which, unfortunately, the necessary data are lacking. The functional analysis was focused on the more complete assemblages associated with living floors, while the smaller *"Initialinventare"* have not yet been examined. This is, of course, a very attractive topic for further, more detailed examination and future functional analysis will need also to focus on the *"Initialinventare"*.

Attested hafting arrangements

In general terms, many of the pieces show distinct evidence for the use of bindings, independent of the exact tool use. Bindings leave quite distinct scarring evidence, especially around the haft limit (e.g. Fig. 20k) (Rots 2002a; 2003; 2004) where a lot of pressure is concentrated. For this reason, the haft limit area generally shows explicit wear evidence (Fig. 20c & 20l - o). Details concerning the hafting arrangement used were proposed for 35 pieces, for example five axes/adzes, two scrapers/choppers, four scrapers/*rabots*, nine projectiles, a knife and a perforator. Given that tool use is a determining factor influencing the choice of a particular hafting arrangement, pieces are grouped accordingly. Depending on the tool's motion or the pressure exerted during use, a hafting arrangement will need to have particular characteristics. A few examples of relevant experimental hafting arrangements are included for comparison (Fig. 34).

Hafted axes seem to have been mainly hafted in male arrangements (i.e. the stone tool is pressed into a hole in the haft; axial tool direction), most probably in a straight wooden haft (Fig. 20p). There are no indications for the use of bindings. In the case of one axe, only the central zone was in contact with the haft, in other words both extremities protruded from the haft. The latter observation supports the use of straight hafts instead of bent/latero-distal ones. The hafted adzes tend to be hafted in male split arrangements, in which the stone tool is inserted in a cleft and fixed with bindings. Whether the hafts in question are straight or latero-distal cannot be determined with certainty, but on the basis of morphological issues the latter option is favoured.

Hafted scraper/choppers were set in a male terminal arrangement, i.e. fixed in a hole in the extremity of a straight – probably wooden – haft (Fig. 20q). The hafted end scraper used for scraping/chopping seems to have been hafted on a juxtaposed – probably wooden – haft (ventral haft contact) on which it was fixed with bindings (perhaps vegetal ones).

All hafted scrapers/*rabots* show contact with a hard hafting material; in one case this material could be identified as wood. Three pieces demonstrate at least some contact with bindings. The most reliable indications are observed around the haft limit, which is logical given that the corresponding tool width is generally more important and the edges may have protruded from the haft. As experimentally demonstrated, this significantly increases the formation of binding-related scarring (Rots 2002a; 2004). The best supported hafting arrangement is a straight, male split handle – probably out of wood – in which the stone tool is fixed with bindings. This tool is similar in idea to the Australian "tula chisel", which is also used for woodworking tasks (for instance) but attached to the handle with resin. The "worn-out" "tula chisel" is referred to as a "tula slug" and is morphologically quite similar to the scrapers/*rabots* in question here (McCarthy 1976). An alternative hafting arrangement that is partially supported by the evidence is a lateral hafting arrangement in which the scraper is mounted in the centre of a wooden straight or slightly curved split haft. Such a tool is used with one hand on each of the extremities and generally in a pushing motion away from the user, in a way comparable to ethnographically known scraper planes for wood working or hide working (Beyries 2002; Skakun 2008).

The projectiles show indications of the use of bindings for fixation next to a contact with a hard haft material. On the evidence of two pieces, the haft was probably of the male split type and most likely manufactured out of wood. Only on one piece was a residue observed that might indicate the use of some adhesive, but this is still highly speculative and a matter for further investigation. Given the post-excavation procedures used for cleaning (including the use of acids), the survival of any residue is unlikely. The observation that bindings were used for fixing the projectiles does, however, not imply that no adhesive was used as both can easily be used in combination, as is attested archaeologically (Mallet 1992). Such a procedure was also tested experimentally and has several advantages, such as securing the bindings and protecting against moisture that could potentially loosen them (Rots 2002a).

One knife was obliquely hafted with bindings, while a perforator shows evidence of a contact with a hard haft material. The size of another perforator suggests the use of some adhesive, but this was not confirmed microscopically. Again, this is not evidence of absence, given the aforementioned destructive cleaning procedures in use at the excavation. Finally, several pieces for which no particular use could be proposed show evidence of the use of bindings and contact with a hard haft material.

To conclude, three kinds of male hafting arrangements were observed (Fig. 34): male split terminal hafting in a straight haft (scrapers, scrapers/*rabots*, projectiles), a male split hafting in a bent or latero-distal haft (adzes) and a lateral male hafting in a straight handle (axes). Even if identical hafting arrangements may have been used for very different tool functions, it is clear that the handle morphologies (length, thickness) may differ significantly (i.e., scrapers versus projectiles). Only one juxtaposed arrangement was observed (end scraper), but it has to be stressed that the distinction between a male split and a juxtaposed arrangement is not always easy to make given that the only difference rests in the contact of one face with either a hard (haft – male split) or soft material (bindings – juxtaposed) (Rots 2002a; Rots et al. 2006). The contact of the other face is identical (haft in both cases) as well as the impact on the tool's edges. The latter is mainly determined by the haft width in comparison to the stone tool width. Finally, some adhesives may have been used, but this remains speculative for now.

All attested hafting arrangements are quite straightforward from the perspective of retooling. No or hardly any adhesive is involved, meaning that hafting can take place anywhere and anytime. A hafting arrangement with bindings is quickly loosened for retooling purposes and a stone tool that falls out of its haft during use can quickly be remounted. All evidence thus points to the use of flexible hafting procedures. The haft itself is also not the most complicated type to produce since many wood species can be split to form a suitable haft. Only for percussion activities is it necessary to use a wood species that shows good resistance to shocks (e.g. ash).

Fig. 34. Experimental reconstruction of inferred hafting arrangements: (far left) lateral hafting in make arrangement with resin; (left) male split terminal hafting in straight wooden haft, fixation with leather bindings; (centre) male lateral hafting in straight wooden haft, perpendicular tool direction and orientation of active part (as adze), fixation by pressure, supported with bindings; (right) male split terminal hafting, perpendicular tool direction and axial orientation of active part (as axe), fixation with leather bindings; (far right) male split latero-distal hafting, fixation with leather bindings.

Abb. 34. *Experimentelle Rekonstruktion der angenommen Schäftungsarten: (links außen) laterale Schäftung mit Resin; (links) terminale Klemmschäftung in geradem Holzschaft; Fixierung durch Lederbindungen; (Mitte) laterale Klemmschäftung in geradem Holzschaft, rechtwinklig zur Arbeitskante (als Keil/Querbeil), Fixierung durch Druck mit Unterstützung von Bindungen; (rechts) terminale Klemmschäftung, rechtwinklig zur Arbeitskante (als Keil/Querbeil), (rechts außen) latero-terminale Klemmschäftung, Fixierung durch Lederbindungen.*

Spatial data

In order to examine whether the analysed tools show any meaningful spatial patterning the results were plotted onto the excavation grid (Figs. 35 - 37). The available spatial data is limited and is restricted to the square and layer number in which the artefact was found (Richter 1997). Any spatially meaningful patterning will therefore necessarily be relatively coarse. In addition, the archaeological units, defined by Richter as reflecting potential living horizons (Richter 1997: 62), are not spread evenly over the excavated area (about 50 m^2) and some of these units only encompass a part of the excavated area (more details in Richter 1997). This may hamper a broader view on spatial patterning. Results are therefore provisional.

Only three archaeological units will be discussed here, given that the examined tool sample needs to be sufficiently large in order to investigate meaningful patterning. A06 and A08 obviously represent the largest tool sample, but also A02 is included. For each unit, the excavated area is indicated by the figures (Figs. 35-37).

A02

Artefacts were excavated in squares A1 and Z1-5 (Richter 1997). It is not clear why two pieces lie outside the excavated area. Based on details provided by Richter, one piece may belong to archaeological unit A01 (cf. Richter 1997: Abb. 57). Excavation of

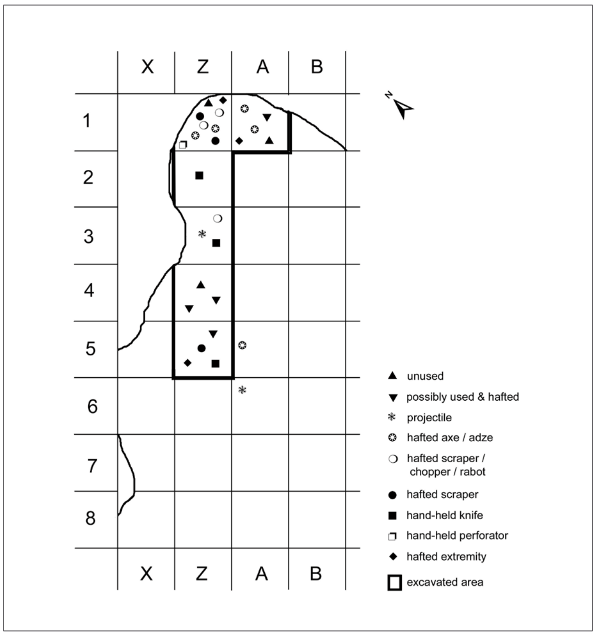

Fig. 35. Spatial distribution of tools from archaeological unit A02 incorporating results of the functional analysis (absolute 3D-coordinates were not available for the implements, which are therefore randomly positioned within the squares).

Abb. 35. *Räumliche Verteilung der Werkzeuge aus der archäologischen Einheit A02 unter Berücksichtigung der Ergebnisse der Funktionsanalyse (dreidimensionale Lagedaten waren nicht verfügbar; Werkzeuge wurden daher zufällig in den Quadraten positioniert).*

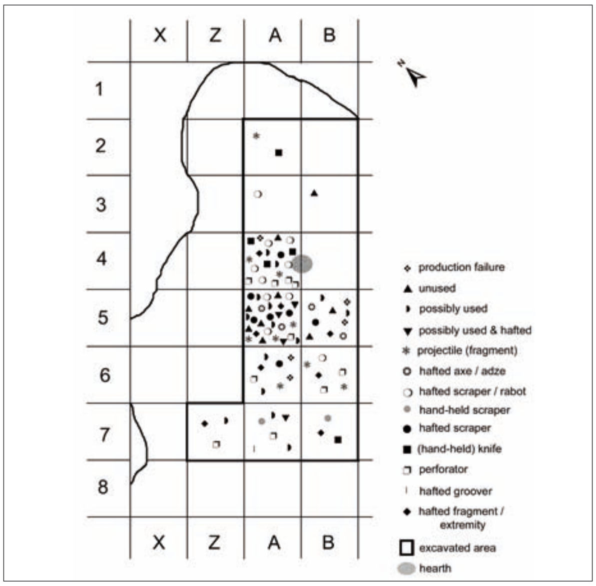

Fig. 36. Spatial distribution of tools from archaeological unit A06 incorporating results of the functional analysis (absolute 3D-coordinates were not available for the implements, which are therefore randomly positioned within the squares).

Abb. 36. Räumliche Verteilung der Werkzeuge aus der archäologischen Einheit A06 unter Berücksichtigung der Ergebnisse der Funktionsanalyse (dreidimensionale Lagedaten waren nicht verfügbar; Werkzeuge wurden daher zufällig in den Quadraten positioniert).

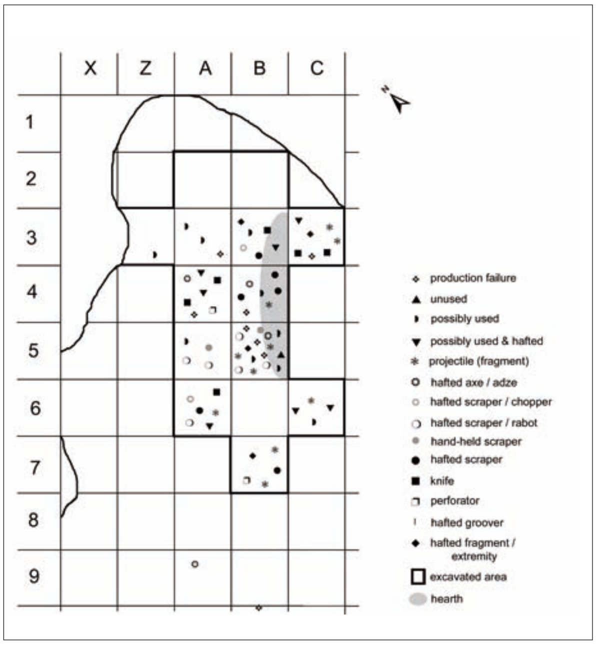

Fig. 37. Spatial distribution of tools from archaeological unit A08 incorporating results of the functional analysis (absolute 3D-coordinates were not available for the implements, which are therefore randomly positioned within the squares).

Abb. 37. *Räumliche Verteilung der Werkzeuge aus der archäologischen Einheit A08 unter Berücksichtigung der Ergebnisse der Funktionsanalyse (dreidimensionale Lagedaten waren nicht verfügbar; Werkzeuge wurden daher zufällig in den Quadraten positioniert).*

square A5 is only mentioned for archaeological unit A04 (cf. Richter 1997: Abb. 72) or for archaeological units belonging to older occupation cycles. Given the uncertainties involved, these two pieces must be discarded from the spatial analysis.

The used implements are distributed over the excavated squares in a random fashion with a concentration of used pieces at the back of the cave in the adjacent zones A1 and Z1 (cf. Fig. 35). There is a tendency for the hafted axes/adzes, hafted scrapers/choppers and the hafted scrapers to be located there, as are most of the hafted extremities and a few unused and possibly used pieces. Projectiles are absent in these zones and were found closer to the entrance of the cave.

Whether the back of the cave should be considered as a disposal area is not clear, but it is a possibility. Most of the pieces found there are linked with woodworking tasks and it seems doubtful that the heavy duty work (e.g. axing/adzing) would have taken place at the back of the cave. It has to be acknowledged, however, that the tool sample is quite small.

A06

Archaeological unit A06 encompasses the excavated squares A2-7, B2-7 and Z7 (Fig. 36). The majority of analysed pieces is in squares A4, A5 and B5. There is an obvious concentration of most tools in square A4 and A5. This area corresponds to an area in which a lot of charcoal was found (A4, A5 & A6 of Layer G2, cf. Fig. 1; Richter 1997). A hearth was found on the border of square A4 and B4. The artefacts are clearly concentrated around this hearth, while there is an absence of tools in B4. The actual number of artefacts found in square B4 is 948, which indeed contrasts with the 2 135 and 2 242 found in A4 and A5 respectively (Richter 1997: Abb. 82). The absence of tools in B4 may be explained by the location of the hearth; tool use or discard proves to be absent southeast of the hearth.

Given the high concentration of tools in only 2m^2 and the absence of more detailed spatial data, it seems quite meaningless to examine the internal patterning in closer detail, as most of the artefacts are obviously already clustered together to some degree.

A08

The excavated squares are Z3, A2-6, B2-7, C3 and C6 (Fig. 37). Again two pieces lie outside this excavated area. Both most likely belong to archaeological unit A09 (Richter 1997: Abb. 97), which is classified together with archaeological unit A08 as belonging to one occupation cycle. The presence of both tools is thus not very problematic even though they have no impact on the spatial results presented here.

A hearth was found on the edge B3 - B5, it is likely that it continued in the unexcavated zones C4 and C5. No data are available concerning its presence in C3. Most analysed pieces are concentrated in B5, but include several production failures and unused or possibly used implements. The actual used pieces seem to be more evenly distributed over different squares. The absence of tools in square B6 may again be explained by a significantly lower artefact number (108) in comparison with the surrounding squares - A5: 1 099 (= main artefact concentration of A08), A6: 466, B5: 659, B7: 278, C6: 511 (Richter 1997: Abb. 92). The same applies to squares A2, B2 and Z3 with total artefact numbers of 220, 53 and 181 respectively.

In spite of the main artefact concentration being located in A3-5 and B4, most used tools were found in B5. This suggests a link between tool distribution and the hearth. The absence of pieces in B6 is in this regard surprising.

Knives are distributed over different squares without a true concentration, but they seem to be more or less evenly distributed around the hearth. Aside from this, no particular spatial patterning with regard to tool use can be derived.

To conclude, the spatial analysis provides very little additional data. There are no true activity areas; the only tendencies that can be derived are the potential existence of a waste area at the back of the cave (in unit A02) and the preferential association of used tools with the hearth(s). The spatial analysis unfortunately remains very incomplete. A more meaningful and comprehensive spatial analysis can only be undertaken when equal tool numbers are examined for each archaeological unit and when the assemblage is viewed by stratigraphic layer, implying that the contained specific archaeological units are examined together. Given the differing numbers of tools analysed per archaeological unit and the omission of certain archaeological units from the functional analysis, such a combined study was not yet possible.

The current lack of explicit spatial patterning is not necessarily a direct reflection of Neanderthal behaviour, since cave sites are known to be problematic for discerning activity areas in contrast to open-air sites, given the concentration of artefacts within a restricted area.

Conclusion

A first important conclusion that can be drawn from the presented analysis is that hafted tools were present on a systematic basis at Sesselfelsgrotte. Hafting mainly involves tool uses for which it is a precondition, for example as projectiles and hafted axes or adzes, but it is not exclusively restricted to those tasks. Hafting is also demonstrated for tasks for which one can easily imagine that a haft may have facilitated tool use (e.g. increase the exerted pressure), as exemplified by the wood whittling tools. Tools for which no explicit advantage of hafting can be imagined were rarely hafted at Sesselfelsgrotte. Not only the occurrence of hafting itself, but also the evidence for hafting of tools for which hafting is not a precondition of use are equally important results with behavioural implications. The systematic use of hafting of course indicates that tool use was anticipated and planned.

The number of identified production failures remains relatively restricted and is, not surprisingly, highest in the case of the bifacial tools. Especially when hafted, bifacial pieces need to be reduced in thickness and many problems and breakages may occur during this process. On technological grounds and in consideration of the relatively low number of production failures, one cannot really consider Sesselfelsgrotte to be a lithic production site or a production centre of hafted tools, despite the wide availability of raw materials in the area (Richter 1997). All pieces seem to be linked with local use (in a broad sense) and this creates the impression that we are dealing with either a domestic site or a specialised hunting site (i.e. including animal processing). The range of represented tool uses mainly supports the first idea. The main functions of tools are linked with animal processing tasks or maintenance activities (e.g. wood shaping) and one would not expect the latter tasks to be carried out at a hunting stand, especially given the indications for the existence of specialised tools for these woodworking activities. Apart from this, there are no indications from a functional perspective for any form of technological specialisation.

Based on the functional data, there is some anticipation of the need for hafting during the stone tool production process; this is visible among the bifacial tools, but also among the scrapers/*rabots*, the latter preferentially showing a triangular morphology which is not always first achieved by (intensive) retouching. This suggests that the morphological requirement for hafting was already taken into account during knapping. Other than that, there are few indications that hafting formed a true and integral part of the tool production process. There is, however, evidence of morphological adjustments to the stone tool after hafting to line up the edges with the haft's edges, as for instance on one of the projectiles. When considering the degree of integration of hafting into the stone tool production process, it seems that while the future use and prehensile mode of the tool might be taken into account during the stone tool production process (in a relatively opportunistic way), hafting was not necessarily an integral part of this process, with the implication that it may have taken place at another time and/or location or perhaps even been carried out by another person. Again, there is no clear indication for specialisation.

The functional data show no chronological patterning for the time period represented at Sesselfelsgrotte, neither at the level of tool use nor with regard to hafting characteristics and intensity. In this stage of research it was not yet possible to examine from a functional perspective J. Richter's interpretative model for an increase in "expert knowledge" of raw materials coupled with increasing occupation duration. Up to now, the functional analysis focused on the so-called *"Konsekutivinventare"* only and future analyses should include studies of *"Initial-inventare"* to address this issue.

The functional analysis leaves no doubt that Neanderthals were capable of anticipating tool use and producing hafted tools. Up to a degree, morphological issues relative to hafting were already taken into account during stone tool production and hafting was an integral part of a planned process. The presence of projectiles attests to the practice of hunting in some form at least, a circumstance already indicated by finds of wooden spears such as those from Lehringen (Movius 1950; Thieme & Veil 1985; Thieme 1997), Schöningen (Thieme 1997) and Clacton (Singer et al. 1973). At Sesselfelsgrotte, stone-tipped spears were in use, the existence of which was also already attested by other evidence (Boëda et al. 1999). Spears were both thrust and used as projectiles (i.e. presumably hand-thrown).

From a cognitive point of view, it is important to remark that alongside projectiles and percussion tools, other tools were hafted, such as scrapers and knives, for which hafting is not a precondition for use. Similar observations have been made for Middle Stone Age sites in Northeast-Africa (Rots & Van Peer submitted). The main difference observed between MSA sites and the Sesselfelsgrotte is the degree to which hafting is integrated in the stone tool production process. Whether this can be used as an argument for differing cognitive abilities between Neanderthals and anatomically modern humans is an issue that needs to be addressed by future studies. In addition and as a priority, the potential temporal variation in the patterns emerging from different Neanderthal sites should also be examined.

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Note: All drawings adapted from Richter (1997).

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