Short-term occupations at the lakeshore: a technological reassessment of the open–air site Königsaue (Germany)

Kurze Aufenthalte am Seeufer: eine technologische Neubetrachtung der Freilandfundstelle Königsaue (Deutschland)

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Abstract - Comprehending the movements and settlement dynamics of prehistoric hunter-gatherers across a territory is important for understanding the lifestyle of archaic hominins. North-central Europe is a significant area for studying this issue because the different climatic oscillations during the Pleistocene affected the extent of ecological habitats and spread of floral and faunal species between different regions. This paper aims to contribute new data to the debate on Neanderthal mobility by exploring the lithic assemblages from levels A, B, and C of Königsaue. The results of the technological analysis document the use of the Levallois method in all three archaeological levels and the production of Keilmesser in levels A and C. Comparing the archaeological materials and Levallois experimental knapping series indicates high fragmentations of chaînes opératoires, suggesting that the anthropogenic occupations at the lakeshore were short-term. Furthermore, in levels A and C, Levallois cores were exported off-site, whereas in level B, Levallois flakes were transported. This difference in the toolkit composition supports the hypothesis of logistical mobility during the Keilmesser occupations and residential mobility during the Levallois-Mousterian settlement.

***Zusammenfassung -** Von besonderer Bedeutung für das Verständnis der Lebensweise archaischer Menschen ist eine Erforschung der Bewegungs- und Besiedlungsdynamik prähistorischer Wildbeuter. Dazu ist das nördliche Mitteleuropa ein besonders geeigneter Raum, da die pleistozänen Klimaschwankungen Auswirkungen auf Habitatgröße und Ausbreitung von Pflanzen- und Tierarten verschiedener Regionen hatten. Diese Arbeit legt neue Daten der Steinartefakte aus den archäologischen Horizonten A, B und C von Königsaue zur Diskussion der Mobilität von Neandertalern vor. Die technologische Analyse erbrachte für alle drei Horizonte den Nachweis der Levalloistechnologie und zwar sowohl mit Verfahren nur einen Zielabschlag als auch mit dem Ziel mehrere Abschläge in gleich- oder bipolarer Abbauweise zu erhalten. Kerne mit einer Schlagfläche und gleichgerichtetem Abbau, diskoide Kerne und solche mit getrennten Schlag- und Abbauflächen treten ebenfalls auf. In den Horizonten A und C gibt es neben Keilmessern und bifaziell retuschierten Geräten auch Abschläge der bifaziellen Modifikation. Ihr geringer Anteil läßt vermuten, dass hier fertige Geräte importiert und überarbeitet wurden. Im Horizont B fehlen diese Modifikationsabfälle. Vergleicht man die ausgegrabenen Steinartefakte mit Grundformzahlen von experimentell hergestellten Levalloiskernen zeigen sich häufig Brüche in den Phasen der Operationskette: in den Horizonten A und C wurden Kerne, im Horizont B dagegen Levalloisabschläge exportiert. Daher werden die Horizonte A und C als Ergebnis wiederholter, kurzfristiger Aufenthalte von von zentralen Stationen aus operierenden Neandertalern gesehen. Im Gegensatz dazu werden die anderen Brüche in der Operationskette und der geringere Anteil an Faunenresten in Horizont B als Ergebnis von von Neandertalern wiederholt und kurz bewohnten Stationen interpretiert. Die anders zusammengesetzten Geräteinventare legen nahe, für Mitteleuropa postulierte Differenzen zwischen Keilmessergruppen und der Levallois-Moustérien-Fazies auf Unterschiede in Mobilitätsmuster und Landschaftsnutzung zurückzuführen.*

Keywords - Middle Palaeolithic; Keilmessergruppen; lithic technology; Neanderthal mobility
Mittelpaläolithikum; Keilmessergruppen; Steingerätetechnologie; Mobilität der Neanderthaler

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Introduction

In recent decades, an increasing number of studies have focused on understanding the movements and settlement dynamics of Palaeolithic hunter-gatherers on the landscape. The fundamental concepts of these investigations are based on Binford (1977, 1980, 1983) who first contributed to the comprehension of mobility patterns and types of anthropogenic occupations in modern foragers. In his model, Binford (1980, 1982) proposed differentiating between residential mobility, in which all group members displace from one locality to another, and logistical mobility, in which only a few individuals move from the residential camp for specialized tasks. From this perspective, residential mobility is associated with domestic activities in

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long- and short-term settlements (residential camps), whereas logistical mobility is related to short-term occupations (locations) serving as hunting stations, killing sites, or bivouacs (Binford 1980, 1982). Ethnographic studies have documented that hunter-gatherers frequently relocate in order to avoid foraging in previously depleted areas, and the frequency of these movements is influenced by the richness of biotic resources (Binford 1972, 1982; Kelly 1983, 1995). In high-biomass environments, forager groups need to move to at least twice the previous foraging radius, whereas logistical groups' radii could overlap because their sporadic exploitations could have left exploitable resources (Binford 1982). Conversely, in low-biomass environments, mobility is characterized by point-to-point displacements with movements of the residence from one rare place with access to water, food, and fuel to another in the region (Binford 1982). On the base of these observations, Binford (1980, 1982) distinguished two main systems of settlement strategies: foragers, who depend on daily hunting and gathering for obtaining food, and collectors, who rely on logistical organization of the landscape to acquire resources. The forager and collector systems were not considered opposing principles but behavioural and organizational alternatives applicable in concurrent mixes of strategies (Binford, 1980).

Although Binford's approach (Binford 1980, 1982) in exploring the Palaeolithic archaeological record was innovative in a period dominated by processual archaeology, his model received criticism. The most debated argument encompassed the basis of the foragers-collector continuum that was developed on short-term ethnographic observation and was lacking a mechanism to explain the long-term system changes in evolutionary trajectories (Ames, 1991; Fitzhugh, 2003; Perreault & Brantingham, 2011; Price & Brown, 1985). Another discussion was focused on the inadequacy of the Middle-Range theory developed by Binford to explain the role of mobility in the creation of archaeological assemblages (Bettinger, 1987; Bettinger et al., 2015). Moreover, the main function of the environmental changes has been questioned for the inattention on other variables (e.g. social relationships, exchange, storage) that could have influenced as well the hunter-gatherers settlement strategies (Blurton Jones, 1991; Goland, 1991; Grove, 2009; Wiessner, 1982). Although these critiques are well founded, the resolution of most Palaeolithic archaeological assemblages are not so fine grained to infer many of the claimed information and Binford's forager-collector model (Binford 1980, 1982) continues nowadays to be one of the best examples for exploring the variability of the settlement dynamics in prehistoric hunter-gatherers. Identifying the different types of occupations and mobility patterns has been very useful for archaeologists introducing new parameters to interpret the archaeological record beyond the cultural viewpoint. Generally, long-term occupations are characterized by the spatial differentiation of task areas, a broad faunal spectrum, the recurrence of fire places, and the recovery of different phases of lithic production (Barsky 2013; Carbonell i Roura 2012; Costamagno et al. 2011; Picin & Carbonell 2016; Richter 1997; Rivals et al. 2009; Thiébaut et al. 2009). Conversely, short-term occupations show minimal investment in the spatial organization of the site, low faunal spectrum diversity, and limited knapping activities (Barsky 2013; Conard & Adler, 1997; Costamagno et al. 2011; Gaudzinski 1995; Meignen et al. 2007; Roebroeks et al. 1992a; Rosell et al. 2012; Talamo et al. 2016; Vallverdú et al. 2005). However, short-term occupations are not always easy to identify. Recognizing the transience of the activities is easy in cases where few remains are discovered, but in archaeological sites with thick palimpsests of frequent and repeated settlements, understanding the type and duration of the anthropogenic occupations is challenging. The problem is even more complex when short- and long-term occupations are not separated in the sedimentary sequence, yielding a mixture that is difficult to differentiate (Conard 2001; Vaquero 2008).

North-central Europe is an interesting area for studying the mobility of hunter-gatherers because the different climatic oscillations during the Pleistocene affected the extent of ecological habitats and spread of floral and faunal species between different regions (Kahlke 1999; Koenigswald 2011; Tzedakis 1994). Cyclical glacial periods characterized by cool/cold climates were followed by interglacial intervals characterized by improved climatic conditions and increased average temperatures (Tzedakis 1994). Thus, during the Pleistocene, north-central Europe was an area of discontinuous human settlements with local extinctions and repopulation from the southern territories (Hublin & Roebroeks 2009).

The climatic oscillations after the Marine Isotopic Stage (MIS) 5e were a challenging phase for northern European Neanderthals that had to adapt their hunting and subsistence strategies to new ecological conditions. The extension of the steppe/tundra environment in western-central Europe favoured the dispersal of the "*Mammuthus-Coelodonta*" faunal complex from the Arctic territories including the woolly mammoth, woolly rhinoceros, muskox, and reindeer (Kahlke 1999). Within this faunal turnover, some local species such as Irish elk, horse, and red deer, showed high environmental adaptability to the climatic shift and maintained their stable regional occupation (Koenigswald 2011). The new Arctic faunal complex was composed of animals that could behave as semi-sedentary under favourable conditions, but long seasonal migrations toward richer grazing lands were normally undertaken. For example, modern herds of reindeer can seasonally displace in an area of up to 442'000 km^2, whereas in semi-sedentary conditions, small groups move in an area of 25'000 km^2 (Bergman et al. 2000).

In response to these new faunal features, Neanderthals increased their foraging radius and modified technical behaviours. Within the utilized core technologies, the production of bifacial tools named *Keilmesser* between approximately MIS 5d and 3 has been documented (Jöris, 2006). This artefact, found in a vast territory across Ukraine, Hungary, the Czech Republic, Poland, Germany, and eastern France, is characterized by a single sharp working edge, which is formed by bifacial retouch from one side after the other, opposed by an unworked or roughly worked back (Bosinski 1967). This type of tool shows a wide range of shapes and has been typologically categorized into different groups based on qualitative features (Bordes 1961; Bosinski 1967; Chmielewski 1969; Kowalski 1967, 1969; Krukowski 1939; Koulakovskaya et al. 1993).

During the Middle Palaeolithic in central Europe, Neanderthal technical behaviours were not perfectly homogenous, and there is various evidence of lithic assemblages without bifacial tool production. So far, these collections are clustered into a broad Levallois-Mousterian group and include some sites in Germany (Königsaue B, Sirgenstein I-II, Große Grotte VIII-II, Buhlen II, Kartstein III, Großes Schulerloch, and Balve IV) (Bosinski 1967; Mania & Toepfer 1973; Wagner 1983) and Poland (Piekary II, Zwierzyniec, Nietoperzowa Cave, Ciemna VII, Koziarnia 18, Hallera A-B, and Zamkowa Dolna) (Kozłowski 2014; Wiśniewski et al. 2013). Core technologies used in this group are similar to those utilized in the *Keilmessergruppen* although they have not received the same attention as bifacial tools.

Understanding the Mousterian technological variability in central Europe and possible causes that could have induced Neanderthals to prefer only core technologies to their combination with bifacial methods are not fully comprehended. Current hypotheses suggest either the presence of two different cultural traditions (Kozłowski, 2014; Mania & Toepfer, 1973) or the result of different seasonal site occupations (Richter 1997, 2006; Uthmeier 2004). In the latter proposition, the *Keilmessergruppen* and the Levallois-Mousterian facies have been interpreted to be the outcomes of annual land-use cycles performed by the same Neanderthal bands. During autumn and winter, logistical mobility in the lowlands facilitated the production of uni- and bifacial tools in a context of low raw material diversity, whereas during spring and summer, residential mobility in mountainous environments caused an increase in the use of core technologies and production of denticulates in a context of high raw material diversity (Richter 2006). The main criticisms of these two hypotheses are that the *Keilmessergruppen* and the Levallois-Mousterian facies are too similar in certain aspects to support mere cultural differences (Conard & Fischer 2000), whereas the absence of zooarchaeological studies on seasonality (e.g. season of death analysis on teeth) make the latter proposition untested. This paper aims to add new data to the current debate about the mobility of prehistoric hunter-gatherers in central Europe by exploring the lithic assemblages of Königsaue, an open-air site with a succession of *Keilmesser* and Levallois-Mousterian facies.

Methodology

In this study, the technological analysis of the archaeological lithic materials from levels A, B, and C of Königsaue was carried out following the *chaîne opératoire* concept. This methodology defines the reconstruction of the various processes of flake production from the procurement of raw materials, through the phases of manufacture and utilization until the final discard. The *chaîne opératoire* provides systematic sequences of the flaking activities in which it is possible to determine the temporal phase and the position of the artefact produced (Inizian et al., 1992). In the technological analyses, the core reductions were differentiated between Levallois, discoid, hierarchized and simple core methods. The identification of Levallois technology is carried out following the criteria documented by Boëda (1994, 2013). The core volume is divided in two hierarchically related surfaces, one being the platform face and the other being the production face. The production face is organized such that the morphology of products is predetermined and this predetermination is based on the management of lateral and distal convexities. The fracture plane for the removal of predetermined flakes is subparallel to the plane of intersection between the two faces whereas the striking platform is organized to allow the removal of the predetermined flakes from the production surface. This requires that the intersection of the striking platform surface and the flaking surface must be perpendicular to the flaking axis of the predetermined flakes. Levallois technologies are divided between preferential, in which the objective corresponds to the production of a single blank per prepared surface, and recurrent modalities (unidirectional, bidirectional and centripetal), in which the goal is to produce several blanks from a single flaking surface.

The analysis of discoid technology is carried out following the general descriptions described by Boëda (1993). The core volume is divided in two unhierarchically related surfaces. The fracture plane for the flakes production is secant to the plane of intersection between the two faces. The production face is organized such that the morphology of products is determined through the maintenance of a peripheral convexity. In this perspectives, are differentiated the modalities discoid *sensu lato*, in which the production objectives are varied, and discoid *sensu stricto*, in which the main objective is to obtain pseudo-Levallois points and core-edge flakes (Mourre, 2003).

Several authors argued that the criteria identified by Boëda (1993, 1994) on Levallois technology are too strict in comparison with the dynamic processes of the knapping events. The main criticism points out that Levallois method is not a fixed system of flakes production but includes some variability in terms of methods, objectives and reduction sequences (Bar-Yosef & Van Peer, 2009; Dibble & Bar-Yosef, 1995; Van Peer, 1992). This flexibility could be expressed with a change, during the sequence, from one Levallois modality to the other (Delagnes, 1995; Bietti & Grimaldi, 1995; Van Peer, 1992) or with an opportunistic reduction to cope with the raw material constrains and nodule morphologies (Grimaldi, 1998; Guette, 2002; Kuhn, 1995). The debate also extended to the technological similarities between Levallois recurrent centripetal and discoid methods, and the equifinality in flakes production suggesting the clustering of these knapping methods in a broad centripetal recurrent group (Lenoir & Turq, 1995; Slimak, 1998; Turq, 2000). Although some flexibility in the application of Levallois methods is recognized, the criteria identified by Boëda (1993, 1994) are important information for the interpretation and discrimination between different technical behaviours. The excessive broadenings of the Levallois definitions and the rejection of some technical criteria could blur the limits between the different methods hiding their variability. In this perspective, the concept of hierarchized technologies could shed light on intermediate core morphologies that could not strictly fit in Levallois or discoid concepts. Firstly identified in discoid context, the hierarchized method is characterized by core configuration with secant fracture planes and hierarchization of the flaking surfaces (Martí et al., 2009; Vaquero & Carbonell, 2003). The direction of the detachments differentiates the hierarchized methods in unidirectional, bidirectional or centripetal.

In lithic assemblages are also common simple core technologies characterized by unhierarchized core surfaces and an opportunistic flake production. The reduction sequences are often short and the striking platforms are not prepared. The direction of the flake production on the flaking surfaces discriminated the simple cores in unidirectional, bidirectional and centripetal.

The flake assemblages were classified by dimensional base criteria and only those ≥ 2 cm were analysed. Some of the lithic items are permanently displayed at the Landesmuseum für Vorgeschichte in Halle (Germany) and not included in this study. Because of the equifinality in the blank production between Levallois, discoid and hierarchized technologies (Picin et al. 2014), the identification of Levallois flakes is based on the overall morphology of the blank and the external flaking angle that should measure about 90°. Flakes bearing bigger values of external flaking angles are discriminated on the base of the direction of the dorsal scar patterns (e.g. unidirectional, bidirectional, centripetal).

In the assemblage of retouched tools, simple scrapers, demi-Quina and Quina scrapers were analysed following the criteria of Bourguignon (1997) whereas the study of bifacial knives (*Keilmesser*) was carried out following the volumetric subdivisions documented by Boëda (1995).

Understanding the technological organization of prehistoric hunter-gatherers is a difficult issue because the lithic assemblages recovered in the archaeological record are the results of palimpsests of different occupational events characterized by the fragmentation of the operative chains, transport of lithic items from and into the site, re-sharpening and recycling (Bourguignon et al. 2004; Turq et al. 2013; Vaquero, 2011). Thus far, integrity of archaeological assemblages has been investigated through the application of raw material petrographic analysis (Turq et al. 2013), refitting (Vaquero 2008), and recently by the application of the Cortex and Volume ratios, new methods that allowed the recognition of patterns of core and flake transport quantifying the missing cortex surface area and volume loss (Dibble et al. 2005; Douglass et al. 2008). Another approach used for exploring the fragmentation of the *chaînes opératoires* is the comparison between the archaeological lithic assemblages and the experimental knapping materials (Brenet 2011; Picin 2014; Picin & Vaquero 2016). The investigation of the flake productivity in several technologies consented to estimate the amount of flakes in different technological categories by core unit and weight of raw material (Brenet, 2011; Picin 2014; Picin & Vaquero 2016).

In this study, 17 Levallois recurrent unidirectional, 11 Levallois recurrent centripetal and 4 bifacial discoid (*sensu lato*) knapping experiments on flint nodules are used for calculating the rates of flake productivity (see more information about the knapping experiments in Brenet, 2011, and Picin & Vaquero, 2016). The variables investigated are the number of unbroken flakes and their total weight in the categories Cortical, No Cortical, Management and Production. Using the ratio between these two variables, the amount of flakes by technological categories is computed and these data are used for calculating the estimated number of flakes by weight of raw material.

Site and context

The open-air site Königsaue is located 108 m a.s.l. near the town Aschersleben in eastern Germany (51°49’N, 11°24’E) (Fig. 1). The site was discovered on the shore of Aschersleben Lake, an ancient lake 12 km long that was silted up in historical times (Mania and Toepfer 1973). Since 1851, the area of Aschersleben has been exploited for quarrying the lignite beds discovered near and underneath the former lake. Opencast mining was carried out until 1996 when the

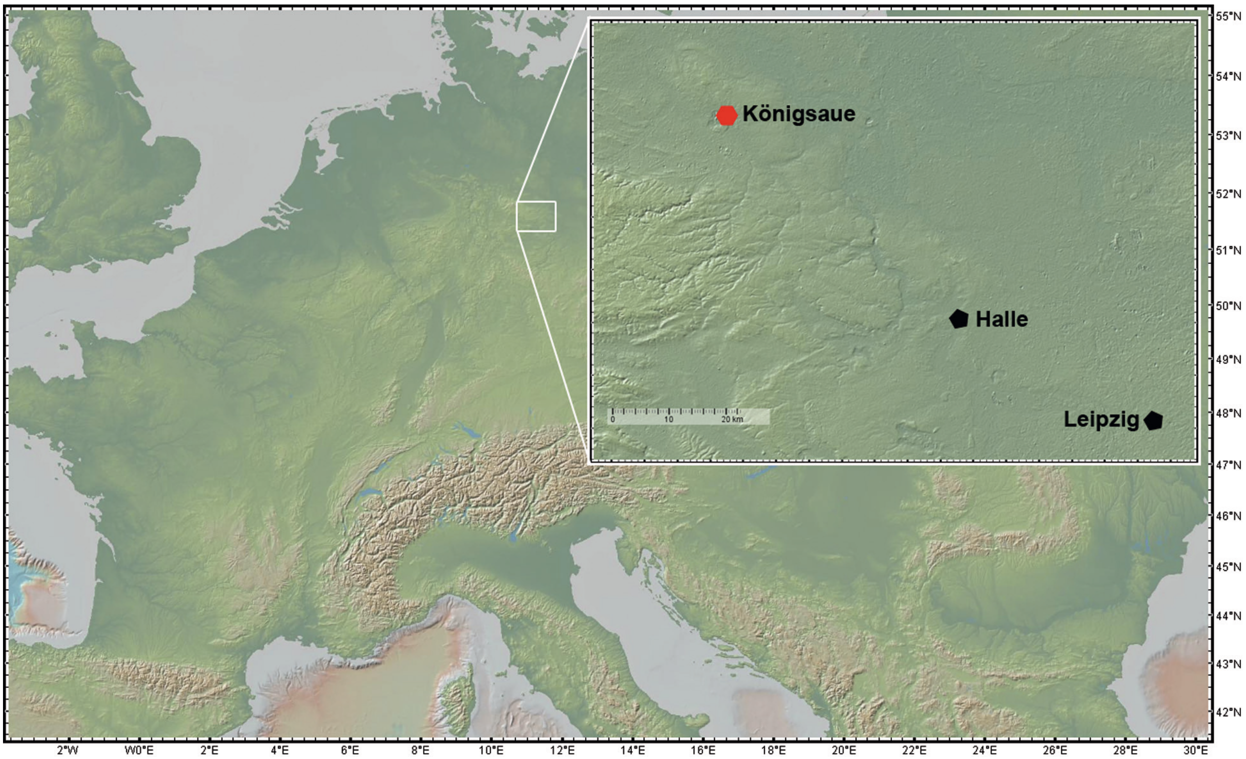

Fig. 1. Map showing the location of Königsaue (Germany) (base map from GeoMappApp).

Abb. 1. *Karte mit Lage der Fundstelle Königsaue (Deutschland) (Basiskarte von GeoMappApp).*

mining pit was turned into a recreational lake named Königsauer See. In 1963, Mania identified some Palaeolithic remains in the sediments exposed by the lake basin and between July 1963 and July 1964 carried out a rescue excavation for recovering the archaeological finds (Mania and Toepfer 1973).

The stratigraphic sequence of the Aschersleben Lake was 25 m thick and included 12 climatic microcycles (Fig. 2; Mania & Toepfer 1973). Each microcycle was composed of the following: a) fluvial deposit (gravel and sands) in the lower part; b) limnic and telmatic deposits (gyttja and peat) in the middle part; and c) solifluction deposits with frost structures in the upper part. Individual cycles were separated from each other by evidence of denudation (Burkhardt et al. 1970; Mania & Toepfer 1973). The Middle Palaeolithic archaeological levels (A, B, and C) were discovered in the sediments of cycle Ib (Figs. 2 - 3).

The chronology of the sequence was estimated by sedimentary analyses, paleoecological studies, and radiocarbon dates spanning from the last Interglacial (MIS 5e) to the Holocene (Burkhardt et al. 1970; Grootes 1977; Hedges et al. 1998; Mania & Toepfer 1973). Mania and Toepfer (1973) attributed cycle III to the Hengelo and cycle II to the Moershoofd interstadial, suggesting that cycle Ib, where the Middle Palaeolithic layers were embedded, was associated with the Brörup interstadial (MIS 5c). The radiocarbon dates of the sediments supported this interpretation until 1998 when two pieces of resin, discovered in layers A and B, were dated (Hedges et al. 1998). The results of 43'800 ± 2'100 ^{14}C years BP for layer A and 48'400 ± 3'700 ^{14}C years BP for layer B indicated a younger age for the prehistoric occupations. Mania (1999) pointed out that these dates are too young compared to the assigned geological attribution, generating a debate about the uncertainty of the site's chronology (Jöris 2006; Koller et al. 2001; Mania 2015; Rots 2015; Ruebens 2013; Wiśniewski 2014; Wragg Sykes 2015). To explore this issue, this study sent two bone samples, one each from levels A and B, to the Klaus-Tschira-AMS facility at the Curt-Engelhorn Centre in Mannheim (Germany) for dating. The bone fragment from level B did not yield any collagen, whereas the reindeer femur from level A was dated to 41'820 ± 390 ^{14}C years BP (MAMS-24487) using ultrafiltration pre-treatment. This ^{14}C date was calibrated using OxCal v 4.2 (Bronk Ramsey 2009; Bronk Ramsey & Lee 2013) and IntCal13 (Reimer et al. 2013). The sample ranges between 45'570 and 44'850 calBP (68.2 %), and between 45'940 and 44'500 calBP (95.4 %). The reindeer bone showed good preservation of the collagen, but due to technical problems at the laboratory, the carbon and carbon-nitrogen ratio values could not be determined. Unfortunately, a single date is not sufficient to discuss the chronological issues of the site, and a further extensive dating program is mandatory.

Pollen analyses on the peat and mud sediments of layer A showed abundant *Pinus* sp. and *Betula* with

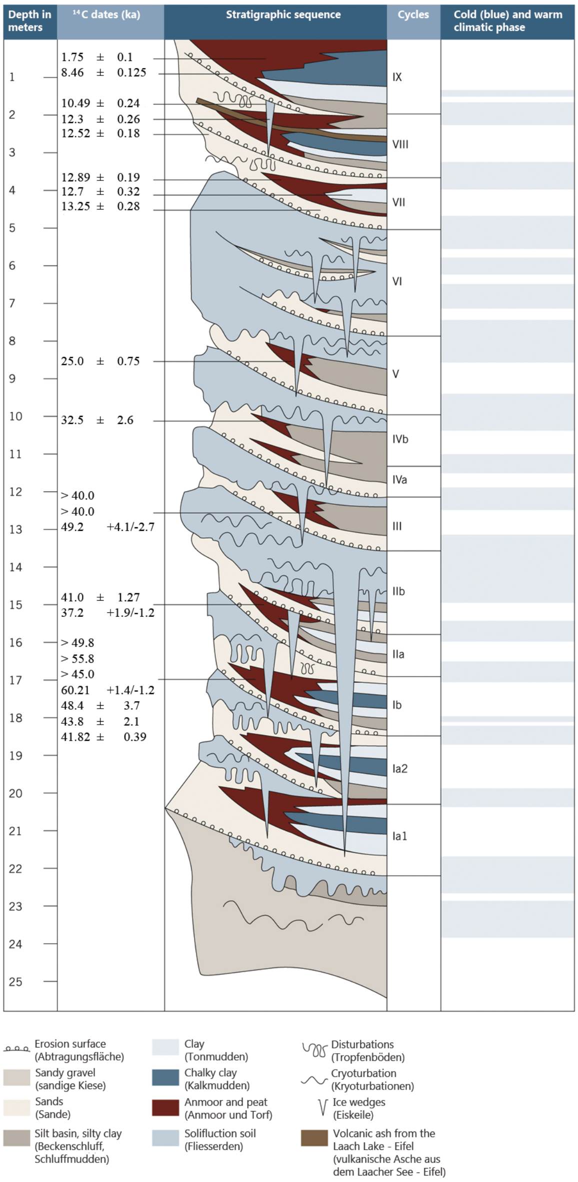

Fig. 2. Stratigraphic and chronological sequence of Aschersleben Lake (modified and reprinted with permission of Landesamt für Denkmalpflege und Archäologie Sachsen-Anhalt).

Abb. 2. *Stratigraphie und Chronologie der Schichtenfolge vom Ascherslebener See (verändert und gedruckt mit Erlaubnis des Landesamts für Denkmalpflege und Archäologie).*

herbs taxa and a lesser percentage of *Picea*, *Alnus*, *Tilia*, *Ulmus*, *Corylus*, and *Quercus* (Mania 1999). Conversely, layers B and C showed higher frequencies of *Pinus* sp. compared to *Betula*, *Salix*, *Picea*, and *Alnus*. Other taxa such as *Quercus*, *Tilia*, *Ulmus*, and *Carpinus* were recorded in small quantities. Herbs taxa were quite frequent, especially Gramineae, *Artemisia*, *Helianthemum*, *Chenopodiaceae*, *Thalictrum*, *Armeria*, Ericaceae, *Calluna*, Ranunculaceae, Cyperaceae, Asteraceae and *Plantago* (Mania 1999). The paleoecological study suggests an environment in the neighbourhood of a lake characterized by forested and meadow steppe.

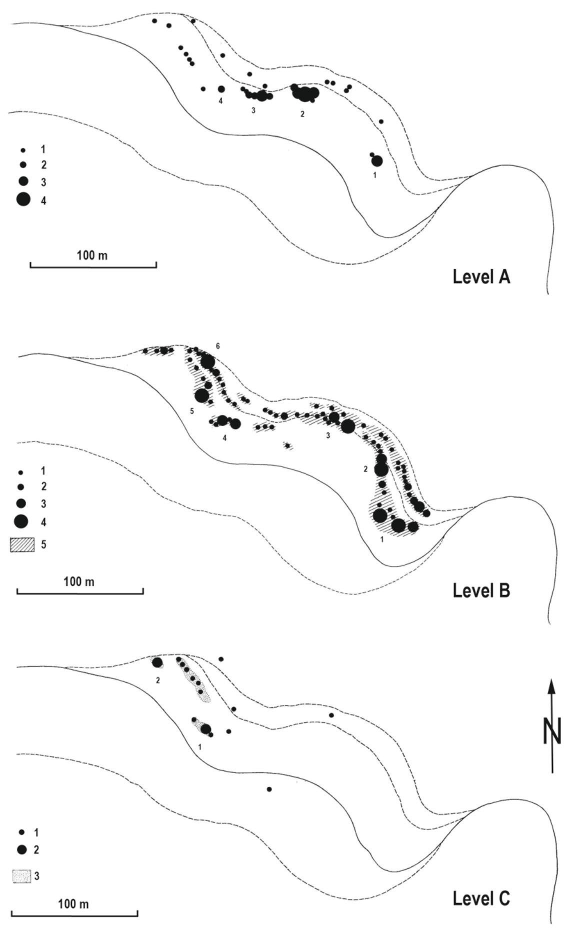

Fig. 3. Spatial distribution of the lithic artefacts in levels A, B and C of Königsaue. Legend: 1. 1-50, 2. 50-100, 3. 100-200 and 4. > 200 artefacts; 5. Faint find scatter without exact recording of artefact numbers; 3. Accumulations of charcoals and bone remains. Numbers on the map indicate accumulation of artefacts (modified from Mania & Toepfer 1973).

Abb. 3. *Räumliche Verteilung der Steinartefakte der Horizonte A, B und C von Königsaue. Legende: 1. 1-50, 2. 50-100, 3. 100-200 und 4. >200 Artefakte; 5. Nicht in der Verteilung erfaßte, lockere Fundstreuung; 3. Konzentrationen von Holzkohle und Knochen. Zahlen auf der Karte zeigen Artefaktkonzentrationen (verändert nach Mania & Toepfer 1973).*

In layer A, the study of faunal remains revealed high frequencies of reindeer (*Rangifer tarandus*), horse (*Equus* sp.), wolly mammoth (*Mammuthus primigenius*), and steppe bison (*Bison priscus*) with occasional consumption of European ass (*Equus hydruntinus*), woolly rhino (*Coelodonta antiquitatis*), narrow-nosed rhinoceros (*Dicerorhinus hemitoechus*) and red deer (*Cervus elaphus*) (Fig. 4). In layer B, the faunal remains show the hunting of horse, reindeer, and bison, and one example each of mammoth, wild ass, and red deer. Conversely, in layer C, only a few fragments of reindeer were discovered. Some remains of carnivores, i.e. of cave hyena (*Crocuta crocuta spelaea*), wolf (*Canis lupus*), and cave lion (*Panthera spelaea*) were also detected in the faunal assemblages. Only level B,

	A		B		C		
	NISP	MNI	NISP	MNI	NISP	MNI	Total NISP
Mammuthus primigenius	6	4	6	1			12
Equus sp.	46	4	25	3			71
Equus (Asinus) hydruntinus	3	1	1	1			4
Coelodonta antiquitatis	3	1					3
Dicerorhinus hemitoechus	1	1					1
Cervus elaphus	2	1	12	1			14
Rangifer tarandus	71	5	14	2	4	1	89
Bison priscus	74	3	22	2			96
Crocuta spelaea	6	2	1	1			7
Canis lupus			1	1	1	1	2
Panthera (Leo) spelaea			1	1			1
Microtus arvalis			1	1			1
Microtus gregalis			1	1			1
Total	**212**		**85**		**5**		**302**

Fig. 4. NISP of macro- and micromammals by layers from Königsaue (MNI = minimum number of individuals; NISP = number of identified specimens). Modified from Mania & Toepfer (1973).

Abb. 4. *NISP von Groß- und Kleinsäugern in den Fundhorizonten von Königsaue (MNI = Mindestindividuenzahl; NISP = Anzahl bestimmter Stücke). Verändert nach Mania & Toepfer (1973).*

however, held a distal epiphysis of a horse phalanx I and a fragment of a calcaneus of bison showing traces of hyena gnawing (Mania & Toepfer 1973).

As in many localities in North-central Germany, the area of Aschersleben is abundant of Erratic flint nodules, with colour tonalities ranging from black/grey to black/brown, transported by the glacier advances from Fennoscandia during the Elsterian and the last phase of the Saalian (Richter et al. 1986; Wansa & Junge, 2011). The distribution of similar Erratic flint nodules over a vast area impedes a precise association with the flint outcrops and, consequently, the investigation of the strategies of raw materials procurement.

Results

Level A

The lithic assemblage of level A was composed of 1'478 flint and 12 quartzite artefacts. For this study, 1'106 flint items were analysed (Fig. 5). The numerous small chips and quartzite artefacts that suffered severe surface weathering alterations were not included. Flakes and fragments of flakes made up the bulk of the assemblage; there were relatively few cores and retouched tools.

The technological analysis revealed the use of different knapping methods (Fig. 6). The Levallois preferential technology was the most commonly used, whereas the recurrent unidirectional modality was present in only one core (Figs. 6 & 7). The configuration of the cores' volume was maintained by detaching predetermining Levallois and trimming striking platform flakes. The cores' convexity was created by core-edge flakes and pseudo-Levallois points (also called core-edge dos limité flakes). The small number of pseudo-Levallois points indicates that they were by-products of the flaking sequence, not the intended products. Although several preferential Levallois cores were identified, there were very few preferential Levallois flakes, whereas Levallois unidirectional flakes were numerous (Figs. 7 & 8). In the analysis, one Levallois point, three bidirectional, and one orthogonal Levallois flakes were also recovered. The latter examples could have been the resulting products of core rotation during the knapping processes, a common strategy used in the

	A		B		C		Total	
	n	%	n	%	n	%	n	%
Flake	548	*49.5*	1766	*59.7*	98	*43.8*	2412	*56.2*
Flake fragment	473	*42.8*	952	*32.2*	101	*45.1*	1526	*35.6*
Tool	22	*2*	24	*0.8*	12	*5.4*	58	*1.4*
Tool fragment	20	*1.8*	6	*0.2*	3	*1.3*	29	*0.7*
Core	26	*2.4*	154	*5.2*	5	*2.2*	185	*4.3*
Core fragment	14	*1.3*	48	*1.6*	4	*1.8*	66	*1.5*
Chunks	3	*0.3*	7	*0.2*	1	*0.4*	11	*0.3*
Chert pebble			3	*0.1*			3	0.1
Total	**1106**	*100*	**2960**	*100*	**224**	*100*	**4290**	*100*

Fig. 5. Counts and percentages of the lithic artefacts of levels A, B and C of Königsaue.

Abb. 5. *Mengen und Häufigkeiten der Steinartefakte der Horizonte A, B und C von Königsaue.*

	A		B		C		Total	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Levallois preferential	4	*15.4*	22	*14.3*			26	*14.1*
Levallois rec. unidirectional	1	*3.8*	12	*7.8*			13	*7*
Levallois rec. bidirectional			3	*1.9*			3	*1.6*
Levallois centripetal			3	*1.9*			3	*1.6*
Levallois orthogonal			2	*1.3*			2	*1.1*
Levallois undetermined			9	*5.8*			9	*4.9*
Discoid	2	*7.7*	9	*5.8*			11	*5.9*
Hierarchized unidirectional			7	*4.5*			7	*3.8*
Hierarchized bidirectional			10	*6.5*			10	*5.4*
Hierarchized centripetal	3	*11.5*	13	*8.4*			16	*8.6*
Core with overshoot flake	2	*7.7*	8	*5.2*			10	*5.4*
Unidirectional	6	*23.1*	22	*14.3*			28	*15.1*
Bidirectional	2	*7.7*			1	*20*	3	*1.6*
Orthogonal	2	*7.7*	3	*1.9*	1	*20*	6	*3.2*
Core-on-flake	4	*15.4*	31	*20.1*	3	*60*	38	*20.5*
Total	**26**	*100*	**154**	*100*	**5**	*100*	**185**	*100*

Fig. 6. Counts and percentages of the cores of level A, B and C of Königsaue.

Abb. 6. *Mengen und Häufigkeiten der Kerne der Horizonte A, B und C von Königsaue.*

Middle Palaeolithic to maintain convexity and avoid producing hinged blanks (Delagnes 1995).

The recovery of several unidirectional flakes and cores highlights the use of the unidirectional pattern. Although the striking platforms were commonly prepared, the unidirectional cores showed some degree of expediency. Within some cores in which several flakes were opportunistically detached, the presence of a hyper-exploited core reduced with the bidirectional method on both sides followed by a last short unidirectional production and fragmented core with unidirectional exploitation using the fracture as the striking platform is noteworthy.

A common behaviour related to Levallois and simple unidirectional production is the repeated detachment of several flakes from the same striking platform. In some cases, this strategy produced secondary Levallois preferential flakes (see later discussion in the section about Level B) and, in more frequent cases, hinged blanks that were removed by blanks that reshaped the flaking surface. Another consequence of the repeated unidirectional production was the significant decrease in the angle of the striking platform, giving the ventral surface of the cores a pyramidal morphology.

In some cases, the technical expedient used to avoid the production of hinged flakes was to exploit a larger portion of the striking platform in order to maintain convexity or to shift the flake production to bidirectional or orthogonal. A clear example is the diacritic lecture of the negative scars of three refitted flakes (here named A, B, and C) (Fig. 9: 1). Flake A shows that after the first series of detachments, the core was turned, and the production restarted counter-clockwise from the opposite side. The repeated unidirectional detachments produced several hinged flakes. After the detachment of flake A, the knapping event continued counter-clockwise with the production of flake B that was biased by a siret fracture. Successively, production continued clockwise with the detachment of flake C that restored the flaking surfaces. Although the flakes' platforms are faceted, the external flaking angles of the refitted flakes exceed the 90° characteristic of Levallois modality, suggesting the use of a more general orthogonal technology.

The analysis of secondary *chaînes opératoires* revealed the presence of bifacial discoid cores, characterized by the complete exhaustion of the convexity before the discard (Fig. 7: 5 - 6), and hierarchized centripetal artefacts (Fig. 6). Generally, the hierarchized centripetal method has been placed between the discoid and Levallois technologies due to the dynamic processes involved in the flaking methods (Vaquero & Carbonell 2003). The appearance of this kind of core in this context might be explained as an adaptation of the knapper to the morphology of the blanks when some invasive detachments abruptly decrease the dorsal convexity. Two orthogonal cores, two undetermined cores due to a knapping accident that removed the flaking surface, and several core-on-flakes were also present in the assemblage. These latter artefacts mainly showed unidirectional exploitation of the flake ventral surfaces and centripetal exploitation in only one example. The striking platform was generally prepared with a small detachment on the thicker side of the blank.

The category of retouched tools comprised mainly scrapers and *Keilmesser* (Figs. 9 & 10). Many of these latter artefacts are permanently displayed at the Landesmuseum für Vorgeschichte in Halle (Germany), but silicone replicas are available for analysis. The *Keilmesser* of level A are characterized by an oblique, blunt back in the proximal part and a leaf-point like in the upper part. Although significantly different in dimension and shape, these tools share using plano-convex reduction, the shaping of a long, straight cutting edge, and the recurrent rejuvenation of the cutting edges (Kot 2013). Following the typological attribution of Bosinski (1967), these artefacts are clustered in the group *Inventartyp Schambach*.

The use of the soft hammer (Fig. 11) and bifacial retouch was not limited to the *Keilmesser* but also used on some scrapers to regularize a portion of the blanks

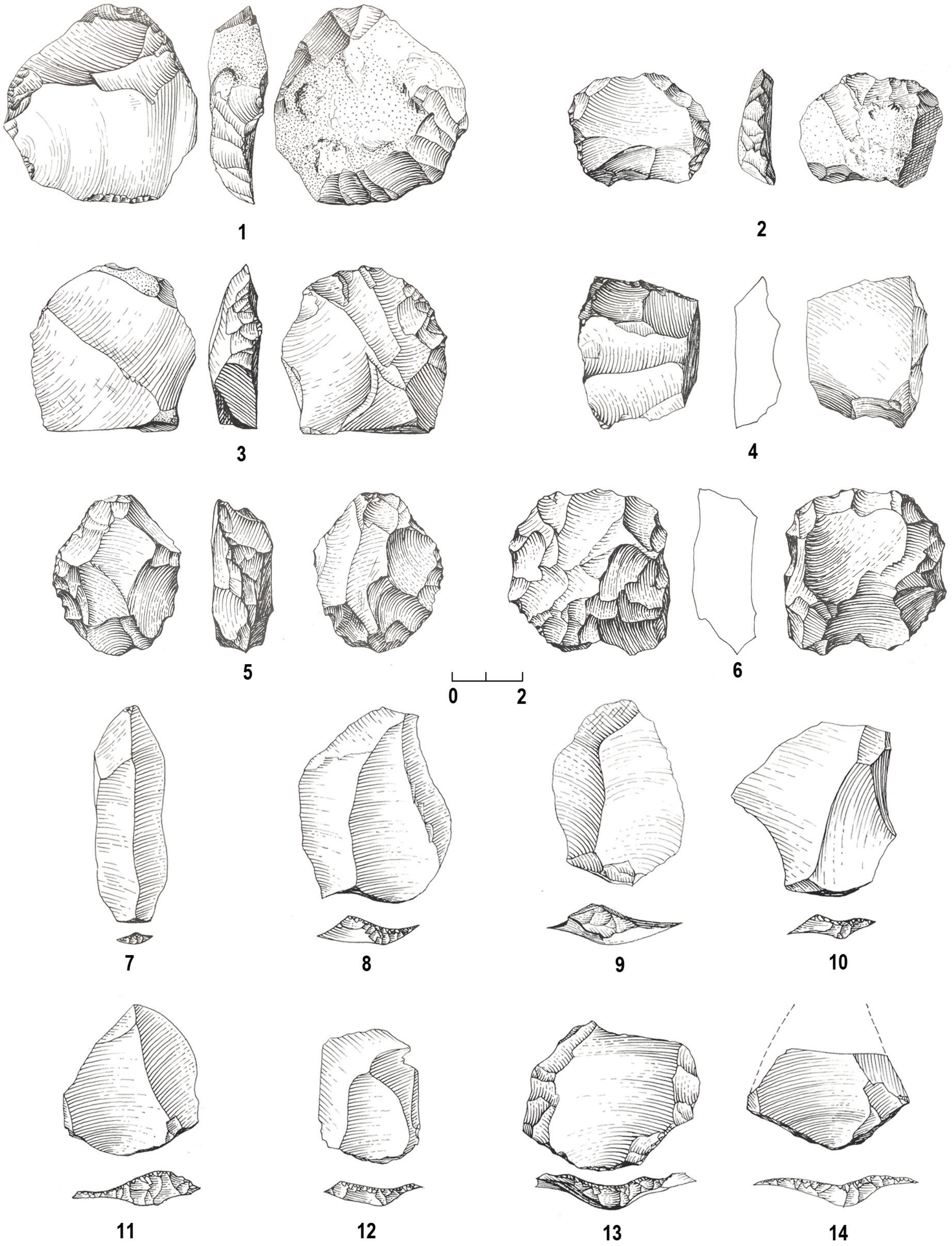

Fig. 7. Levallois preferential core (1, 2), Levallois recurrent unidirectional core (3), fragment of Levallois recurrent bidirectional core (4), discoid core (5, 6), Levallois flake (7-14) of level A of Königsaue (modified from Mania & Toepfer 1973).

Abb. 7. *Levalloiskern mit Negativ eines Zielabschlag (1, 2), Levalloiskern mit wiederholtem, gleichgerichteten Abbau (3), Fragment eines Levalloiskerns mit wiederholtem, gleichgerichteten Abbau (4), diskoider Kern (5, 6), Levalloisabschlag (7-14) aus Horizont A von Königsaue (verändert nach Mania & Toepfer 1973).*

and facilitate the handling or hafting of the tools. Similarly, seven other scrapers were thinned on the proximal side using unidirectional (n = 3) and lateral (n = 4) detachments, probably for hafting purposes. In the scraper assemblage, some tools presented extensive reuse of the blanks. A pseudo-Levallois

	A		B		C		Total	
	n	%	n	%	n	%	n	%
Cortical flake (>50%)	46	*4.5*	127	*4.7*	3	*1.5*	176	*4.5*
Cortical flake (<50%)	84	*8.2*	269	*9.9*	16	*8*	369	*9.4*
Naturally core-edge flake	19	*1.9*	102	*3.8*	2	*1*	123	*3.1*
Cortical core-edge flake	9	*0.9*	45	*1.7*	1	*0.5*	55	*1.4*
Trimming striking platform	27	*2.6*	109	*4*	6	*3*	142	*3.6*
Ordinary flake	22	*2.2*	58	*2.1*	6	*3*	86	*2.2*
Predetermining Lev. flake	48	*4.7*	240	*8.8*	17	*8.5*	305	*7.7*
Levallois pref. flakes	3	*0.3*	19	*0.7*			22	*0.6*
Levallois rec. unidirectional	21	*2.1*	33	*1.2*	4	*2*	58	*1.5*
Levallois rec. bidirectional	3	*0.3*	10	*0.4*			13	*0.3*
Levallois orthogonal	2	*0.2*	10	*0.4*			12	*0.3*
Levallois point	1	*0.1*	2	*0.1*			3	*0.1*
Core edge removal flake	39	*3.8*	216	*7.9*	9	*4.5*	264	*6.7*
Pseudo-Levallois point	8	*0.8*	73	*2.7*	2	*1*	83	*2.1*
Unidirectional flake	18	*1.8*	99	*3.6*	5	*2.5*	122	*3.1*
Bidirectional flake			3	*0.1*			3	*0.1*
Centripetal flake			2	*0.1*			2	*0.1*
Kombewa-type flake	9	*0.9*	13	*0.5*			22	*0.6*
Re-shaping flaking surface	20	*2*	88	*3.2*	3	*1.5*	111	*2.8*
Translation of the striking platform	1	*0.1*	1	*0*			2	*0.1*
Knapping accident	76	*7.4*	247	*9.1*	17	*8.5*	340	*8.6*
Bifacial shaping	119	*11.7*			7	*3.5*	126	*3.2*
Fragment with cortex	170	*16.7*	307	*11.3*	33	*16.6*	510	*13*
Fragment without cortex	276	*27*	645	*23.7*	68	*34.2*	989	*25.1*
Total	**1021**	*100*	**2718**	*100*	**199**	*100*	**3938**	*100*

Fig. 8. Counts and percentages of the flakes of level A, B and C of Königsaue.

Abb. 8. *Mengen und Häufigkeiten der Abschläge der Horizonte A, B und C von Königsaue.*

point was recycled and retouched as a scraper after complete surface patination. A core fragment was used first for the production of two small, bidirectional flakes and then retouched as a scraper. In the same way, a cortical flake fragment was turned first as a core-on-flake using the fracture as the striking platform to produce four unidirectional flakes. Next, the platform was thinned with a bifacial retouch and one side was retouched as a scraper. This evidence of extensive modification, reshaping the cutting edge, and reusing the blanks suggests careful economy of raw materials and discard at the site of part of the traveling toolkit.

Level B

The lithic assemblage of level B was composed of 3'966 flint and 25 quartzite artefacts. This study analysed 2'959 flint items and one quartzite handaxe (Fig. 5). The numerous small chips and quartzite artefacts that suffered surface weathering alterations were not included. Flakes and fragments of flakes made up the bulk of the assemblage; there were relatively few cores and retouched tools (Fig. 5). The technological analysis indicated that the Levallois method was most commonly used, especially in the preferential and recurrent unidirectional modalities, whereas bidirectional, centripetal, and orthogonal types were recorded less frequently (Figs. 6 & 12). Analysis of scars on the cortical blanks showed that the beginning of the exploitation followed a unidirectional pattern. The configuration of the core's volume was created by detaching predetermining Levallois and trimming striking platform flakes and maintained by detaching core-edge, pseudo-Levallois point (or core-edge *dos limité*), and overshot flakes. The use of these latter artefacts to retain the core preparation was a common expedient used during the Middle Palaeolithic in Levallois recurrent unidirectional contexts (Delagnes 1995; Meignen 1995). Comparing the amount of Levallois cores and products indicated the existence of Levallois recurrent unidirectional and Levallois preferential as two independent knapping strategies (Figs. 6 & 8). Conversely, the use of bidirectional and orthogonal Levallois modalities might have been the result of technical means to avoid producing hinged blanks and maintain core convexity (Delagnes 1995). In five Levallois preferential cores, recurrent detachment from the same point of the striking platform and production of secondary Levallois preferential flakes were observed. In these Levallois preferential cores, the retained convexity is used for the opportunistic production of another (a)typical Levallois flake before discard. The dorsal surface of the blank produced is characterized by the negative scars of the previous Levallois preferential flake or by a flat surface, since the second blank was detached on the negative scar of the first Levallois preferential flake (Fig. 12: 3 - 5). Although Boëda (1994) pointed out that only one flake could be produced with the preferential modality, this flake production could not even be considered recurrent since the preceding removal does not prepared the surface for the subsequent one. This problematic on preferential Levallois cores was already stressed by De Loecker (2005) suggesting to broad the interpretation of these artefacts in an "extended" Levallois category. However, the definition of these artefacts as secondary preferential flakes could be an intermediate term for distinguishing this particular procedure from the Levallois preferential *sensu stricto* as was illustrated at Chêne

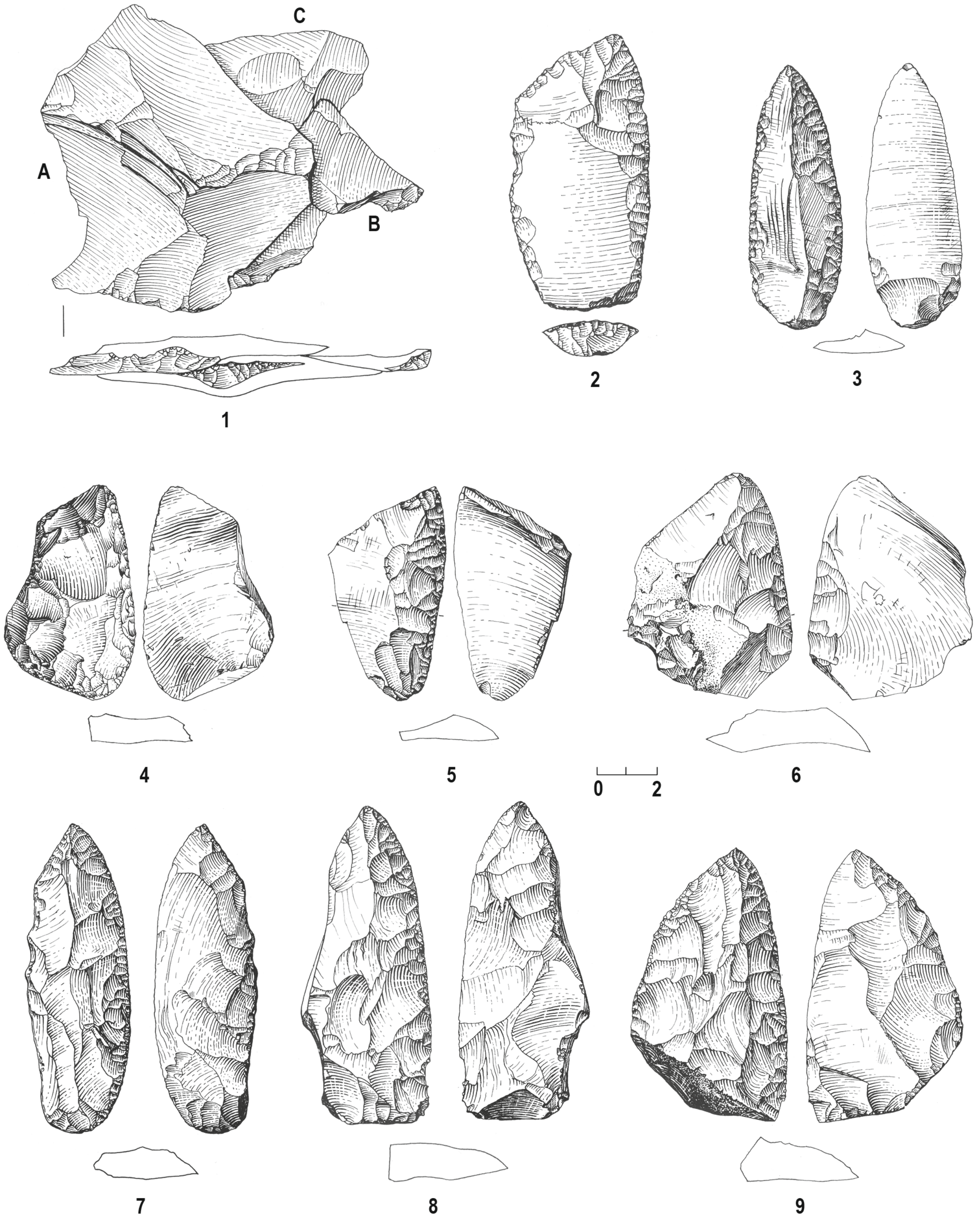

Fig. 9. Flakes refitting (1), scraper (2), Mousterian point (3), demi-Quina scraper (4-6), Keilmesser (7-9) of level A of Königsaue (modified from Mania & Toepfer 1973).

Abb. 9. *Zusammengeaβte Abschläge (1), Schaber (2), Moustérienspitze (3), demi-Quina-Schaber (4-6), Keilmesser (7-9) aus Horizont A von Königsaue (verändert nach Mania & Toepfer 1973).*

Vert, France (Dawson et al. 2012). The recurrent production from the same point of the striking platform, also detected in level A, is common in other utilized technologies and demonstrated by the abundant number of hinged flakes. Another feature, identified in nine undetermined Levallois cores, was

	A		B		C		Total	
	n	%	n	%	n	%	n	%
Scraper	15	*55.6*	15	*62.5*	2	*16.7*	32	*50.8*
Quina scraper					4	*33.3*	4	*6.3*
demi-Quina scraper	3	*11.1*			3	*25*	6	*9.5*
Double scraper	1	*3.7*	4	*16.7*	1	*8.3*	6	*9.5*
Keilmesser	6	*22.2*			1	*8.3*	7	*11.1*
Bifacial tool	1	*3.7*	2	*8.3*			3	*4.8*
Point	1	*3.7*					1	*1.6*
Faustel			1	*4.2*			1	*1.6*
Denticulate			2	*8.3*	1	*8.3*	3	*4.8*
Total	**27**	*100*	**24**	*100*	**12**	*100*	**63**	*100*

Fig. 10. Counts and percentages of the retouched tools of level A, B and C of Königsaue.

Abb. 10. *Mengen und Häufigkeiten der retuschierten Geräte der Horizonte A, B und C von Königsaue.*

	A		C		Total	
	n	%	n	%	n	%
Cortical flake (>50%)	4	*3.4*			4	*3.2*
Cortical flake (<50%)	7	*5.9*			7	*5.6*
Flakes	76	*63.9*	7	*100*	83	*65.9*
Core edge removal flake	1	*0.8*			1	*0.8*
Re-shaping flaking surface	1	*0.8*			1	*0.8*
Knapping accident	3	*2.5*			3	*2.4*
Fragment with cortex	1	*0.8*			1	*0.8*
Fragment without cortex	26	*21.8*			26	*20.6*
Total	**119**	*100*	**7**	*100*	**126**	*100*

Fig. 11. Counts and percentages of the flakes produced with soft hammer of level A and C of Königsaue.

Abb. 11. *Mengen und Häufigkeiten der Abschläge mit weichen Hammer der Horizonte A und C von Königsaue.*

the opportunistic detachment of a few more flakes once exhaustion of the ventral convexity did not allow production to continue.

Common, hierarchized centripetal and hierarchized bidirectional cores were present in the assemblage (Fig. 6). As previously stated, hierarchized centripetal cores are considered to exist between discoid and Levallois technologies. The bidirectional variant is characterized by preparation of the striking platform and bidirectional production in a direction secant to the line of intersection between the striking and flaking surfaces.

Secondary *chaînes opératoires* are also characterized by bifacial discoid and simple unidirectional cores (Fig. 6). The former artefacts were small and abandoned when convexity was exhausted. The recovery of a single diagnostic flake indicated the occasional use of the translation of the striking platform to continue with the reduction. Conversely, unidirectional cores showed the application of different strategies. The first, recorded in 15 cores, comprised the use of the natural convexity of fragments or small semi-cortical pebbles for the opportunistic detachment of up to three flakes. Analysis of the removal's negatives indicated that the artefacts produced were small (n = 28, σ = 21.39 mm, S.D. = 10.23 mm). In the second flaking strategy, seven cores were characterized by abrupt unidirectional production. In some cases, the striking platform was created by the removal of one or two flakes, whereas in others, the natural flat surfaces of the nodules were exploited. Although the method was reminiscent of blade technology, it is worth noting that these cores did not resemble the alternate rotating or semi-rotating technologies described by Delagnes (2000). Moreover, the blanks produced were flakes and lacked the metric attributes to be classified as blades. In the last example, seven cores showed a hierarchized pattern, with the preparation of the striking platform and the unidirectional production secant to the line of intersection of the two surfaces. The unidirectional exploitation was also applied to core-on-flakes. The removals were mostly concentrated on the proximal side of the flakes removing part of the platform or bulb. The resulting Kombewa-type flakes were few (Fig. 8).

The assemblage of retouched tools was composed mostly of scrapers with smaller numbers of double scrapers and denticulates (Fig. 10). The analysis also detected a Fäustel, a handaxe on a quartzite pebble and a retouched artefact with a bifacial production limited to a small portion of the cutting edges (Figs. 13: 13, 15 & 16). It is worth noting that these latter artefacts differ substantially from the bifacial knives of level A, and the bifacial flaking might have been related to the regularization of the edges for better handling.

Level C

The lithic assemblage of level C was composed of 295 flint, 1 quartzite, and 1 quartz artefacts. This study analysed 223 flint items and one quartz core (Fig. 5). The small chips and quartzite artefact that suffered surface weathering alterations were not included.

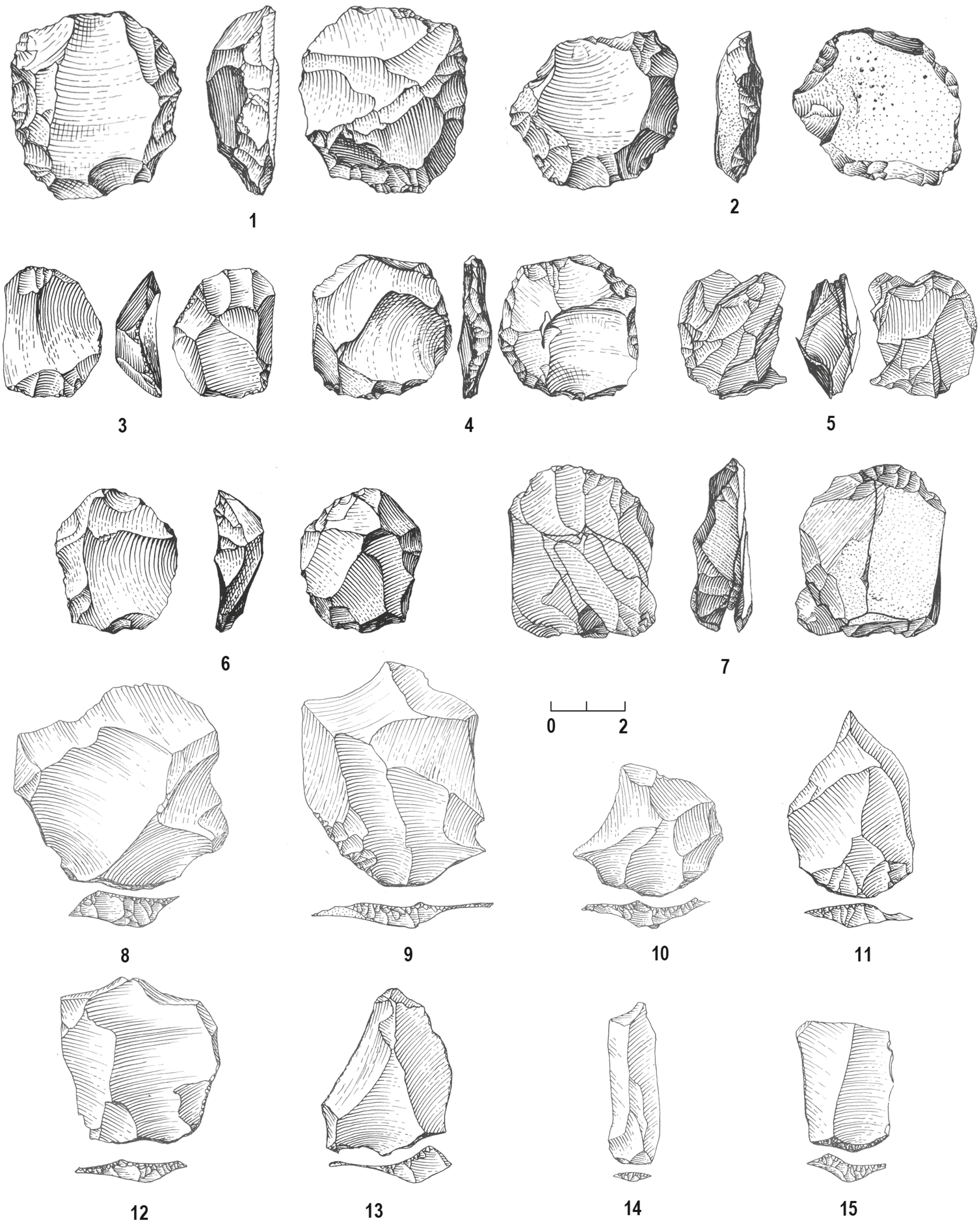

Fig. 12. Levallois preferential core (1, 2), Levallois preferential core with secondary production (3 - 5), Levallois recurrent unidirectional core (6), Levallois recurrent bidirectional core (7), Levallois flake (8 -15) of level B of Königsaue (modified from Mania & Toepfer 1973).

Abb. 12. *Levalloiskern mit Negativ eines Zielabschlags (1, 2), Levalloiskern mit Negativ eines Zielabschlags und sekundärer Produktion (3-5), Levalloiskern mit wiederholtem, gleichgerichtetem Abbau (6), Levalloiskern mit wiederholtem, bipolaren Abbau (7), Levalloisabschlag (8-15) aus Horizont B von Königsaue (Mania & Toepfer 1973).*

Flakes and fragments of flakes made up the bulk of the assemblage, whereas there were few cores and retouched tools (Fig. 5). In the core assemblage, the application of hierarchized methods was absent whereas the few recovered artefacts showed marked expediency (Fig. 6). The first core was characterized

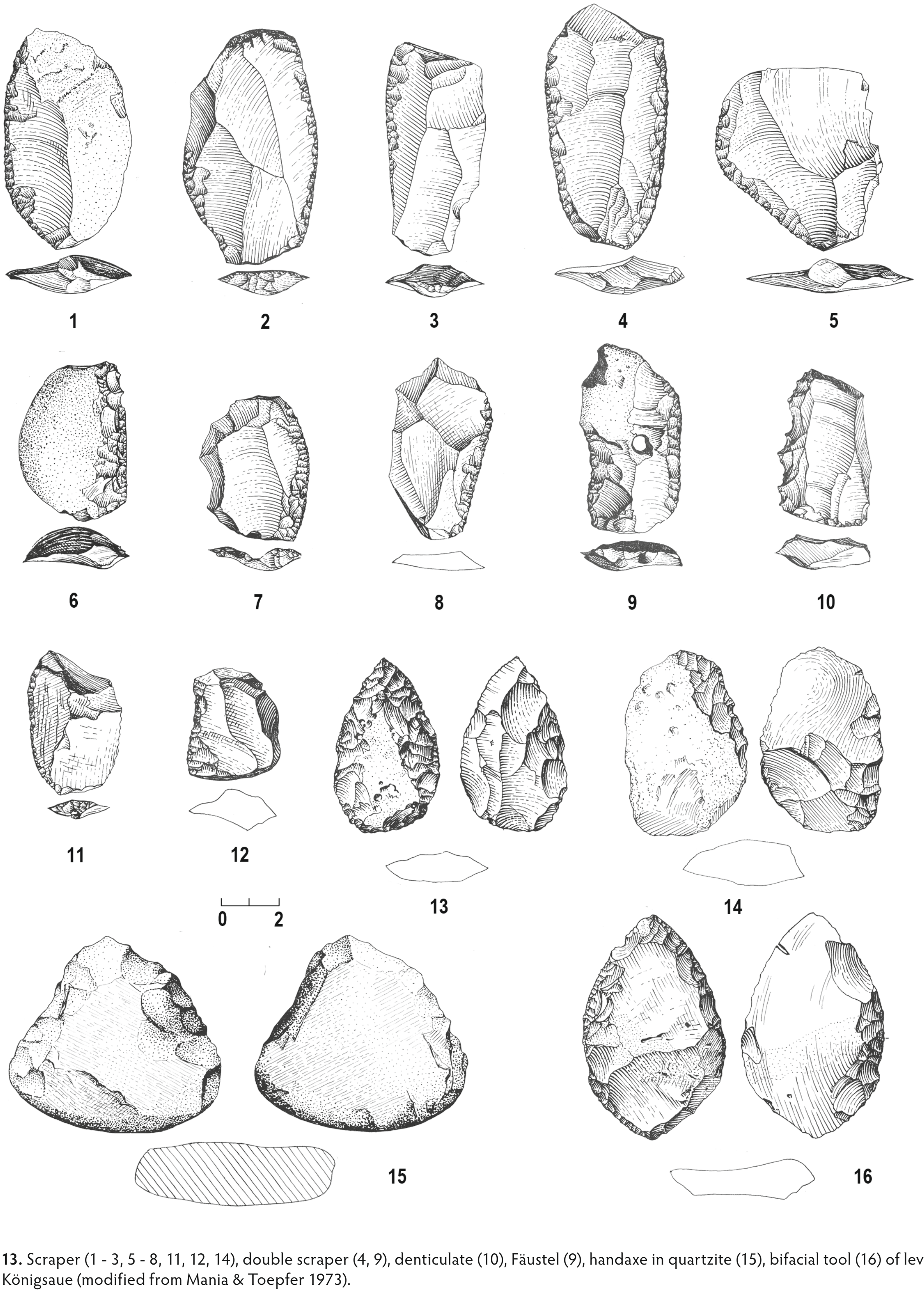

Fig. 13. Scraper (1 - 3, 5 - 8, 11, 12, 14), double scraper (4, 9), denticulate (10), Fäustel (9), handaxe in quartzite (15), bifacial tool (16) of level B of Königsaue (modified from Mania & Toepfer 1973).

Abb. 13. *Schaber (1-3, 5-8, 11, 12, 14), Doppelschaber (4, 9), gezähntes Gerät (10), Fäustel (9), Faustkeil aus Quarzit (15), bifazielles Gerät (16) aus Horizont B von Königsaue (verändert nach Mania & Toepfer 1973).*

by a bidirectional production on the ventral surface and a lateral detachment, probably used to maintain the convexity (Fig. 14: 1). The striking platform was not prepared, and analysis of the negative flake scars indicated that the blanks produced were quite large (n = 5, σ = 50.8 mm, S.D. = 16.2 mm). The second core

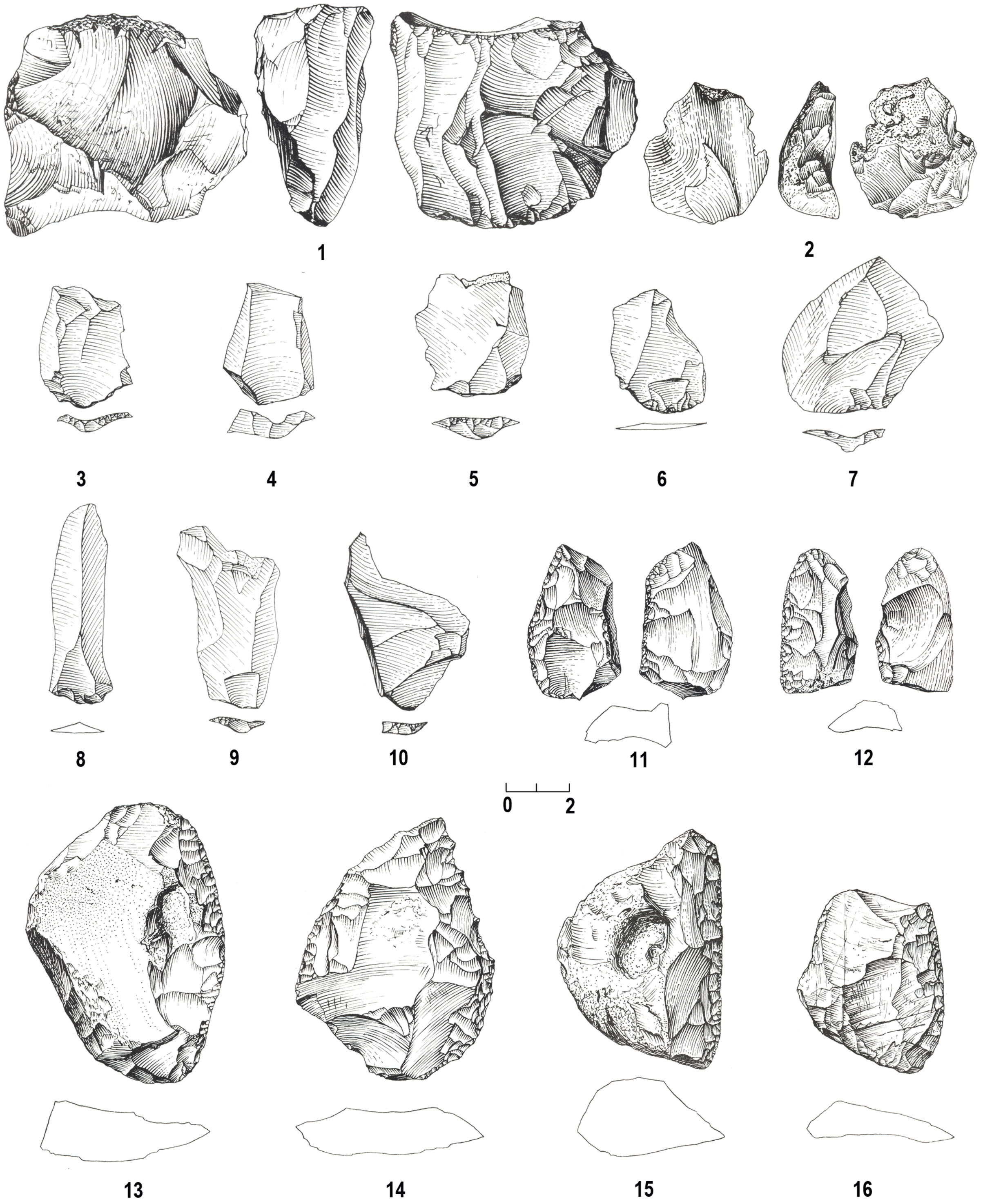

Fig. 14. Bidirectional core (1), core-on-flake (2), Levallois flake (3-5), flake (6-9), pseudo-Levallois point (10), demi-Quina scraper (11, 12, 16), Keilmesser (13), Quina scraper (14,15) of level C of Königsaue (modified from Mania & Toepfer 1973).

Abb. 14. *Kern mit bipolarem Abbau (1), Randabschlag (2), Levalloisabschlag (3-5), Abschlag (6-9), Pseudolevalloisspitze (19), demi-Quina-Schaber (11, 12, 16), Keilmesser (13), Quina-Schaber (14, 15) aus Horizont C von Königsaue (verändert nach Mania & Toepfer 1973).*

was made of quartz and characterized by the opportunistic detachment of two flakes. Short production was also recorded in two core-on-flakes where a single flake was detached from the proximal ventral surface (Fig. 14: 2). Conversely, the third core-on-flake was probably a portion of a pyramidal or un-hierarchized core in which three small flakes (n = 3, σ = 10.6 mm, S.D. = 2.3 mm) were produced from the ventral surface.

Analysis of the flake assemblage revealed the presence of by-products characteristic of the phases of core decortication, configuration, and production (Fig. 8). Within cortical flakes, core-edge removal flakes, and predetermining blanks, the presence of four Levallois recurrent unidirectional flakes is noteworthy (Fig. 8 & 14).

The assemblage of the retouched artefact was composed of scrapers, Quina and demi-Quina scrapers, and a *Keilmesser* (Fig. 10). The Quina scrapers were made on thick cortical blanks with the first stage of denticulation successively modified by a scalar retouch in order to regularize the cutting edge and create a large working area (Bourguignon 1997). The Quina and demi-Quina scrapers showed a steep working edge and different resharpening events (Fig. 14: 11, 12, 14 - 16). In some examples, the ventral surface of the tools was thinned by the detachment of few flakes, probably in order to facilitate the handling or hafting. The thinning was also applied to a scraper with the detachment of three flakes that removed the platform and the bulb. The *Keilmesser* recovered in level C differs from those in level A (Fig. 14: 13). The abrupt, cortical edge on one side impeded the leaf point- like reduction in the upper part and prevented any removals from the dorsal proximal side. The cutting edge showed some rejuvenation events by flat removals. The few by-products of bifacial shaping confirmed the use of the soft hammer (Fig. 11).

Statistical analysis

After the technological analysis, the metric attributes of the lithic assemblages were explored using statistical analyses. The comparison between the length of cortical and non-cortical flakes revealed similar mean values between levels and a Kruskal-Wallis test indicated no significant median differences (Fig. 15). A Mann Whitney test was also performed comparing the length between level A and B and there were no significant differences between the median values (No cortex: *p* = 0.2943; 1 - 49 %: *p* = 0.7175; 50 - 100 %: *p* = 0.824). However, the comparison between level A and B of the frequencies between the length intervals in cortical flakes indicated similar trends for cortical artefacts whereas in semi-cortical flakes, level A shows lower percentages in the category 40 mm and higher values in the 60 mm (Fig. 16).

The study focused also on the comparison between the Carination Index and the length of flakes. The Carination Index is an estimation of the volumetric shape of cores and is calculated as the ratio between length and width/thickness. A Mann Whitney test indicated no significant median difference between Levallois and hierarchized cores of level A and B whereas a t-test show as well no statistical differences in discoid cores (Fig. 17). Although this result pointed out volumetric correspondences between core categories, significant differences in length were observed between core-edge removal flakes (Fig. 18), between Levallois flakes (Mann Whitney test: *p* = 0.0412) and between core-edge removal flakes (Mann Whitney test: *p* = 0.0146) of level A and B. The comparison of Levallois flakes by length intervals shows that in level B, the categories between 2 and 4 cm were more abundant, whereas, in level A, the categories between 3 and 6 cm were well represented (Fig. 19).

In order to assess the integrity of the lithic assemblages, several knapping experiments were used for calculating the productivity rates of Levallois and discoid technologies (Appendix: Tabs. 1-3). Although some bigger blanks are present, the size of cores, and the cortical and no cortical flakes in the three levels (Figs. 15, 17 & 18), suggested that the raw material used at Königsaue were of small dimension. The chert pebbles, found in level B, are very small (weight: n = 3, σ = 47.6 g, S.D. = 9.8 g) with length values (n = 3, σ = 46.3 mm, S.D. = 3.2 mm) very similar to those of flakes (Figs. 15, 17 & 18) suggesting that slightly bigger nodules were choose for flake production. In this perspective, the rate of productivity for Levallois and discoid technologies were calculated for 0.25 and 0.1 kg of raw material (Fig. 20, Appendix, Tabs. 1-3). Since the productivity rates for Levallois technology shows very similar values, the estimation of Levallois recurrent unidirectional was also used for the modality Levallois preferential and recurrent bidirectional whereas the values of Levallois recurrent centripetal were applied for the Levallois orthogonal and undetermined. In hierarchized cores, cores with overshoot surface and core fragments with preparation of the striking platform, the productivity was

	No Cortex			1 - 49% Cortex			50 - 100% Cortex		
Level	A	B	C	A	B	C	A	B	C
n	222	976	52	112	416	19	46	127	3
Mean	33.7	32.6	33.1	39.0	37.7	32.3	35.8	36.0	33
S.D.	13.3	11.9	9.4	16.8	15.1	8.8	12.5	14.1	8
Kruskal-Wallis test	*p*=0.3241			*p*=0.4324			*p*=0.9658		

Fig. 15. Counts, mean, standard deviation (S.D.) and Kruskal-Wallis test of the length of the cortical and non-cortical flake assemblages of level A, B and C of Königsaue.

Abb. 15. *Mengen, Mittelwert, Standardabweichung (S.D.) und Kruskal-Wallis Test der Länge kortexbedeckter und kortexfreier Abschläge der Horizonte A, B und C von Königsaue.*

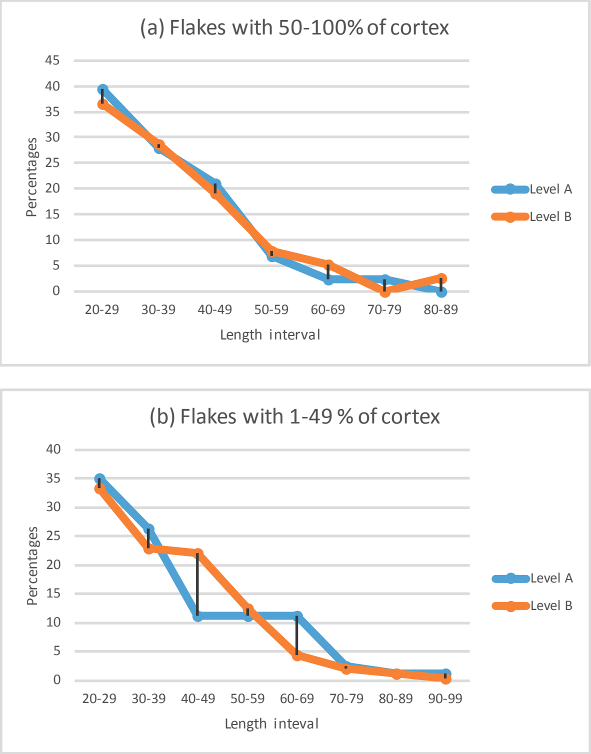

Fig. 16. Comparison between the percentages of cortical (a) and semi-cortical (b) flakes by length intervals of level A and B of Königsaue.

Abb. 16. *Vergleich der Anteile von Längenklassen zwischen Kortexabschlägen (a) und Abschlägen (b) mit Kortex der Horizonte A und B von Königsaue*

calculated as a mean of the values of the three technologies. In Figures 21 and 23, were added to the count the number of core fragments, showing a preparation of the striking platform, and Levallois cores that are permanently displayed at the Landesmuseum für Vorgeschichte in Halle (Germany).

The results of comparison between the lithic assemblage and the experimental flake productivity of level A documented the presence of more cortical and no cortical flakes than expected both for nodules of 0.25 and 0.1 kg (Fig 22). Conversely, in core management and production categories a deficit in the flake assemblage is supported for nodules of 0.25 kg whereas in pebbles of 0.1 kg a surplus of flakes is recorded (Fig. 22). In level B, the model revealed a deficit in the number of cortical and no cortical flakes for nodules of 0.25 kg and a surplus of flake production in nodules of 0.1 kg (Fig. 24). In the category core management and production, cobbles of 0.25 kg show a deficit of flake whereas in smaller artefacts are documented more flakes than expected (Fig. 24).

Discussion

Hunter-gatherers move on the landscape in relation to the distribution of resources and the periods of when and where those resources become available. Ethnographic studies associate types of forager mobility with different ecosystems (Binford 1978, 1980, 2001; Kelly 1983, 1995). Residential mobility is mainly used

	Levallois core		Discoid core		Hierarchized core	
Level	**A**	**B**	**A**	**B**	**A**	**B**
n	5	51	2	9	3	30
Mean	14.6	19.6	20.2	29.4	33.1	25.7
S.D.	3.4	21.5	1.7	12.1	2.8	9.9
Mann Whitney	*p*=0.5881		*t*=1.032, df=9, *p*=0.3291		*p*=0.1328	

Fig. 17. Counts, mean, standard deviation (S.D.) and Mann Whitney test (t-test for discoid cores) of the Carination Index of the core assemblages of level A and B of Königsaue.

Abb. 17. *Mengen, Mittelwert, Standardabweichung (S.D.) und Mann-Whitney Test (t-Test für diskoide Kerne) eines Index zur Beurteilung der Form der Kerne der Horizonte A, B und C von Königsaue.*

	Levallois flake			Core-edge removal flake			Pseudo-Levallois point		
Level	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
n	30	74	4	39	216	9	8	73	2
Mean	41.3	35.7	34.8	30.5	35.1	31	32	32.5	29
S.D.	12.8	12.0	4.3	11.9	12.0	9.0	12.0	10.8	7.1
Kruskal-Wallis test	*p*=0.1073			*p*=0.0418			*p*=0.9301		

Fig. 18. Counts, mean, standard deviation (S.D.) and Kruskal-Wallis test of the length of Levallois, core-edge removal flakes and pseudo-Levallois points of level A, B and C of Königsaue.

Abb. 18. *Mengen, Mittelwert, Standardabweichung (S.D.) und Kruskal-Wallis Test der Länge von Levalloisabschlägen, Randabschlägen und Pseudolevalloisspitzen der Horizonte A, B und C von Königsaue.*

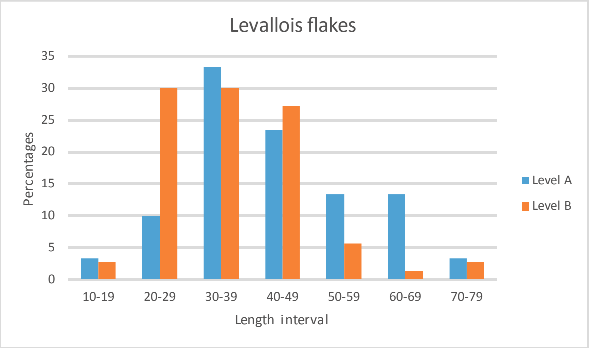

Fig. 19. Bar chart of comparison between the percentages of Levallois flakes by length intervals in level A and B of Königsaue.

Abb. 19. *Histogramm zum Vergleich der Längenhäufigkeiten bei Levalloisabschlägen der Horizonte A und B von Königsaue.*

in homogeneous environments where resources are primarily scattered throughout the region, whereas logistical mobility is more related to zones with seasonal climates where resources are patchy. Although hunter-gatherers might have broad control over the abundance of biotic resources in their territory, the climatic oscillation and orographic setting of the landscape strongly influence the allocation of supplies, increasing their patchiness and consequently, the risk of failures by foragers. Anticipate mobility, food sharing, and diversification in the subsistence strategies are critical behaviours to minimize the risk of food shortage (Brantingham 2006; Hawkes et al. 1993; Kent 1991). From this perspective, foragers pondered the use of different types of mobility by weighing the logistical costs of traveling back to the central place against the benefits of moving the residential base (Kelly 1995). In a high-mobility context, transporting unprocessed resources is more convenient in small foraging radii, whereas field processing of resources is more beneficial over larger radii because of the increased load utility (Bettinger et al. 1997; Lupo 2007; Metcalfe & Barlow 1992). These different strategies of mobility and settlement dynamics leave different traces on the occupation floors (Binford 1980). During logistical displacements, only extractive activities were carried out, and the archaeological record should show some redundancy in the lithic and faunal assemblages. Conversely, in residential camps, a broader variety of domestic activities should be documented.

The technological analyses of levels A, B, and C of Königsaue show the use of similar core technologies in *Keilmessergruppen* and Levallois-Mousterian facies (Figs. 6 & 8). Levallois technology is commonly utilized in the preferential, uni- and bidirectional modality, whereas in secondary *chaînes opératoires*, the use of discoid, hierarchical, and uni- and bidirectional methods are recorded. *In-situ* knapping activities in the three levels have been observed, but prepared core technologies show a fragmentation of the operative chains. In level A, the comparison between the number of cores and Levallois flakes indicates an export off-site of Levallois cores (Figs. 6 & 8). This pattern of core export is also observed after the computation of flake productivity that show a surplus of cortical flakes and a deficit of products and core management artefacts in cobbles of 0.25 kg (Fig. 22). In level C, the technological analysis shows by-products of Levallois reduction events, but Levallois cores are

	Lev. rec. unidirectional		Lev. rec. centripetal		Discoid		Mean	
	0.25	0.1	0.25	0.1	0.25	0.1	0.25	0.1
Cortical	5	2	6	2	5	2	6	2
No cortical	12	5	13	5	8	3	10	4
Management	23	9	22	9	17	7	21	8
Production	6	2	10	4	15	6	10	4

Fig. 20. Flake productivity rates in experimental Levallois recurrent unidirectional, Levallois recurrent centripetal and discoid by 0.25 and 0.1 kg of flint.

Abb. 20. *Abschlaghäufigkeiten bei experimentell durchgeführtem Levalloiskonzept mit wiederholtem, gleichgerichtetem Abbau beziehungsweise wiederholtem, umlaufendem Abbau sowie diskoidem Kern bei Feuersteinknollen von 0,25 und 0,1 kg.*

Level A	n core	Expected Cortical flakes		Expected No Cortical flakes		Expected Management flakes		Expected Production flakes	
		0.25	0.1	0.25	0.1	0.25	0.1	0.25	0.1
Levallois preferential	6	30	12	72	30	138	54	36	12
Levallois rec. uni.	1	5	2	12	5	23	9	6	2
Discoid	2	10	2	16	6	34	14	30	12
Hierarchized centr.	3	18	6	30	12	63	24	30	12
Core overshoot flake	2	12	4	20	8	42	16	20	8
Core Fragments	5	30	10	50	20	105	40	50	20
Total	**19**	**105**	**36**	**200**	**81**	**405**	**157**	**172**	**66**

Fig. 21. Counts of the expected flake productivity of level A of Königsaue.

Abb. 21. *Menge erwarteter Abschläge in Horizont A von Königsaue.*

Level A	Expected Cortical flakes		Expected No Cortical flakes		Expected Management flakes		Expected Production flakes	
	0.25	**0.1**	**0.25**	**0.1**	**0.25**	**0.1**	**0.25**	**0.1**
n Archaeological flakes	158	158	298	298	250	250	95	95
n Estimated exp. Flakes	105	36	200	81	405	157	172	66
n A – n E	53	122	98	217	-155	93	-77	29

Fig. 22. Comparison and difference between the number of flakes of level A and the expected amount of flakes based on the experimental productivity rates.

Abb. 22. *Menge und Unterschiede zwischen Abschlägen aus Horizont A und der aufgrund der Experimente erwarteten Abschlagzahl.*

Level B	n Core	Expected Cortical flakes		Expected No Cortical flakes		Expected Management flakes		Expected Production flakes	
		0.25	**0.1**	**0.25**	**0.1**	**0.25**	**0.1**	**0.25**	**0.1**
Levallois preferential	25	125	50	300	125	575	225	150	50
Levallois rec. uni.	12	60	24	144	60	276	108	72	24
Levallois rec. bidir.	3	15	6	36	15	69	27	18	6
Levallois centripetal	3	18	6	39	15	66	27	30	12
Levallois orthogonal	2	12	4	26	10	44	18	20	8
Levallois undeter.	9	54	18	117	45	198	81	90	36
Discoid	9	45	18	72	27	153	63	135	54
Hierarchized uni.	7	42	14	70	28	147	56	70	28
Hierarchized bidir.	10	60	20	100	40	210	80	100	40
Hierarchized centr.	13	78	26	130	52	273	104	130	52
Core overshoot flake	8	48	16	80	32	168	64	80	32
Core Fragments	23	138	46	230	92	483	184	230	92
Total	**124**	**695**	**248**	**1344**	**541**	**2662**	**1037**	**1125**	**434**

Fig. 23. Counts of the expected flake productivity of level B of Königsaue.

Abb. 23. *Menge erwarteter Abschläge in Horizont B von Königsaue.*

Level B	Expected Cortical flakes		Expected No Cortical flakes		Expected Management flakes		Expected Production flakes	
	0.25	**0.1**	**0.25**	**0.1**	**0.25**	**0.1**	**0.25**	**0.1**
n Archaeological flakes	543	543	1223	1223	798	798	467	467
n Expected flakes	695	248	1344	541	2662	1037	1125	434
n A - n E	-152	295	-121	682	-1864	-239	-658	33

Fig. 24. Comparison and difference between the number of flakes of level B and the expected amount of flakes based on experimental productivity rates.

Abb. 24. *Menge und Unterschiede zwischen Abschlägen aus Horizont B und der aufgrund der Experimente erwarteten Abschlagzahl.*

missing, supporting the hypothesis that they were part of the transported toolkit (Figs. 6 & 8). The small dimension of the flake assemblages is in contrast with the bigger size of *Keilmesser*, Quina scrapers and some tools suggesting that bigger nodules were collected in other localities. Conversely, in level B, comparing the number of cores and flakes indicates a pattern of exporting blanks off-site in cobbles of 0.25 kg (Fig. 24). In the example of nodules of 0.1 kg, the model instead supports the exporting of cores off-site or a mix of strategies of exporting configured cores and importing artefacts at the site (Fig. 24).

This study points out that the discrepancy between the *Keilmesser* and the Levallois-Mousterian levels is not only related to the absence of bifacial knives but also to the composition of the transported toolkit, suggesting two different types of mobility on the landscape. In levels A and C, the technological data indicate a strategy of logistical mobility with knapping events of toolkit maintenance and artefact production for urgent needs. The recovery of several by-products of bifacial flaking (Fig. 11) indicates that bifacial knives and *Keilmesser* tools were transported to the site already configured, and only resharpening events were carried out at the lakeshore. In levels A and C, bifacial knives were associated with Quina and demi-Quina scrapers (Fig. 10), another type of tool related to the high mobility context (Meignen et al. 2007). Moreover, the transport of configured cores supports the hypothesis of logistical displacements around the base camp because carrying costs of these artefacts are lower in reduced mobility (Jennings et al. 2010; Kuhn 1994; Surovell 2009). In level A, the archaeological finds were scattered over a shoreline of more than 200 m with four main accumulations, whereas in level C, two main clusters of artefacts were distributed over an area of ~100 m (Fig. 3; Mania & Toepfer 1973). Thus, the spatial distribution, fragmentation of operative chains, presence of Quina and demi-Quina scrapers, and abundant number of faunal remains suggest that levels A and C were probably a palimpsest of repeated short-term occupations by Neanderthals that temporally visited the lakeshore.

In level B, the archaeological finds were scattered over a shoreline of more than 200 m and clustered in approximately six concentrations (Fig. 3) (Mania &

Toepfer 1973). The amount of lithic items was greater than level A, but the number of faunal remains was significantly lower. The operative chains were fragmented, and the transport of flakes rather than cores was advantageous for mobile groups in terms of low carrying costs (Kuhn 1994; Surovell 2009). All these aspects support the hypothesis that level B was also a palimpsest of short-term occupations, but of residential mobility. This different strategy of displacement is also evident when comparing the length of Levallois flakes between levels (Fig. 19). This pattern indicates that in level A, cores arrived at the site with different stages of reduction, whereas in level B, the domestic activities required more intense exploitation of the core volumes because bigger Levallois flakes were systematically exported.

An unresolved problem is understanding the amount of artefacts transported into the site. Unfortunately, the common recognition of allochthonous raw materials could not be performed at Königsaue because the glacier advances from Fennoscandia in north-central Europe transported the same types of flint nodules over large areas (Richter et al. 1986). Thus, the artefacts of the transported toolkit could only be presumed by their degree of reduction. This group could include some thinned scrapers and Levallois cores in levels A and B that showed the opportunistic detachment of a few more flakes once the ventral convexity was exhausted and production could not continue.

Keilmessergruppen and Levallois-Mousterian in Central Europe

During the Middle Palaeolithic, Neanderthals exploited a variety of ecological habitats using a broad dietary spectrum (Fiorenza et al. 2015). Strategies of mobility and artefacts transports changed according to the aims of displacements, the environmental settings and raw materials distributions. In this perspective, settlement dynamics in open-air and cave sites of Central Europe documented different use of the landscape taking advantage of animal routes and water availability (Conard & Prindiville 2000; Di Modica, 2011; Gaudzinski, 2006; Gaudzinski-Windheuser et al., 2014; Glauberman 2016; Roebroeks 1988; Roebroeks et al. 1992b). Analysis of the lithic assemblages of Königsaue demonstrates that the main difference between the *Keilmesser* and Levallois-Mousterian levels, beyond the presence of bifacial tools, is the logistical and residential mobility strategies. A review of the available information on the lithic series of other archaeological sites in central Europe shows similar patterns. Unfortunately, complete descriptions of the technological categories are missing for many due to the use of different methodologies. This problem impedes comparison with the experimental materials and recognitions of the patterns of artefact transport in/off-site.

In *Keilmessergruppen*, most of the sites could be interpreted as short-term occupations. In northern Europe, at Saint-Illiers-la-Ville (France), a Micoquian handaxe was found within few hierarchized, discoid and unidirectional cores (Blaser & Chaussé 2016). The number of Levallois preferential flakes suggests the export of Levallois cores off-site, whereas the amount of core-edge removal flakes and pseudo-Levallois also implies the systematic export of these artefacts (Blaser & Chaussé 2016). At the German open-air sites of Lichtenberg (Veil et al., 1994) and Pouch-Terrassenpfeiler (Weiss 2016), the lithic collections show higher proportions of retouched tools and bifacial knives within a few cores and small flake productions. Conversely, at Salzgitter Lebenstedt, *Keilmesser* tools are associated with a greater amount of Levallois flakes and cores (Pastoors 2001). A comparison with the experimental material indicates an export of flakes rather than Levallois cores, suggesting a strategy of residential mobility aimed at repeated episodes of hunting reindeer herds (Gaudzinski & Roebroeks 2000). At Sesselfelsgrotte in southern Germany, several layers of complex G indicate a seasonal land use strategy using residential mobility during spring and summer and logistical mobility during late summer and autumn (Richter 2006, 2014). In the Swabian Jura, studies on the lithic assemblages of several cave and open-air sites portray low anthropogenic occupations during the Middle Palaeolithic, suggesting high mobility of small Neanderthals groups (Çep & Waiblinger 2001; Conard et al. 2012). At Biśnik Cave in Poland, the lithic assemblages of levels 11-9 show evidence of sporadic settlements with high percentages of tools, and few cores and flakes, whereas in the upper levels 8-4, the amount of flake production increased (Cyrek et al. 2014). Levallois technology is used in these levels but with different patterns of transport. Flakes in levels 11-9 were exported, whereas Levallois cores in levels 8-4 were transported off-site (Cyrek et al. 2014). At Obłazowa Cave, the Micoquian lithic collection (restricted to a small area of 1.5 m^2 in level XVIIIb) is characterized by a high amount of retouched tools, few flakes, and one core (Valde-Nowak & Nadachowski 2014). A similar pattern is also recorded at Ciemna Cave in the recently excavated CK sector, where many retouched tools with few flakes and cores were discovered (Valde-Nowak et al. 2016). In sector CO, only the Micoquian level 6 shows a greater amount of lithic remains, although the number of cores is still scant compared with flakes and retouched tools (Valde-Nowak et al. 2016). Repeated anthropogenic occupations are documented at Wylotne Cave, where more than 14'000 lithic items have been found. Although the numerous remains might suggest residential use of the natural shelter, the lithic analysis again demonstrates a similar pattern to other Polish sites with high frequencies of retouched tools and smaller amounts of cores (Kozłowski 2006). At Kulna Cave in the Czech Republic, the Micoquian levels 7c, 7a, and 6 show the import of many configured cores to the site, scant flake production with a fragmentation of the operative chains, and high numbers of stone tools (Neruda 2011). At the Bojnice III open-air site in Slovakia, the lithic assemblages are again characterized by fragmentation of the operative chains and transport of retouched tools made of high-quality raw materials from outcrops located approximately 50 km away (Neruda and Kaminská 2015).

In central Europe, there is more proof of Levallois-Mousterian than *Keilmessergruppen* assemblages. Moreover, few technological descriptions of the lithic series are available because many studies were performed with a typological approach. At the open-air site of Hallera Avenue in Poland, the lithic assemblages of the lower and upper horizons indicate repeated short anthropogenic occupations (Wiśniewski et al. 2013). Levallois technology was used less than other un-hierarchized methods that were mostly applied opportunistically. The greater degree of Levallois core exhaustion suggests that the cores were transported from the site along with a wide range of retouched tools (Wiśniewski et al. 2013). At Piekary IIa, low-intensity occupations are recorded in levels 7c and 7b, whereas the densest concentration of archaeological remains is found in level 7a (Zieba et al. 2008). The lithic assemblages show *in-situ* knapping activities with the presence of some refitted cores and flakes as well as fragmentation of the operative chains. Levallois method is well represented in layer 7b, with lesser frequency in levels 7c and 7a. The number of cores is scant compared to the number of flakes. Similarly, the number of retouched tools is quite low (Zieba et al. 2008).

The comparison between the *Keilmessergruppen* and the Levallois-Mousterian facies in Central Europe show similar patterns of settlement dynamics. Although some studies indicate the abundant use of local raw materials (Çep 2000; Cyrek et al. 2014; Neruda 2011; Valde-Nowak et al. 2016), the lithic series display a general trend of high mobility on the landscape in both cave and open-air sites. In *Keilmesser* assemblages, retouched tools and cores have an important role in the toolkit composition, whereas in Levallois-Mousterian, hierarchical cores are the preferred transported artefacts. This strategy is consistent with logistical mobility, whereas the examples of flake export could be associated with residential movements on the territory (Kuhn 1994; Surovell 2009).

Conclusion

The technological reassessment of the lithic assemblages of Königsaue reveals that in the *Keilmesser* and Levallois-Mousterian levels, Neanderthals followed different mobility strategies, settling the Aschersleben lakeshore for repeated short-term occupations. Climatic fluctuations and patchiness of resource availability could have influenced hunter-gatherer displacement tactics with the use of logistical or residential moves. Comparison with other archaeological sites in central Europe shows similar patterns, with a general trend of high mobility in Neanderthal groups during the late Middle Palaeolithic. Using experimental materials to evaluate the integrity of the archaeological lithic series is an important method in understanding the fragmentation of the operative chains and types of artefacts transported off-site. Further studies and comparisons of *Keilmessergruppen* and Levallois-Mousterian lithic assemblages will enhance the knowledge of Neanderthal lifestyles and seasonal land use in central Europe.

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	Br13-18					Le1-7					Pa1-4				
	n	Weight	Ratio W/n	n by 0.25 Kg	N° by 0.1 Kg	n	Weight	Ratio W/n	n by 0.25 Kg	n by 0.1 Kg	n	Weight	Ratio W/n	n by 0.25 Kg	n by 0.1 Kg
Cortical	93	4529	49	5	2	105	4114	39	6	3	80	3857	48	5	2
No cortical	215	4613	21	12	5	126	3343	27	9	4	128	2047	16	16	6
Management	138	1660	12	21	8	85	1444	17	15	6	96	694	7	35	14
Production	77	2953	38	7	3	41	1899	46	5	2	32	1353	42	6	2

Appendix: Tab. 1. Computation of flake productivity by 0.25 kg and 0.1 kg of flint in experimental Levallois recurrent unidirectional technology. Modified after Brenet (2011).

Appendix: Tab. 1. Berechnung der Abschlaghäufig bei Feuersteinknollen von 0,25 und 0,1 kg in der experimentellen Levallois rezidivierenden unidirektionalen Technologie. Verändert nach Brenet (2011).

	Br8-12					Bo3-4					LR1-4				
	n	Weight	Ratio W/n	n by 0.25 Kg	n by 0.1 Kg	n	Weight	Ratio W/n	n by 0.25 Kg	n by 0.1 Kg	n	Weight	Ratio W/n	n by 0.25 Kg	n by 0.1 Kg
Cortical	132	5512	42	6	2	66	3665	56	5	2	98	4346	44	6	2
No cortical	253	4255	17	15	6	131	2583	20	13	5	261	5472	21	12	5
Management	176	1387	8	32	13	78	822	11	24	9	184	4143	23	11	4
Production	77	2868	37	7	3	53	1761	33	8	3	77	1329	17	14	6

Appendix: Tab. 2. Computation of flake productivity by 0.25 kg and 0.1 kg of flint in experimental Levallois recurrent centripetal technology. Modified after Brenet (2011) and Picin (2014).

Appendix: Tab. 2. Berechnung der Abschlaghäufig bei Feuersteinknollen von 0,25 und 0,1 kg in der experimentellen Levallois rezidivierenden zentripetal Technologie. Verändert nach Brenet (2011) und Picin (2014).

	D1-4				
	n	Weight	Ratio W/n	n by 0.25 Kg	n by 0.1 Kg
Cortical	150	7038.8	47	5	2
No cortical	229	3666.9	32	8	3
Management	101	1464.8	15	17	7
Production	128	2202.1	17	15	6

Appendix: Tab. 3. Computation of flake productivity by 0.25 kg and 0.1 kg of flint in experimental bifacial discoid technology. Modified after Picin (2014).

Appendix: Tab. 3. Berechnung der Abschlaghäufig bei Feuersteinknollen von 0,25 und 0,1 kg in der experimentellen bifaciale disckoidem Technologie. Verändert nach Picin (2014).

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