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Looking for provisioning places of shaped tools of the late Neanderthals: A study of a Micoquian open-air site, Pietraszyn 49a (southwestern Poland)

À la recherche des lieux d'approvisionnement en outils des derniers néandertaliens : étude d'un site micoquien de plein air, Pietraszyn 49a (Sud-Ouest de la Pologne)

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A R T I C L E I N F O

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A B S T R A C T

The purpose of this article is to yield new insights into the topic of provisioning places of late Neanderthals using records from the central European Micoquian workshop Pietraszyn 49a, located in southwestern Poland. The site has been radiometrically dated back, using optically stimulated luminescence, to the final phase of Marine Isotope Stage (MIS) 4 or the beginning of MIS 3. The technological study, supported by numerous refits, shows that the main goals of manufacturing were shaped tools typologically corresponding to knives, handaxes, and bifacial scrapers. Considering the large variety of lithic raw materials and technical features, it can also be concluded that this assemblage resulted from the activity of at least several individuals. A microscopic investigation of use-wear traces indicates that this place was integrated within other elements of foraging zones, such as killing or butchering sites.

R É S U M É

L'objectif de cet article est d'approfondir notre connaissance des lieux d'approvisionnement des derniers néandertaliens, à partir des données fournies par un atelier micoquien d'Europe centrale, Pietraszyn 49a, localisé dans le Sud-Ouest de la Pologne. Le site a été daté radiométriquement par luminescence stimulée optiquement, de la dernière phase du stade

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Outils façonnés
Chaîne opératoire
Approvisionnement

isotopique marin 4 ou du début du stade 3. L'étude technologique, basée sur un nombre important de réaménagements, montre que le principal objectif du façonnage était de confectionner des outils correspondant typologiquement à des couteaux à dos, des bifaces et des racloirs à retouche bifaciale. Au vu de la grande variété des matières premières lithiques et des caractéristiques techniques, on peut également conclure que cet assemblage résulte de l'activité de plusieurs individus au moins. L'étude, réalisée au microscope, des traces d'utilisation/usure montre que le site était intégré à un réseau d'autres sites d'approvisionnement, de types haltes de chasse ou aires de dépeçage.

1. Introduction

Assemblages with shaped tools of the so-called central European Micoquian (CEM), Prądnicien (Pradnikian) or Keilmessergruppe are one of the hallmarks of the late Middle Palaeolithic in Europe (Bosinski, 1967, 2006; Chmielewski, 1969; Conard and Fischer, 2000; Jöris, 2006; Kozłowski, 2014; Krukowski, 1939; Mania, 1990; Sobczyk, 1975). A long tradition of research on this phenomenon has resulted in a broad scope of studies. The most discussed issues have concerned the spatial, chronological, functional, and morphological diversity of bifacial tools (Boëda, 1995; Burdukiewicz, 2000; Frick et al., 2017; Iovita, 2014; Jöris, 2001, 2004, 2006; Koulakovska et al., 1993; Migal and Urbanowski, 2006; Richter, 1997; Ruebens, 2012; Uthmeier, 2016; Veil et al., 1994).

Little attention has been devoted to the organisation of technologies within the zones in which humans extracted and transformed raw materials into shaped tools. The classical model of technological organisation of the CEM introduced nearly two decades ago by Richter (1997, 2006) primarily focused on the variety of tools, while human behaviour within the aforementioned zones remained beyond the scope of central interest. It was assumed that the season of human activity was the key factor influencing tool diversity. A recent study also omitted the question of provisioning and producing shaped tools, focusing instead on the reconstruction of primary tool shapes based on highly reduced artefacts (Neruda and Kaminská, 2013) or the variability of core reduction methods regarding mobility (Picin, 2016). Therefore, little is known about the dynamics and structure of tool shaping, as well as the relationships between various places within foraging areas of the CEM, compared to other Middle Palaeolithic units (Depaepe, 2004).

In this paper, we discuss the significance of workshops where shaped tools were made, answering the question regarding the organisation of production. First, we discuss principles governing the manufacturing of lithic tools and the directions for production. Second, we determine the productivity of shaped tools manufactured in such places. Finally, we undertake a discussion regarding the relationship of workshops with other sites where other activities, such as killing or butchering, were conducted. We are convinced that such fragments of foraging zones must have influenced the extraction system of late Neanderthals regarding the quality and quantity of hunting tools, as well as the efficiency of extraction of food resources.

While discussing this issue, we rely on several assumptions. First, the production of shaped tools was aimed at obtaining ready-to-use specimens that would meet the condition of repeated sharpening (Morrow, 1996), being also resistant to damage (Bamforth, 1986). It is assumed that the process of maintaining the tool probably resulted from specific shaping, which allowed the edge to be renewed through a series of detachments oriented toward the appropriate side of the tool (Boëda, 1995; Iovita, 2014). Second, manufacturing was based on routine knowledge about the size and availability of resources and the opportunity to devote adequate time to perform this type of task. In other words, the exploration of areas combined with the exchange of tools had to be included in the plans regardless of the supply strategies used (Binford, 1979; Gould and Saggers, 1985; Kuhn, 1995; Tomasso and Porraz, 2016). Finally, for the purpose of this paper, a provisioning place may be defined as a place of production of ready-to-use tools made of local raw material or transported from an immediate proximity of the site. As such, the structure of the provisioning places is illustrated by a predominance of waste corresponding to almost all stages of tool manufacturing.

As a case study, the open-air site Pietraszyn 49a (SW Poland) was used. The uniqueness of the location lies in the fact that we can "decode" almost the entire process of bifacial tool production, from the selection of raw materials to the ready-to-use form. The reconstruction of operational schemes was possible because the data set accomplishes both the condition of representation and completeness (Soressi and Geneste, 2011). Geophysical dating (OSL) indicates that the remains were deposited at the end of MIS 4 or the beginning of MIS 3. Understanding the significance of the new records requires a short overview of Micoquian settlement in the Oder and Vistula Rivers valleys north of the Carpathians and the Sudetes.

2. Human occupational patterns related to the CEM north of the Carpathians and Sudetes in the last glacial period

The case study belongs to the CEM, which is the most widespread cultural complex of the late Middle Palaeolithic, which forms a part of the northern frontier settlement in central Europe (Burdukiewicz, 2000; Kozłowski, 2014; Sudoł, 2013; Wiśniewski, 2016). These sites are known from mountain areas (Valde-Nowak and Cieśla, 2014), uplands (Cyrek et al., 2014; Valde-Nowak et al., 2014) and lowlands (Schild, 2005; Wiśniewski et al.,

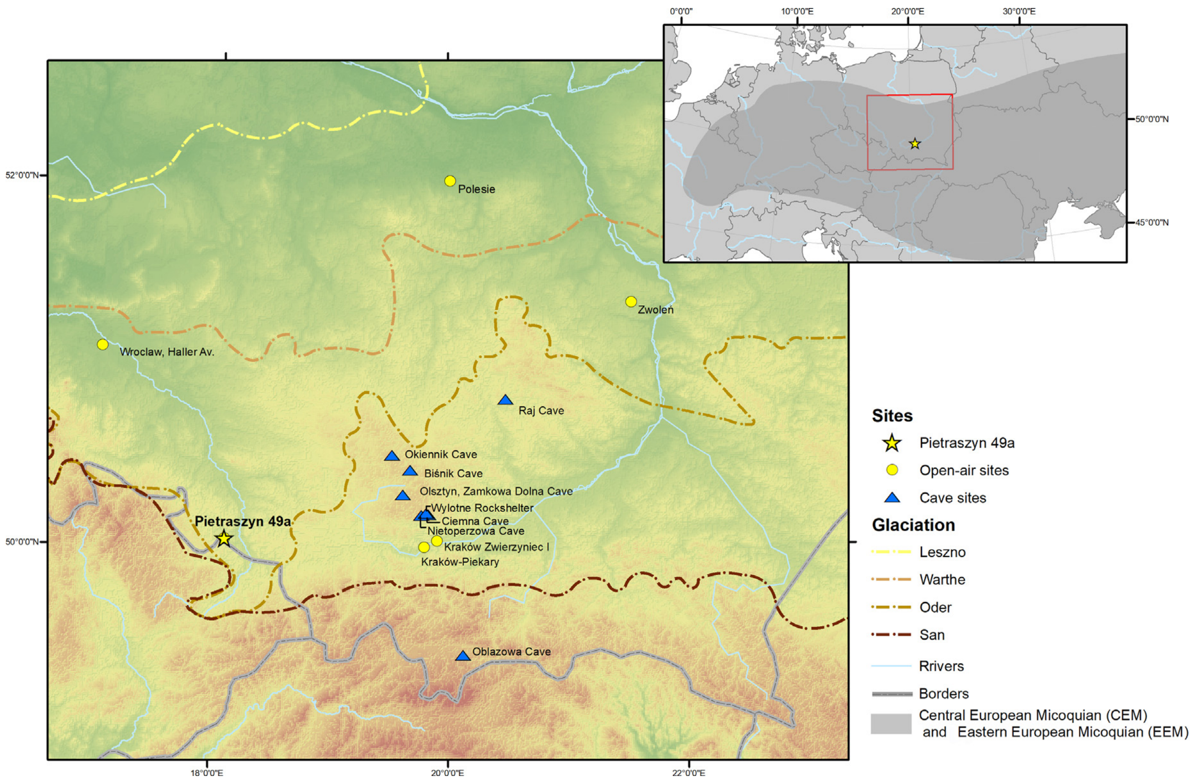

Fig. 1. General map showing the locations of the Micoquian sites dated to MIS 5d-MIS 3 with the extents of Pleistocene glaciations (after Lewandowski, 1988; Litt et al., 2007; Marks, 2005). Source: ASTER GDEM is a product of NASA and METI.

Fig. 1. Répartition des sites micoquiens datés du MIS 5d au MIS 3 dans le contexte de l'extension des glaciations du Pléistocène (par Lewandowski, 1988; Litt et al., 2007 ; Marks, 2005). La source, ASTER GDEM, est un produit de la NASA et du METI.

2013) up to 52°01′ N (Fig. 1, Domańska et al., 2013). A similar geographical range of settlement has been noted in Germany (Richter, 2016; Veil et al., 1994) and in Russia (Ocherednoi et al., 2014; Rolland, 2010).

As far as chronology is concerned, some of the sites are correlated with MIS 5a/5d and MIS 4 (Bosinski, 1967, 2001, 2006; Schild, 2005). However, it should be noted that the precise chronological framework of these early Micoquian sites remains an open question due to the lack of radiometric dating. More numerous and better dated sites are attributed to early MIS 3 (Alex et al., 2017; Bobak et al., 2013; Cyrek et al., 2014; Valde-Nowak et al., 2014, 2016; Żarski et al., 2017). The Micoquian sites from the transition between MIS 4 and MIS 3 are undoubtedly the dominant group among all Middle Palaeolithic sites (Wiśniewski, 2016).

The geographical and chronometric data cited above confirm that the CEM population was well adapted to diverse regional conditions and show that basic resources were mosaically scattered across a large area. This distribution resulted in a highly mobile system of occupation, but one not reflected by the provisioning system for lithic raw materials of Neanderthals. In most cases, transportation of raw materials did not exceed 5 km and only in a few cases more than 35–60 km (Zwoleń) or 100 km (Raj Cave, layer 6) (Féblot-Augustins, 1997; Kozłowski, 1972; Królik, 2005). Similar results were also obtained in Moravia (Neruda, 2011).

The Micoquian sites are abundant in all available siliceous raw materials ranging from radiolarite (Obłazowa Cave) through the "chocolate" flint (Zwoleń), the Świeciechów flint (Raj Cave), the so-called Cracow Jurassic flint (Ojców Cave, Cracow-Piekary complex, Biśnik Cave and Stajnia Cave), and finally glacial erratic flints of different ages (Wrocław, Hallera Av.) (Kozłowski, 1972; Krajcarz et al., 2012; Schild, 2005; Tomaszewski, 2004; Valde-Nowak and Cieśla, 2014; Wiśniewski et al., 2013).

As a part of human occupational patterns of CEM groups, we investigated settlement structures. In light of new excavations and recent studies of old collections from caves and rock shelters, as well as from the open-air sites [e.g., Biśnik Cave, layers 7-8, 4-6, Raj Cave, layer 6; Wrocław, Haller Av. upper level (Cyrek et al., 2014; Kozłowski, 1972; Sudoł, 2013; Wiśniewski et al., 2013)], it seems that the finds associated with short-term stays predominate. In this context, it is worth mentioning that most finds reflect narrow activity limited to core reduction or the use of a dozen retouched tools. The remnants of hearts are very rare (Cyrek et al., 2014).

Only single hunting sites, combined with killing and butchering practices (Zwoleń) or transport of carcasses (Haller Av., Wrocław) (Schild, 2005; Wiśniewski et al., 2013), have been recovered within the studied area, while to the west of the Odra River valley, they are better represented (Mania and Toepfer, 1973; Picin, 2016; Weiss, 2015).

The remnants of residential camps are located in the area of Ojców Plateau, among others in Ciemna Cave (Valde-Nowak et al., 2014, 2016) and probably in Wylotne Rockshelter (Chmielewski, 1969; Jackowska, 2006; Mańka et al., 2006; Milewski, 2006; Targosz, 2006). In both cases, the large number of finds from the CEM suggests multiple stays of human groups.

Surprisingly, in the area of the Oder and Vistula River valleys, except for Wylotne Rockshelter, places with systematic reconstruction of tool kits are missing. Therefore, we hope that the data presented in this paper will further narrow the visible gap.

3. Location of the site, geological background, and history of research

Site Pietraszyn 49a is located in the eastern part of the Głubczyce Plateau (Fig. 1). Its southern part is adjacent to the Moravian Gate, which separates the Carpathian Mountains from the Sudetes, being the most important corridor between the northern and southern parts of Europe. The surface of the Głubczyce Plateau rises to a height of approximately 300 m a.s.l. Its surface gently descends eastwards towards the Oder valley, and northwards, where the Silesian lowlands extend as a part of the European plains. For further geological information, see the supplementary material (Appendix A).

Site Pietraszyn 49a is located approximately 14 m above the recent bottom of the Troja River valley. The site lies on its southern bank (50°03′22.3″N, 18°05′45.4″E, ~218 m a.s.l). To the south of the site, the watershed area is elevated to up to 230 m a.s.l. (Fig. 2).

The history of the discovery of the site is complex. Somewhere near the trenches of the 49a site at the beginning of 90 years, volunteer archaeologists found about 50 artefacts (predominantly bifacial tools). Unfortunately, the exact location of these finds is unknown. According to Foltyn (Fajer et al., 2001a, 2001b; Foltyn et al., 2000), the artefacts were found on the surface of the arable land. The sediments lying below the modern ploughing soil were examined for absolute dating by Foltyn's team. In light of the luminescence dating (TL) of sediments, the age of the finds was correlated with the end of the middle Pleistocene (MIS 6).

In 2001, two amateurs discovered more bifacial tools in this area. We learned about it 10 years later. Field surveys in 2011 involving one of the explorers ended with the discovery of further artefacts (Wiśniewski et al., 2015). Since we did not have knowledge about the exact location of station 49, we designated the place as site 49a. In August 2012, another field survey was conducted, which initiated a multiannual research project. As a result of the field prospection, in 2012 four test trenches were established and led to the discovery concentration of artefacts in trench 1/2012. Further works (2013–2014, 2016) focused on this part of the site, covering 19 m^2 (Fig. 3B). However, in this paper, we present studies of carefully examined materials obtained from 16 m^2, i.e. through 2014.

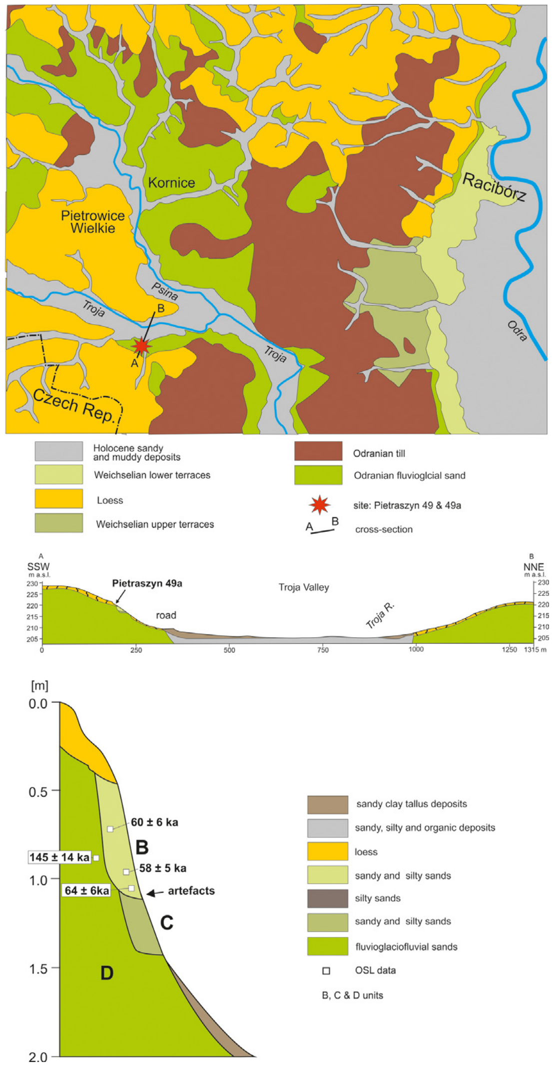

Fig. 2. Geology of the site and its vicinity: (A) geological map of surrounding area of the site Pietraszyn 49a; (B) cross-section trough the Troja River valley; (C) schematic log of the main sediments distinguished in the area of the archaeological site on the southern slope of the river valley. Elaborated by J. Badura.

Fig. 2. Contexte géologique du site et de ses environs : (A) carte géologique des environs du site Pietraszyn 49a ; (B) coupe transversale à travers la vallée de la rivière Troja ; (C) log schématique des sédiments principaux distingués à proximité du site archéologique sur le versant sud de la vallée de la rivière. Élaboré par J. Badura.

4. Methods

4.1. Archaeological methods

To answer the question of whether knapping activities had taken place in the excavated area and to reconstruct potential artefact displacements (Bertran et al., 2010), the bearing and plunge of selected artefacts were recorded according to the methods proposed by McPherron (McPherron, 2005, 2018). Moreover, the aforementioned studies have been supported by analyses of spatial distributions of refitted groups of artefacts (Hofman, 1986;

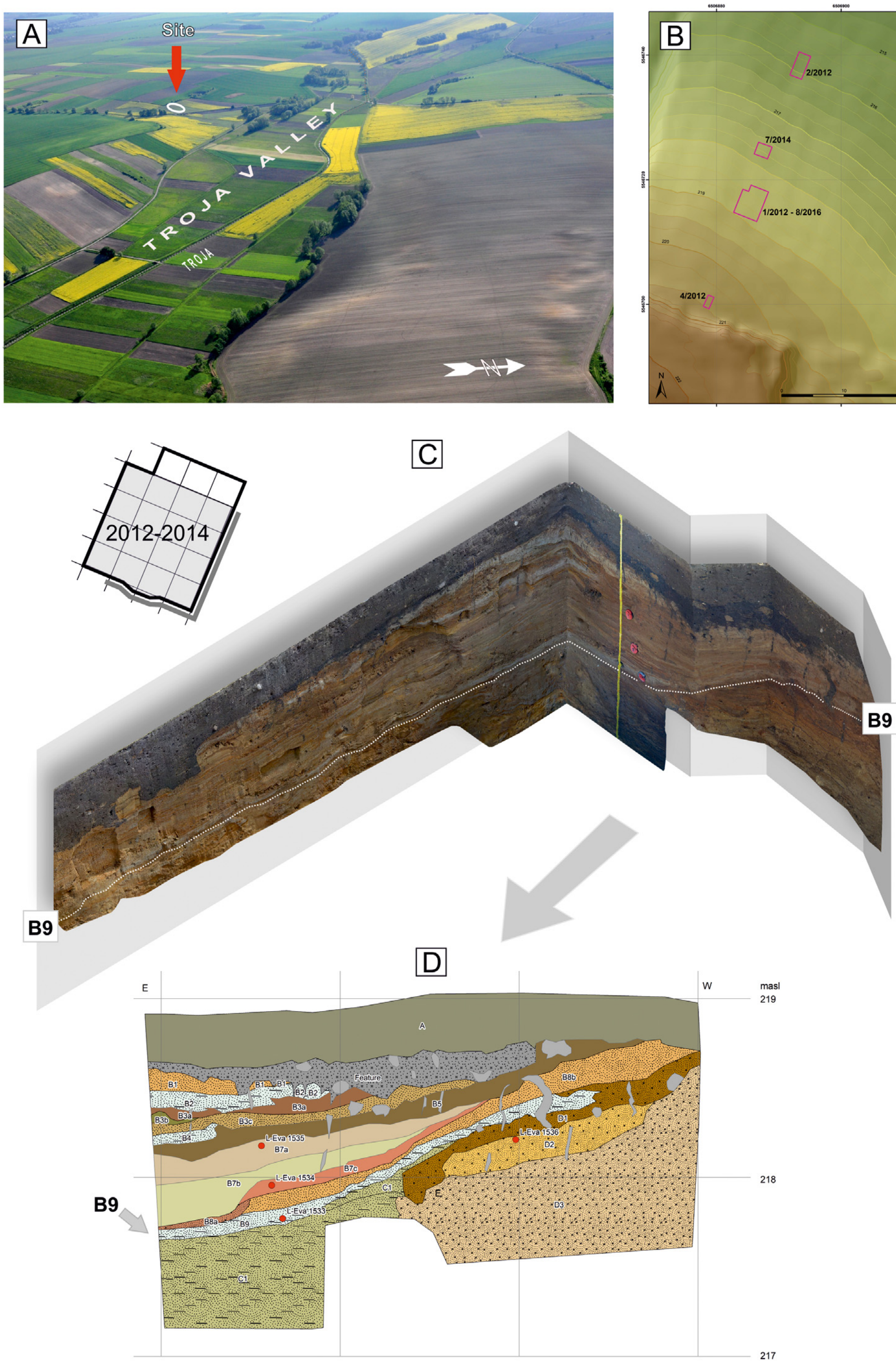

Fig. 3. The site Pietraszyn 49a: (A) aerial view to the west with location of site Pietraszyn 49a, photo by P. Wroniecki, 2015; (B) plan of the location of the trenches; the area analysed in this paper was marked with signature marks; (C) 3D model of the southern section of trench 1/2012-6/2014 (M. Mackiewicz & A. Wiśniewski); (D) drawing of the southern section of trench 1/2012-6/2014 (A. Wiśniewski).

Fig. 3. Le site Pietraszyn 49a : (A) vue aérienne vers l'ouest avec l'emplacement du site Pietraszyn 49a, photo P. Wroniecki, 2015 ; (B) plan de situation des tranchées ; la zone analysée dans cet article a été indiquée par des marques de signature ; (C) modèle 3D de la section sud de la tranchée 1/2012-6/2014 (M. Mackiewicz & A. Wiśniewski) ; (D) dessin de la section sud de la tranchée 1/2012-6/2014 (A. Wiśniewski).

Morrow, 1996). To process and interpret the collected data, open source computer programs PAST and OpenStereo, version 0.1.2 (http://www.igc.usp.br/index.php?id=391), were used (Grohmann and Campanha, 2010). To determine whether the number of finds was reduced by geological processes, the metric structure of the artefacts was compared to experimental data (Bertran et al., 2012; Byers et al., 2015; Dibble et al., 1997; Newcomer, 1971; Schick, 1986). Particularly important is the percentage of the smallest elements, such as chips, which are the most susceptible to displacement under natural conditions. The lithic material presented in this paper has also been analysed for origin, typology, and technology. It is worth mentioning that lithic refitting studies were a significant contribution to the full understanding of the production of shaped tools.

Microscopic studies of lithic artefacts were conducted as well to determine post-depositional alterations, technological features concerning the type of hammers used during knapping and the function of the specimens. Until now, 72 specimens from trenches 1/2012 and 2/2012, as well as individual finds from the surface of the site, have been analysed. In the course of the study, a metallographic microscope was used (Nikon LV150), adapted for use under reflected light. The artefacts were cleaned to avoid contamination using a warm-water bath containing a detergent and were washed with acetone. The detailed identification of individual traces – micro-scars, striations, and polishes – was performed with magnifications of 50×, 100× and 200×. The interpretation of the obtained microscopic images of selected artefacts was conducted based on comparisons with the results of the experimental tests performed earlier by one of the authors (KP), as well as with those of studies conducted by other researchers. The analysis of single bone remains was performed using taphonomic and systematic criteria.

For the detailed analysis of refit sequences of shaped tools, three refits were scanned using a Diondo D3 CT-scanner. The scans with a resolution of 50 μm were then accurately refitted by hand with the help of the AVIZO and Geomagic softwares. 3D refitting has the advantage of analysing each step of the tool shaping sequence in detail without causing damage to the artefacts by gluing them together and manual handling. It has many further applications, like accurate illustration of each detachment step, analysis of gaps, as well as accurate measurements of flake or nodule metrics and angles. This method was developed recently and was successfully applied to the analysis of stone artefacts (Delpiano and Peresani, 2017; Delpiano et al., 2017; Weiss, 2015).

4.2. *Geological research and methods of absolute age determination*

Geological studies were based on archival data and observations collected during field survey and excavation. In the framework of the field project, sediment analyses were conducted. To determine the age of the artefacts of the Pietraszyn 49a site, numerical dating methods were used. The absence of well-preserved organic materials at 49a prompted us to use the OSL method.

The first attempt was based on a quartz-luminescence dating experiment conducted in 2014. However, these first OSL dates were contradicting the geological model assumed for this part of Głubczyce Plateau (Jary, 1996) and the expected age range of Middle Palaeolithic occupation in this part of CE (Bobak et al., 2013; Neruda and Nerudová, 2013). Thus, we decided to take a second series of samples for luminescence dating, now applying the pIRIR225-approach (Buylaert et al., 2009; Thomsen et al., 2008) to coarse potassium feldspar grains. The methodology of both types of OSL dating techniques is described in Appendix B.

5. Results

In this section, we present chronological and geoarchaeological results, including the study of the site formation processes. We also review the characteristics of raw materials, typo-technological data, and the technology of shaped tools based on refitting studies. Additionally, we discuss the tool function.

5.1. *Site stratigraphy*

At site Pietraszyn 49a, four sedimentary units were identified, each with different sedimentary environments. They were labelled as units A–D (starting from the top of the section), while the associated layers forming them were marked with Arabic numbers (Figs. 2 and 3D).

Unit D was represented by fluvio-glacial, cross-bedded deposits. The layer complex consisted of sands with an admixture of gravel (up to several %) and clastic sediments (up to 10%; layer D1-D2). In the top part of the fluvio-glacial sediments, iron compounds were accumulated, related to the paleo-soil development processes. We suppose that they could be dislocated clasts of palaeosoils.

The subsequent units C and B consisted of fluvial sediments. Unit C was composed of sand mixed with silt. Within it, there were structures of convoluted deformations. The uppermost part of the layer was eroded.

Unit B was composed of gravel, sand, and silt. On the surface of the eroded units C and D, a layer of sandy silt was formed (B9). This layer forming the basal part of the accumulation of unit B was 10 to 20 cm in thickness. It consisted of a silt fraction of up to 20%. In the top and middle parts of layer B9, the majority of lithic artefacts and single bones were recorded. Based on this finding, it could be assumed that the accumulation of traces of late Middle Palaeolithic human activity occurred after the sedimentation of this layer. The overlying layers of unit B indicated the development of solifluction (layer B8a and B8b) and fluvial processes in small channels (layer B7b). At the bottom of layer B7b, an erosive pavement, consisting of sand and gravel up to 25%, which towards the top layer changed into medium-grained sand with an admixture of clastic sediments up to several percentage points, was observed.

The complex of unit A at Pietraszyn 49a consisted of a modern humus level (20 cm in thickness) and the remnant of features of the Lusatian culture (Bronze/Iron Age).

A small number of artefacts were also found in trench 2/2012. However, the stratigraphy in this part of the site

Table 1
Total dose rates, equivalent doses based on the central age model and non-fading corrected pIRIR-225 feldspar luminescence ages (see Fig. 3D).
Tableau 1
Débits de dose totaux, doses équivalentes basées sur le modèle d'âge central et les âges de luminescence du feldspath corrigés pIRIR-225 sans décoloration (voir Fig. 3D).

Sample ID	Total dose rate	De (Gy) CAM	
	(mGy/a)	$pIRIR_{225}$	$pIRIR_{225}$ age (ka)
L-Eva 1533	2.44 ± 0.16	147 ± 11	60 ± 6
L-Eva 1534	2.28 ± 0.16	131 ± 11	58 ± 5
L-Eva 1535	1.97 ± 0.15	127 ± 8	64 ± 6
L-Eva 1536	2.04 ± 0.15	212 ± 24	145 ± 14

was different than in trench 1/2012. In the bottom of trench 2/2012, fluvial deposits were recorded. It seems that this layer might be an equivalent of unit D recorded in trench 1/2012. The fluvial deposits were cut by a layer of sand and gravel formed during the process of solifluction. The latter layer provided artefacts. Above, loess was deposited, then covered with contemporary soil. We assume that the loess corresponded to MIS 2. It seems that all of the artefacts recovered from trench 2/2012 were moved from higher parts of the valley slopes.

5.2. *Quartz vs. feldspar luminescence ages*

The two dating methods provided divergent results. The previous age estimates obtained using quartz OSL dating suggested that the basement (D) and the lower part of unit B were formed at the end of MIS 3, while the middle part was formed after the LGM (MIS 1). More precisely, layer B9, containing lithic artefacts, yielded numerical dates spanning from 33.9 ± 3.4 (UJK-OSL-49) to 38.7 ± 3.9 ka (KIE-846). The age of unit D was almost equal to that of B9: 33.6 ± 3.3 (UJK-OSL-50) and 39.1 ± 4.0 (KIE-847). Layer B7a was dated back to 13.5 ± 2.0 (UJK-OSL-48) and 14.0 ± 2.1 (KIE-845).

Feldspar luminescence dating (for more details, see Appendix B.2.2) yielded significantly older age estimates. Figure B2 (Appendix B) shows the distribution of equivalent doses of samples L-Eva 1533, 1534, 1535 and 1536, respectively. It seems that the samples from the Troja valley infill were well bleached, whereas the samples taken from below the channel showed a skewed equivalent dose distribution pointing to incomplete bleaching.

The luminescence ages point to a period of fluvial erosion and subsequent aggradation at approximately 60 ka. This finding matches the transition from MIS 4 to MIS 3 (see Fig. 3C, D), from a cold stadial to a more temperate interstadial. All three luminescence age estimates obtained from inside the valley infill yielded equal results, as they overlap within the given error bars (Table 1).

The sample obtained from below the fluvial sequence yielded an age correlated with the penultimate (Saalian 2: Warthe) glacial cycle. Nevertheless, due to the skewed equivalent dose distribution of the sample (Fig. B2: 4), the age might be overestimated and should be regarded as the maximum age.

In conclusion, the dating of the sediments using the pIRIR225-approach is regarded as the most reliable inference concerning diachronic changes of geology, dynamics of site formation processes and chronological frameworks of human settlement represented by an assemblage of the CEM.

5.3. *Reconstruction of geological processes at the site*

In light of the geological analysis and absolute dating, it is possible to present the following scenario focusing on the southern part of the Troja River valley. It seems that the periglacial valley (C and B) was carved into the gravel sand sediments of the Warthe glaciation (unit D), dated to 145 ± 14 ka BP (MIS 6a/MIS 6b). On the slope of the valley above the erosional discontinuity, there were sandy gravel sediments (D1–D2) represented by structures of solifluction lobes, containing the relics of palaeosoils. The age of this soil is unknown: it might have originated from Eem or early Weichselian. Additionally, the age of unit C is not clear. It likely represents one of the first stages of valley development oriented to the north. Based on OSL dating (pIRIR225-approach), it can be stated that the next stage of the shaping occurred at the turn of the Pleniglacial and the Interpleniglacial (MIS 4/3: unit B, 64–60 ka BP). From the beginning of this stage, deposition of stratified sediments occurred with a significant admixture of fine-grained sand. The structure and texture of the lowermost layer B9 indicate that, during accumulation, a significant role was played by the processes of surface flow and downwash, which are regarded as typical for the highest parts of slopes and the initial parts of the valleys. After the deposition of layer B9 in the area of the Troja River valley, human occupation occurred. Afterwards, within the valley, the solifluction process occurred, as documented by layers B8a and B8a. Even later, the valley was cut due to erosion expressed by sedimentary discontinuity and filling of the erosional channel with a straight sequence (decreased grain-size distribution towards the top). Based on OSL dating (L-Eva 1534 and L-Eva 1535), this stage can be placed at the beginning of MIS 3 (∼ 58–60 kyr). During MIS 2 on the slopes of the Troja River valley, loess sediments were deposited. Loess was gradually moved towards the valley bottom.

5.4. *Spatial distribution, state of preservation and processes of site formation*

The majority of the archaeological material was excavated in trench 1/2012 within layer B9 (Fig. 3B–D). A small number of lithics, which could be interpreted as fragments of the same assemblage, were recorded within unit A. They were found in the Bronze/Iron Age feature, which cuts the layers of unit B, in slope deposits of trench 2/2012 and in modern agricultural soil (Table 2). In the following section, we focus on the findings from trench 1/2012.

The majority of finds from trench 1/2012 are represented by lithic artefacts. Only a few bone remains of vertebrates were recorded. The find distribution was limited to layer B9, with a thickness of up to 20 cm (Fig. 4). An exception was the edge of the river bank, where some of the artefacts occurred outside the range of layer B9. It is likely that they were displaced due to downslope

Table 2
Distribution of lithic artefacts at the site 49a.
Tableau 2
Distribution d'artéfacts lithiques sur le site 49a.

Location	N	%
Main trench (1/2012; 5/2013; 6/2014)	9729	99.25
Trench 7/2014	32	0.33
Trench 2/2012	12	0.12
Surface of site	29	0.30
Undetermined	1	0.01
Σ	9803	100.00

movements. These dislocation processes might not have been very dynamic, as the individual artefacts excavated from unit A form refits with artefacts from layer B9.

The density of artefacts can be described as very high (approximately 610 pieces per square metre), corresponding to "high-density patches" (Roebroeks et al., 1997; Verpoorte et al., 2016). The artefacts were unevenly distributed over the excavated surface. We noted that the finds were clustered in the middle and northern parts of the trench (91.8% of the objects; Fig. 5). At the western edge of the channel, three distinct concentrations (diameters 0.7–0.9 m) were recorded.

To answer the question of whether the finds from the main trench (1/2012), notwithstanding the presence of small clusters, could have been displaced by geological processes, we examined the bearing and plunge of artefacts recorded on the slope and at the flat surface of the riverbank. The Rayleigh test for artefacts bearing on the slope ($Z = 3.718$; $P = 0.024$) and the flat surface ($Z = 4.436$; $P = 0.012$) indicated a lack of uniformity (Figs. 4 and 5). In other words, there is a reason to conclude that the orientation of lithics was governed by unidirectional force. The fabric of the analysed samples from the slope and flat surface of the riverbank, according to a Woodcock diagram, appears to be linear (Lenoble and Bertran, 2004, p. 459). The rose diagram indicated that the artefacts deposited on the slope had a tentative orientation along the north–south axis, i.e. parallel to the axis of the valley and corresponding to the decline of the slope of the Troja valley (Fig. 5). This finding could indicate the movement of artefacts located within the slope of the valley.

In the next step of examination, we analysed the orientation of lines connecting particular refits of artefacts (208 vectors). The rose diagram (0–180°) (Fig. 5c) clearly indicated the following trend:

- a large share of the refits were oriented parallel to the axis of the river bank;
- the second large share of refits was oriented transverse to the axis of the valley.

This trend indicates that the lithics could have been moved slightly in the northern direction due to the movement of low-energy currents towards the axis of the valley and, at the same time, because of gravity in accordance to

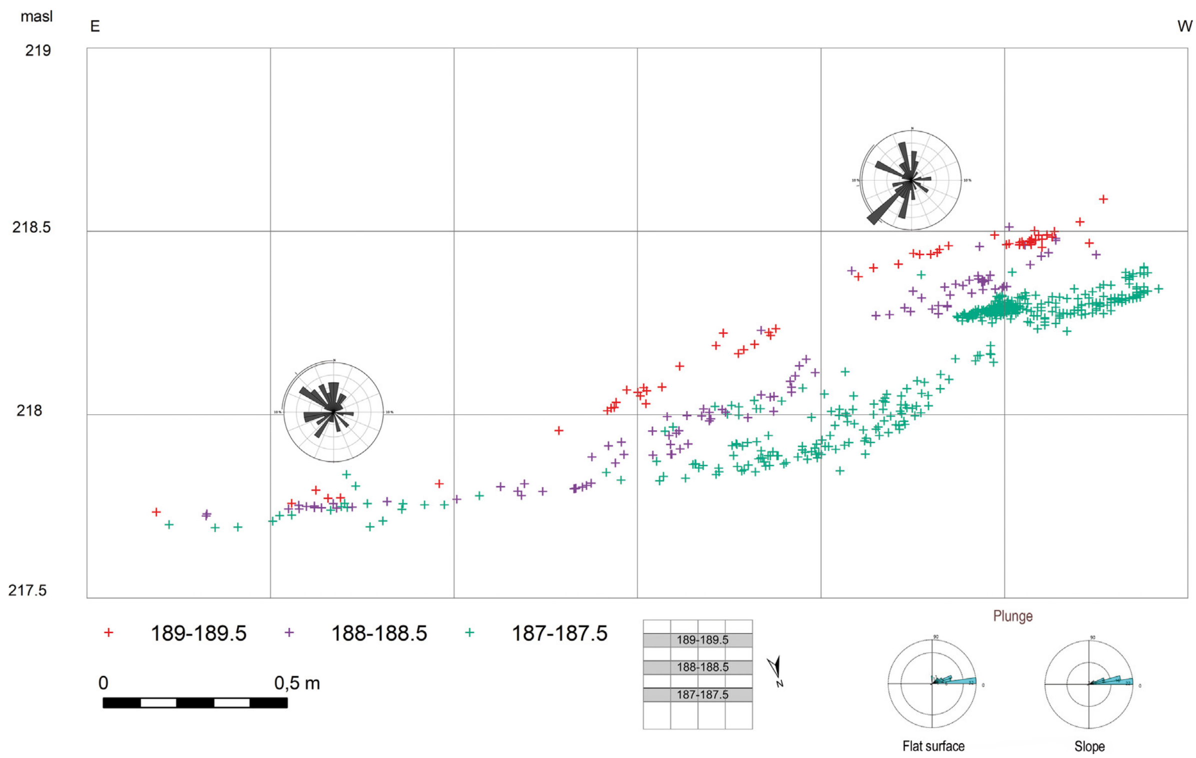

Fig. 4. Vertical projection of lithics in the trench 1/2012 and rose diagrams illustrating bearing and plunge of artefacts in the zone of the slope and the flat surface of the river bank.
Fig. 4. Projection verticale des artéfacts lithiques dans la tranchée 1/2012 et diagrammes en rose illustrant l'orientation et l'inclinaison des artefacts des objets dans la pente et sur la surface plane de la rive du fleuve.

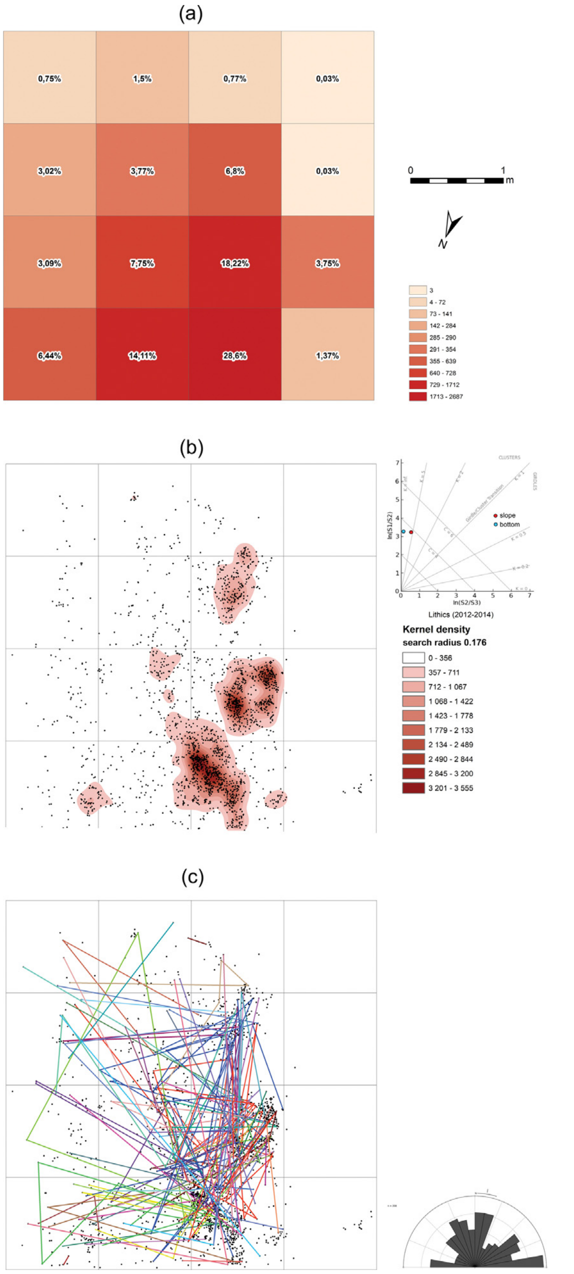

Fig. 5. Spatial distribution of lithic finds in the main trench 1/2012: (a) frequency; (b) spatial distribution with a sign of kernel density and Woodcock's diagram; (c) map of refits and sign of bearing of links between refitted artefacts (coloured lines: refitted groups).

Fig. 5. Répartition spatiale des découvertes lithiques dans le secteur principal 1/2012 : (a) fréquence ; (b) distribution spatiale avec signe de densité de noyau et diagramme de Woodcock ; (c) carte de réaménagement et signe d'orientation des liens entre artefacts réaménagés (lignes colorées: groupes réaménagés).

slope of the riverbank, i.e. to the east. It cannot be excluded that some larger elements, transferred over a significant distance, are the effects of intentional displacement by humans (e.g., an attempt to clean the surface). Further excavations might help answer these questions. The distances between the refitted elements are 0.1 and 3.4 m, with an average of 1.08 m. These parameters indicate that the displacement of the artefacts might be negligible.

It seems that the remnants of clusters associated with human workplaces could be preserved only in the edge zone of the river bank (Fig. 5b). Three small clusters contained a great number of small finds as chips, suggesting that they could have been accumulated when knappers worked near the ground, kneeling, squatting or sitting (Kvamme, 1997; Newcomer and Sieveking, 1980, pp. 349–350; Schick, 1986, pp. 36–41). It is also interesting to mention that the largest number of refits with more than three parts came from these clusters. Thereby, most of the refits were recorded in the central and northern clusters (C2 and C3: Fig. 7b and c). Less frequent were refits covering all three clusters, clusters 1 and 2, or only cluster 1.

The results presented above are in accordance with the results of microscopic examinations of lithics. Almost all of the artefacts analysed showed surface alterations. The main post-depositional modification is surface gloss, the intensity of which varies from light to very intense. These changes are visible both with the naked eye and under the microscope. The origin of this modification is usually related to mechanical and chemical processes. Water and sand activities are believed to be the main source of this type of surface alteration (Levi Sala, 1993, pp. 31–32, 71; Plisson and Mauger, 1988, p. 4; Van Gijn, 1990, p. 53). In the case of lithics from Pietraszyn 49a, there was a relationship between the changes noted on their surfaces and the geological context of their deposition.

In conclusion, the unearthed finds from the main trench (1/2012) indicate the presence of remains of some clusters resulting from human activity. Data on the spread of refits and the relief of the valley surface might, however, suggest that these clusters were partially reduced due to the development of slope processes.

5.5. *Diversity of lithic artefacts and manufacture of tools*

5.5.1. *Lithic raw material*

The artefacts from Pietraszyn 49a were made of erratic flint, deposited in glacial sediments corresponding to the Elsterian (San 2) and Saalian (Oder) glaciations on the Głubczyce Plateau (Lewandowski, 1988; Přichystal, 2013; Salamon, 2015, 2017). The geological data suggest that, within a radius of 5 km from the site, humans could easily procure the appropriate raw material from end moraine deposits. The high quality of erratic flints from Pietrowice Wlk., Pietraszyn, or Maków is widely known (Kozłowski and Pawlikowski, 1989).

In light of refitting studies, it is clear that, in the process of tool production, nodules, chunks or even massive flakes or blades were used. Moreover, the common usage of flat preforms was observed (Fig. 6: 2), while spherical nodules or chunks were rarely processed. Based on refits, it can be stated that the largest nodule had a dimension of 157 mm × 92 mm × 41 mm. Additionally, other rocks transported by glaciers, such as gneiss, quartz, quartzite, mudstone and sandstone, were also used as hammers, anvils or raw material for making other tools, e.g., choppers.

Fig. 6. Selected artefacts from early stage of shaping: (1) flint plate with conjoined pieces (Ptr-7); (2) preform of bifacial tool with isolated back and working edge.

Fig. 6. Exemples d'artefacts dans la phase initiale de façonnement : (1) plaque de silex avec des fragments joints (Ptr-7) ; (2) préforme d'outil bifacial avec dos isolé et tranchant préparés.

5.5.2. Results of the typo-technological analysis

5.5.2.1. Technology and typology. In total, 9803 stone artefacts were obtained from the site through 2014. As stated above, most numerous were the finds from layer B9, followed by finds from the slope sediments, as well as finds from the recent humus and the prehistoric feature (Tables 2 and 3, respectively). In the following analysis, we focus on the finds from layer B9 and from trench 1/2012, which formed clusters and groups of refits, proving the spatial and temporal integrity. These finds represent nearly

Table 3
Distribution of lithic artefacts within the main trench (1/2012, 5–6/2014).
Tableau 3
Distribution des artefacts lithiques dans la tranchée principale (1/2012, 5–6/2014).

Location	*N*	%
Layer	9657	99.26
Feature	26	0.27
Plough horizon	39	0.40
Others	7	0.07
Σ	9729	100.00

Table 4
Lithic artefacts from unit B9 of main trench (1/2012, 5/2013, 6/2014).
Tableau 4
Artefacts lithiques provenant de l'unité B9 de la tranchée principale (1/2012, 5/2013, 6/2014).

Category	*N*	%
Raw material (untasted)	14	0.14
Intial/tested	2	0.02
Flakes and fragments	2098	21.73
Blades and fragments	152	1.57
Chips > 20 mm	7238	74.95
Retouched tools	60	0.62
Tool waste products	4	0.04
Debris (broken raw pieces)	72	0.75
Undetermined	17	0.18
Σ	9657	100.00

99% of all of the artefacts recovered from site Pietraszyn 49a.

The studied lithics are dominated by a variety of debris corresponding to various stages of manufacture of shaped tools (Table 4). Among them, small chips < 2 cm dominate, representing approximately 75% of the assemblage. Flakes and blades, i.e. forms larger than 2 cm (23.41%), are less common. Regarding the flakes, a large number are fragmented as a result of shaping, which usually produces thin flakes susceptible to fracture (e.g., Bergman and Roberts, 1988; Bradley and Sampson, 1978). It is worth mentioning that no cores were recorded in the assemblage.

Based on the presence of fully or partially cortical flakes, it can be stated that humans transported almost all of the nodules or chunks to the site from places likely located nearby.

To collect more precise data regarding the type of wastes that were generated during production, we performed a morphometric analysis of 270 flakes and blades (≥ 2 cm). They have been randomly selected from 722 specimens. As we realised, the collection included both forms – flakes and blades – with one series of scars on the dorsal side and those with at least two series of scars. The first group could be linked to the thinning and shaping phase, whereas the second one had a retouched edge (Demidenko, 2015; Jöris, 2001). Regarding specific waste products associated with the production of shaped tools, it is possible to distinguish:

- examples demonstrating the removal of or accidental damage to tips;
- overpassed flakes covering the opposite edge;
- forms related to lateral thinning of the edge or the tip.

Concerning flake size, the median dimensions are 27.99 mm in length, 25.86 mm in width, and 4.2 mm in thickness, while the longest forms extend up to 78 mm. In general, the main characteristic of the assemblage representing bifacial reduction waste is reflected by a decrease in the number of flakes and an increase in their size (Stahle and Dunn, 1982).

Flake platforms are mostly plain (41.48%), followed by facetted (16.3%) and natural (15.56%) ones. Regarding the place of a point on the platform, flakes with off edge points of impact (52%) and marginal points (48%) dominated. Only approximately 10% of the flakes carried macroscopically visible traces of edge abrasion. A lip was recorded in approximately 37% of the flakes. Together with diffuse bulbs (51.48%), this finding indicates a significant contribution of soft impact (Magnani et al., 2014; Ohnuma and Bergman, 1982).

Table 5
Retouched tools.
Tableau 5
Outils retouchés.

Typological category	*N*	%
Knife	13	21.67
Retouched flake	5	8.33
Retouched blade	1	1.67
Sidescraper	2	3.33
Double-scraper	2	3.33
Leaf-shape scraper	1	1.67
Sidescraper-notched	2	3.33
Other scraper	2	3.33
Notched	1	1.67
Burin	1	1.67
Fragments of bifacial tools	7	11.67
Chopper	1	1.67
Preforms of bifacial tools	13	21.67
Fragments of tools	4	6.67
Undetermined	5	8.33
Σ	60	100.00

Flakes with a strong longitudinal ventral curvature dominated (58.15%) the assemblage, typical for flakes from bifacial reduction (Andrefsky, 1986; Hayden and Hutchings, 1989; Inizan et al., 1999; Presnyakova et al., 2015). In the case of Micoquian shaped tools, curved flakes were mostly created by shaping the convex part of the tool. They bear dorsal traces of a relatively small number of blows, but leading to the removal of large surface flakes. Regarding the plano-convex cross-section of Micoquian bifaces, the convex surface was more intensively formed than the plane side (Boëda, 1995; Jöris, 2001).

Only 0.62% of the assemblage consist of retouched tools (Table 5) represented by shaped tools and tools with ordinary edge retouches. In a few cases, the tools represent macrolithic forms made of larger rock fragments. The analysis of the shaped tools revealed differences concerning the volume and shape of the raw material. The tools were mainly produced from natural chunks or nodules, with some exceptions produced from flakes (Figs. 6 and 8:1). The shaped tools are also heterogenous regarding the stage of the knapping sequence. Some represent the initial roughing-out phase, whereas others are preserved in a state of advanced shaping and thinning. Some others contain traces of the finishing phase combined with an edge and tip regulation. The intensive shaping of different parts of the planned tools is documented by the presence of fragments of the tips and lateral or basal parts (Fig. 7). The tips of the tools can indicate that tools broke off during use on the site. However, we cannot exclude that this type of fragmentation results from the technical mistakes of knappers.

The majority of the tools have a plano-convex cross-section. However, there are also biconvex forms in the collection. In this context, a tendency towards pronounced sharp tips at the expense of the backed edge was observed. On these specimens, the knappers left a thick, passive part

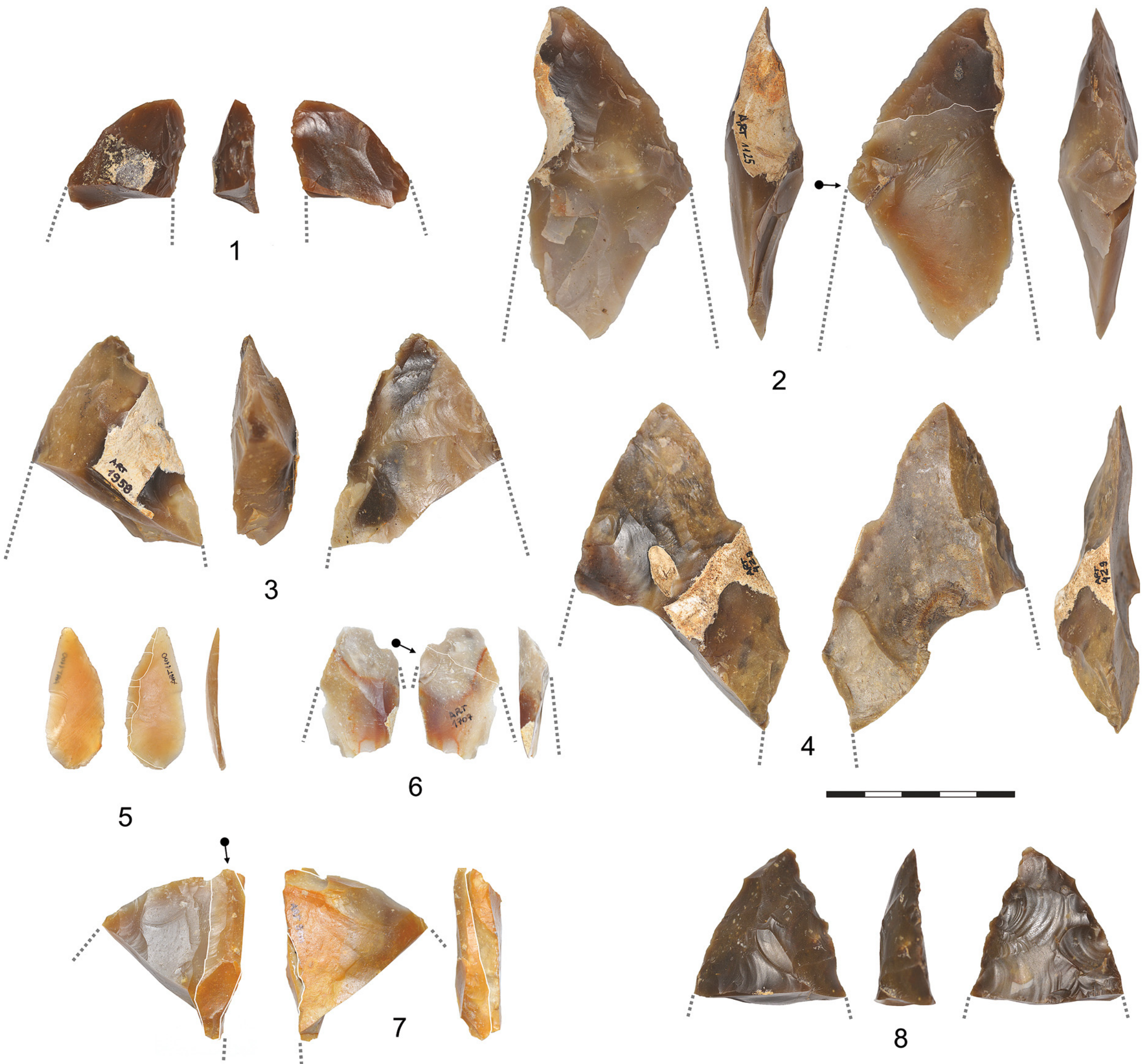

Fig. 7. Selected examples of tool fragments and flakes from shaping: tips of bifacial tools (1–4, 6, 8); flake from shaping of the tip (5) and fragment of tip part with a blade (7).

Fig. 7. Exemples de fragments d'outils et d'éclats de façonnage : extrémités distales d'outils bifaciaux (1–4, 6, 8) ; éclat de façonnage de la pointe (5) ; fragment de l'extrémité distale avec lame (7).

in the form of a base. Backs are often natural, but some were retouched.

A few tools contained traces of lateral tranchet blows (Figs. 7: 7 and 12). It seems, however, that these thinning blows were associated with thinning of the distal parts, rather than with the deliberate formation or resharpening of the cutting edge (Bosinski, 1969; Frick et al., 2017; Krukowski, 1939).

Regarding the location of surface retouch, shaped tools can be divided into unifacial and bifacial specimens. However, we did not notice any differences between the groups of tools. Concerning the traditional classification of tool types, knives dominated (Figs. 8: 1–4 to Figs. 8: 1–3) among the bifacial specimens. As a rule, these forms corresponded to Bockstein or Klausennische types (Bosinski, 1967, 2006; see also Jöris, 2001: 68, Abb. 4.32), which are commonly considered to represent the initial stages of tool use. Their shapes may have been modified during the subsequent sharpening cycles. Shaped sidescrapers are more variable regarding their morphology than knives. Uni-lateral edge-retouched tools were almost exclusively made from flakes or blades (Fig. 8: 4–6). It is necessary to emphasise here that blanks come from various knapping phases of tool manufacture. In a few cases, the tools represented macrolithic forms made of larger rock fragments. The study of the raw material unit used for the production and the evaluation of the intensity of the reduction in tool volume allowed us to distinguish a group of tools prepared on site from a group of tools brought from outside the site.

The data show that the studied location contains mainly waste, including flakes, blades, fragments of tools or

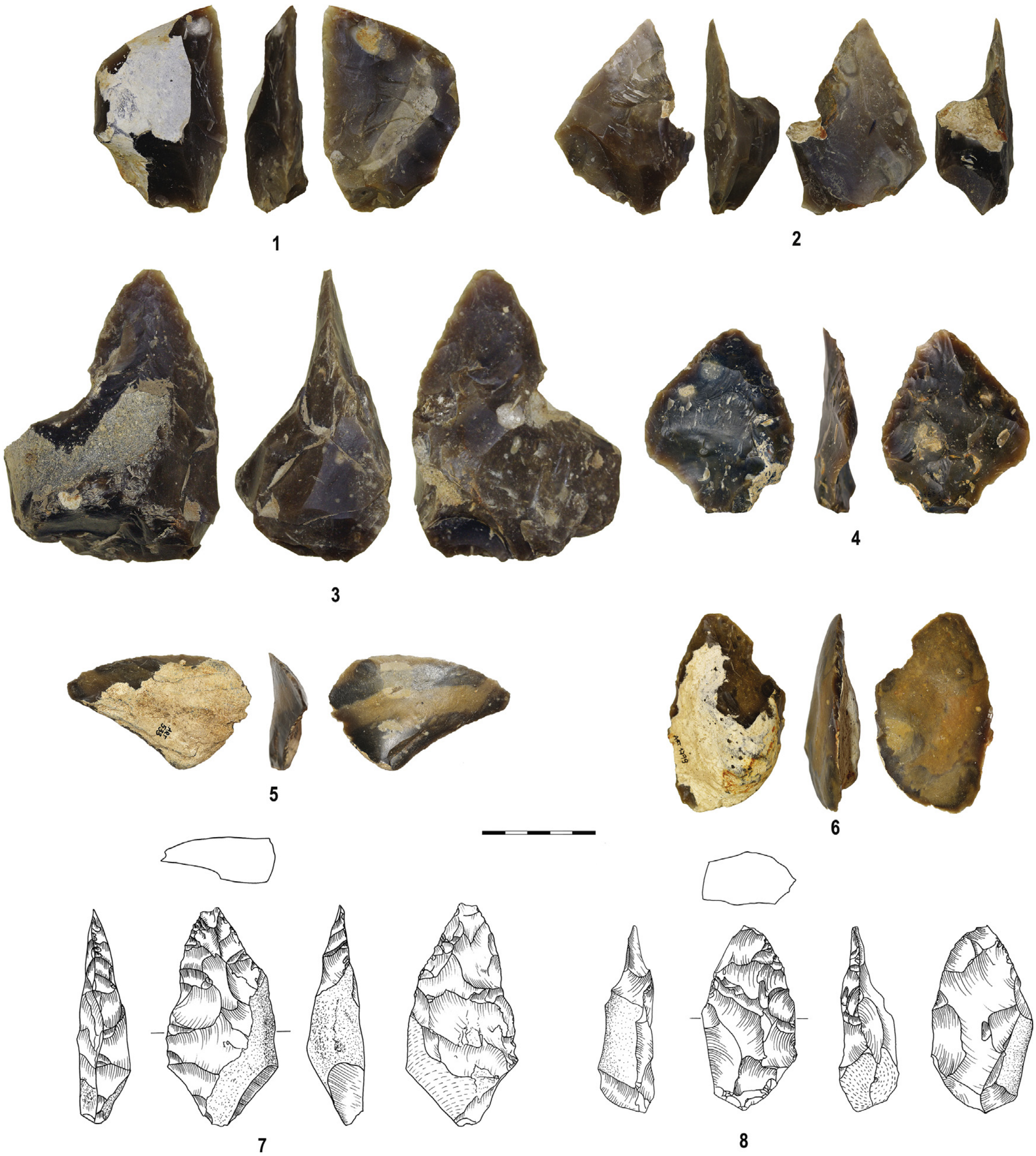

Fig. 8. Selection of tools: knifes (1–3, 7–8) and scrapers (4–6).

Fig. 8. Exemples d'outils : couteaux (1–3, 7–8), racloirs (4–6).

unfinished specimens, as well as a small group of ready-to-use tools. At the same time, it can be assumed that some of ready-to-use tools were taken outside this place. As seen, the technological activity was focused on the production as well as on the use of tools.

5.5.2.2. Techniques of tool production in light of microscopic studies. To understand the process of tool production, we examined separately selected specimens regarding the applied techniques. According to archaeological and experimental studies of material during the manufacture of shaped tools, both mineral and organic hammers might potentially be involved (Byrne et al., 2006; Ibáñez et al., 1990; Keeley, 1980; Pyżewicz, 2013; Rots et al., 2011; Vaughan, 1985; Vergès and Ollé, 2011).

Our study encompassed technological marks created during the early stage of tool shaping and during the final steps of edge regularization. Usage of mineral hammers was confirmed in the cases of platforms of three retouched tools and one flake in a form of linear traces, a large flake coming from the early stage of production, and one of the artefacts bearing traces of abrasion on the edge of the platform, caused potentially by a mineral hammer (Fig. 9: 1–2). During the advanced stages of tool edge

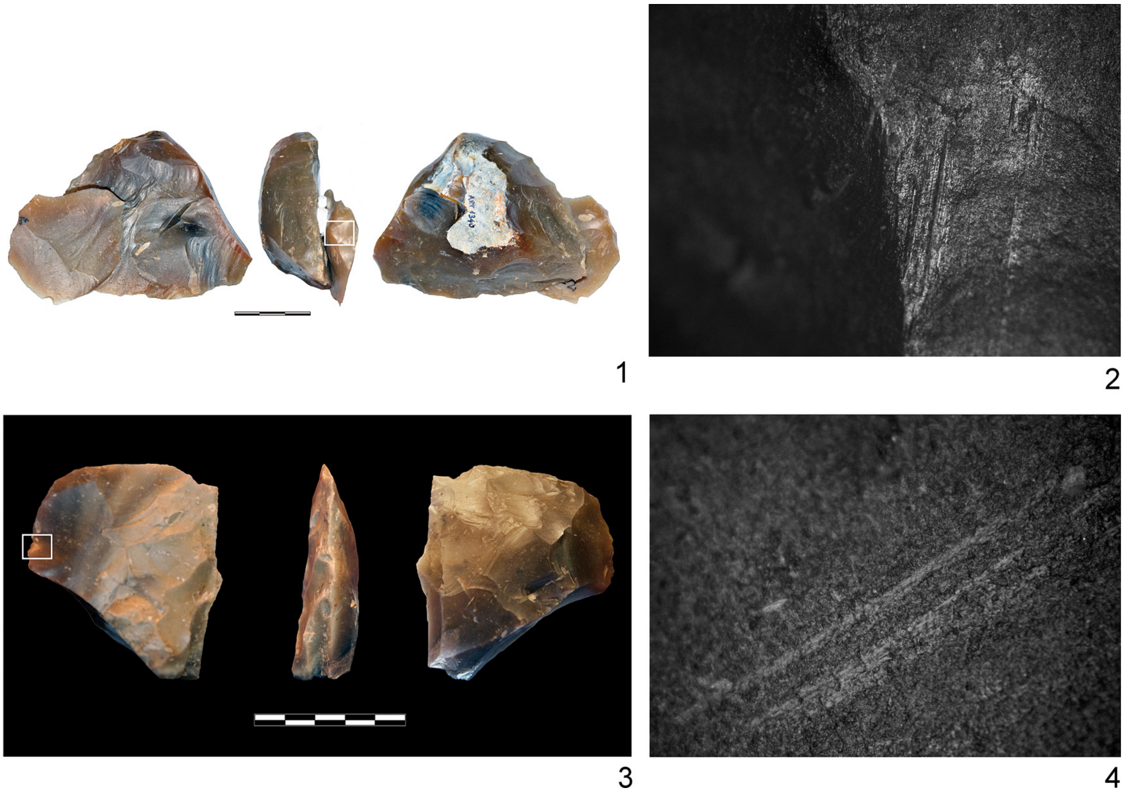

Fig. 9. Technological traces illustrating use of mineral hammer (1-2, refits of flake and preform of the bifacial tool) (magnification 50 ×) and organic hammer made of antler (3-4, fragment of bifacial tool) (magnification 200 ×).
Fig. 9. Traces technologiques illustrant l'utilisation du percuteur minéral (1-2, réaménagement de l'éclat et préforme de l'outil bifacial) (grossissement 50 ×) et du percuteur organique en bois de cervidé (3-4, fragment d'outil bifacial) (grossissement 200 ×).

configuration, both stone and organic hammers were used. Ten tools bore technological features associated with the formation of unifacial or bifacial surfaces, mainly with the use of mineral hammers. Examples are represented by a knife (traces visible near the non-working edge), a combined tool (a sidescraper + notched tool), marginal retouched flakes, and fragments of tools. So far, only two items (fragments of bifacial tools) have provided traces indicating the use of an organic hammer, likely made of bone or antler (Fig. 9: 3–4).

The results described above provided interesting data for the discussion of the techniques involved in the production of shaped tools. It seems that most researchers intuitively reproduced the opinion established in the first half of the twentieth century (Wenban-Smith, 1999, p. 385) that a soft organic hammer played a crucial role in the process of Middle Palaeolithic surface shaping. The importance of a stone hammer for tool shaping was mainly mentioned in the context of Acheulean bifaces (Bradley and Sampson, 1986; Ohnuma and Bergman, 1982). In contrast, our results indicate that the mineral hammer could have also played an essential role in the manufacturing of tools from Pietraszyn 49a. It seems that mineral hammers were not only used during the initial rough-out, but also during the subsequent stages of shaping and finishing, together with an organic hammer. It suggests that, during shaping, hard and soft mineral hammers were used.

Table 6
Groups of refits.
Tableau 6
Groupes d'éléments réaménagés.

Number of groups	Number of refitted elements	%
40	2	50.00
9	3	11.25
11	4	13.75
8	5	10.00
2	6	2.50
3	8	3.75
3	9	3.75
1	10	1.25
1	16	1.25
1	17	1.25
1	30	1.25

5.5.2.3. Tool production in light of refits. A deeper understanding of the processes of tool manufacture and technological organisation would not be possible without refitting studies. Altogether, 327 conjoining pieces were found, constituting 80 refitting groups. Within them, groups composed of two elements dominated: 15% of the refits included more than five elements, and only one group consisted of 30 elements (Ptr-1) (Table 6, Fig. 10).

Dorsal-ventral refits (i.e. flake/blade to flake/blade) dominated all the groups (74%). Less numerous were the connection of flakes to tools or tool parts and flakes to

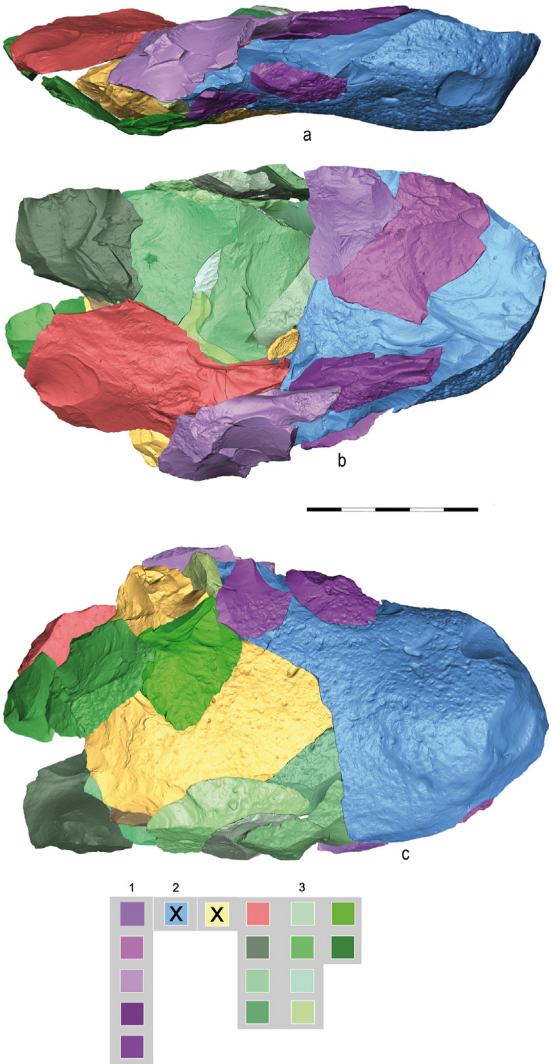

Fig. 10. 3D model of refitted group Ptr-1 exposed from side, flat surface and convex side. Below a schema illustrating three stages of shaping (the colours of the squares correspond to the elements of the refitted group): (1) flakes from thinning; (2) fragment of tool that appeared after the fracture; (3) elements involved in further shaping. X, negative fragments of the refitted group (see Fig. 11).

Fig. 10. Modèle 3D du réaménagement Ptr-1 vu de profil, de la surface plane et du côté convexe. En dessous, schéma illustrant les trois étapes du façonnage (les couleurs des carrés correspondent aux éléments du groupe de réaménagement) : (1) éclats d'amincissement ; (2) fragment d'outil apparu après la fracture ; (3) éléments impliqués dans la poursuite du façonnage ; X, fragments négatifs du groupe de réaménagement (voir la Fig. 11).

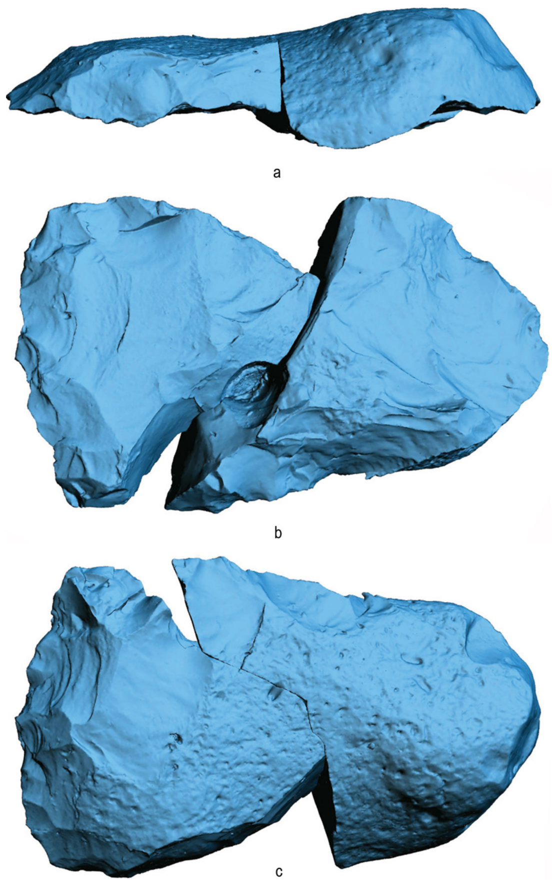

Fig. 11. 3D model of two fragments from refitted group Ptr-1: the fragment on the right has been discarded after the fracture of the preform, while the fragment on the left is a result of further shaping.

Fig. 11. Modèle 3D de deux fragments de réaménagement Ptr-1 : le fragment sur la droite a été abandonné après fracture de la préforme, alors que le fragment de gauche est le résultat de la poursuite du façonnage.

chunks. The latter might be the result of the uncontrolled breakup of nodules during reduction. The former two groups of refits are potentially part of activities related to the removal of natural surfaces and tool shaping. The refits linked to chunks indicate testing of the raw material or attempts to obtain a semi-finished product.

The refitted artefacts also reflect particular shaping stages. Our analysis showed that the roughing-out, shaping, and thinning stages dominate the assemblage. A few refits were associated with nodule testing. Until now, we have not noted refits demonstrating the resharpening of tools brought from outside the site.

Several refitted groups illustrate longer sequences, showing various technical procedures and unexpected problems. The most interesting group reflects an attempt to produce a flat tool (a knife) from a longitudinal flint nodule (Ptr-1: 30 pieces, 155 mm × 95 mm). In this case, the early stage of shaping was partially reconstructed. Initially, the cortical surface was removed from one part of the nodule (Fig. 10). Then, the preform broke into two parts (Fig. 11), one of which was selected for further processing into a knife. The reduction of the knife was stopped after a second attempt to thin out the flat surface.

Another refitted group, Ptr-4, shows successive thinning and edge modifications (Fig. 12). The initial stages representing the roughing-out of the nodule have been preserved. Moreover, this group does not reflect any evidence of abandoning reduction due to a fault in the raw material. The block consists of a tool, five flakes, and a blade. The tool has a semi-circular outline shape and an S-shaped working edge. The tool contains a bifacially retouched edge and a pronounced tip. It also has a retouched back opposite of

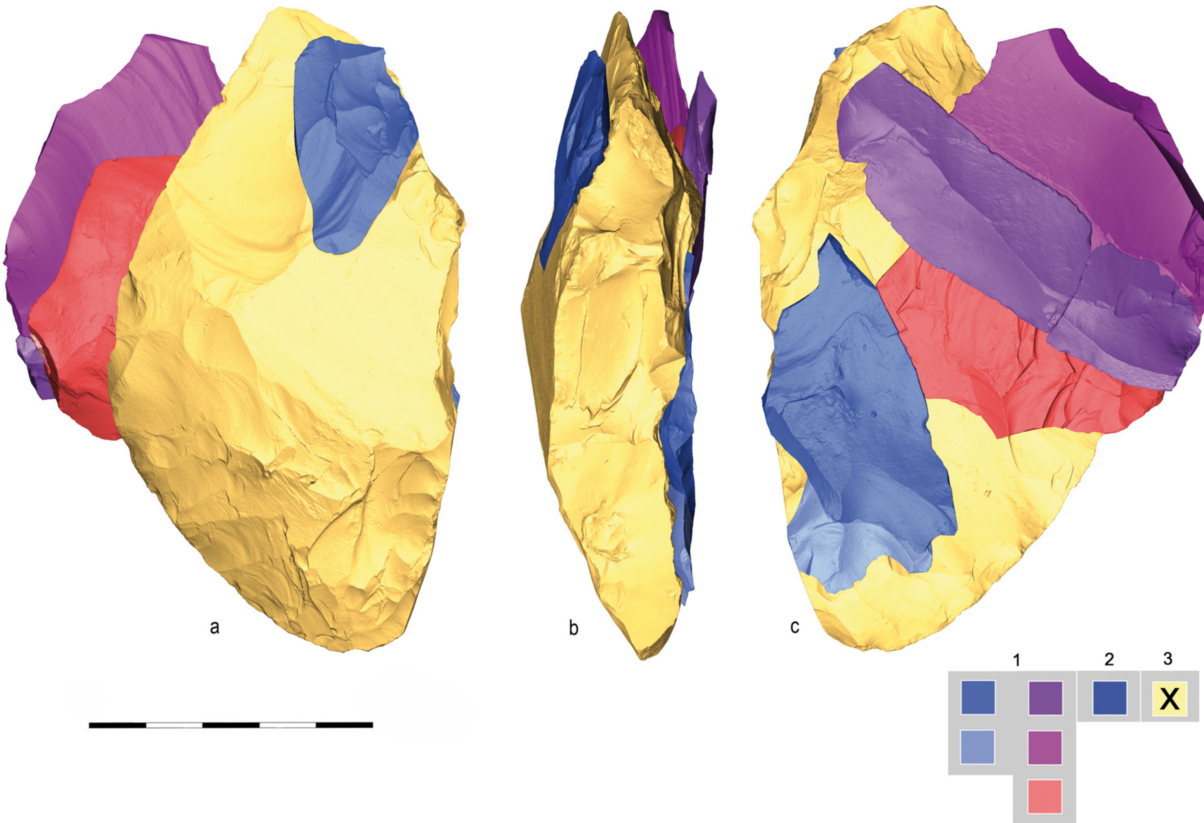

Fig. 12. 3D model of refitted group Ptr-4: (a) convex side, (b) side (back) view, (c) flat surface. Below a schema illustrating the three stages of shaping (the colours of the squares correspond to the elements of the refitted group): (1) flakes from shaping of flat surface; (2) flakes from shaping of posterior part of tool; (3) bifacial tool.

Fig. 12. Modèle 3D du groupe réaménagé Ptr-4 : (a) phase convexe, (b) vue de l'arrière, (c) surface plane. En dessous, schéma illustrant les trois étapes du façonnage (les couleurs des carrés correspondent aux éléments du bloc réaménagé) : (1) éclats issus du façonnage de la surface plane ; (2) éclats issus du façonnage de la partie postérieure de l'outil ; (3) outil bifacial.

the working edge. The cause of finish reduction might have been linked to the formation of a step in the middle part of the tool. Interestingly, microscopic studies indicate the use of this tool (see Section 5.5.3).

5.5.3. *Description of use-wear traces: function of tools*

Among the analysed assemblage, ten artefacts contained ambiguous use-wear traces (Table 7; Figs. 13 and 14). Typologically, this group includes sidescrapers, knives, and retouched flakes, as well as handaxes collected from the surface of the site. It was noted that, in the case of knives, singular retouched edges were used as working parts, while in cases of handaxes, both retouched edges were utilised. Other specimens, such as sidescrapers and retouched flakes, had use-wear traces on their lesser regular edges covered with retouch.

All of the analysed specimens contained use-wear traces associated with butchering activities. On the identified working edges, traces of contact with bones and skin or other organic material were observed. Low-intensity use-wear traces suggest that these tools were not heavily used. In five cases, single linear striations (a handaxe, knives, and retouched flakes) were preserved. Together with the localisation of polish, this finding indicates activities requiring more or less transverse movements of the working edge, such as scraping, curving or cutting. Similar use-wear traces have been recorded on individual tools from the CEM site Lichtenberg in Germany (Veil et al., 1994, p. 56).

Only in one case (a scraper), traces of working in organic material other than animal tissue (probably wood) were confirmed. The distal part showed intense polishing, deeply affecting both surfaces. Preserved linear traces suggested curving or incising into the material.

5.6. *Animal remains*

Within the top part of layer B9, singular animal remains, such as fragments of horse molars (*Equus sp.*), were recorded. Unfortunately, they underwent considerable diagenesis due to contact with water (Lyman, 1994, p. 422). It should be noted that these animal remains cannot be directly connected to the late Middle Palaeolithic artefacts, similar to the other open-air sites known from Poland (Wiśniewski et al., 2009). Until now, only at Zwoleń the

Table 7
Results of microscopic study of lithics (72 artefacts; crosses mean number of observations).
Tableau 7
Résultats de l'étude microscopique d'éléments lithiques (72 artefacts ; les croix représentent le nombre d'observations).

Typological types	Technological traces		Use-wear traces				
	Stone	Stone/ antler	Bone/ antler	Bone/ antler + skin	Bone/ antler + organic material	Bone/ antler + skin + organic material	Organic material (wood?)
Knife	×	×	×	×	×		
Handaxe				×		×	
Sidescraper	×				×		×
Sidescraper + notched	×						
Retouched flake	××××		×	×			
Retouched blade				×			
Undetermined tool	×						
Tool fragment	×××						
Fragment of knife or handaxe		×					
Flake	×						

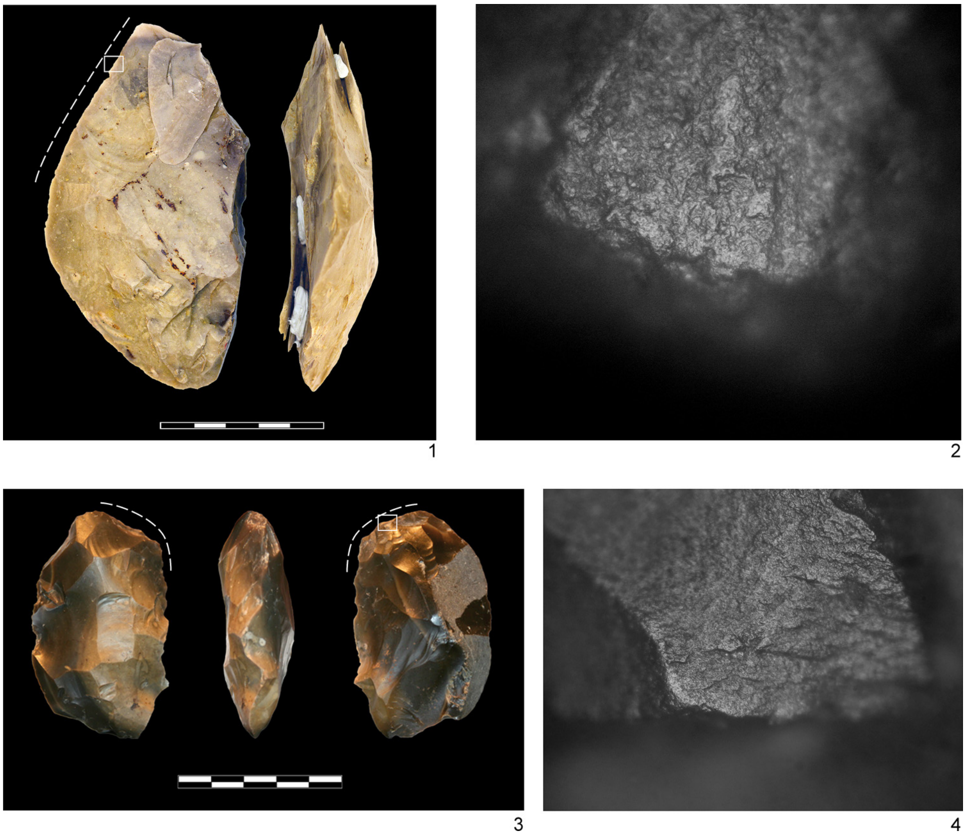

Fig. 13. Bifacial knives with use–wear traces: (1–2) traces on working edge of knife (see Fig. 12) resulting from bone or organic material (hide?) (magnification 200×); (3–4) traces on tip of bifacial knife related to bone and hide (magnification 100×).
Fig. 13. Couteaux bifaciaux avec des traces d'utilisation–usure : (1–2) traces sur le tranchant du couteau (voir Fig. 12) provenant d'un os ou de matière organique (peau ?) (grossissement 200×) ; (3–4) traces sur l'extrémité du couteau bifacial, rapportées à de l'os et la peau (grossissement 100×).

relationship between human activity and horse remains is documented (Gautier, 2005).

6. Discussion

6.1. Chronology of sites Pietraszyn 49 and 49a

The new chronological data presented in this study question the early ages of finds from the nearby site Pietraszyn 49. These first thermoluminescence dates obtained from sediments yielded ages of 193 ± 17 ka and 130 ± 10 ka (Fajer et al., 2001a, p. 206). Consequently, it was assumed that the inventory from Pietraszyn 49 represents the oldest Micoquian site in central Europe dated back to MIS 6 (Fajer et al., 2001a, 2001b). However, our studies indicate that artefacts from site Pietraszyn 49 are related to the same time span as lithics from Pietraszyn

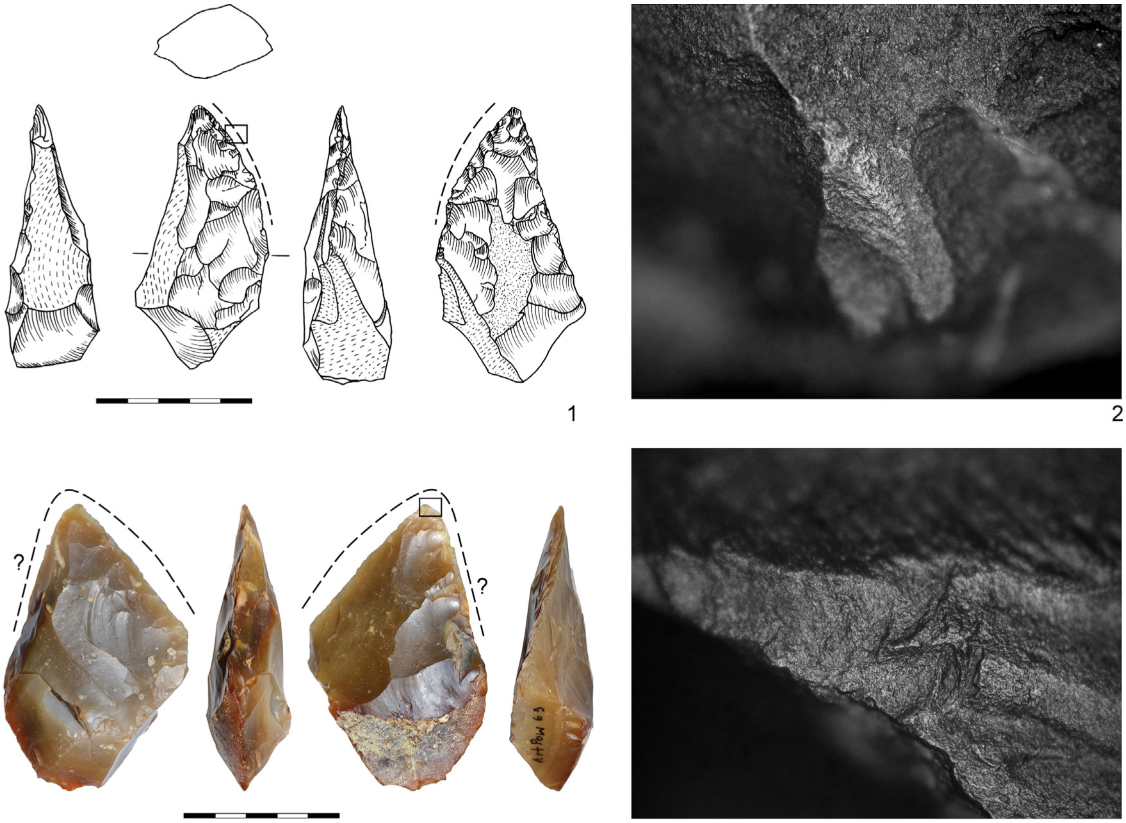

Fig. 14. Bifacial tools with use-wear traces: (1–2) traces on working edge of knife resulted from bone (magnification 100×); (3–4) traces on edges and tip of handaxe resulted from bone, hide and unknown organic material (magnification 100×).

Fig. 14. Outils bifaciaux avec des traces d'utilisation: tranchant du couteau utilisé sur l'os (grossissement 100×) ; (3–4) les bords et la pointe du biface utilisé sur l'os, la peau et un matériel organique inconnu (grossissement 100×).

49a (MIS 4/MIS 3). The association of both groups of finds is supported by stone tools from site 49, being analogous regarding the state of preservation, raw material, and technology of manufacture, with striking morphological similarities to artefacts from 49a (Wiśniewski et al., 2015). Additionally, they were found at the same altitude (approx. 218 m above sea level) in the same part of the valley.

Only the pIRIR225 luminescence age (about 140 ka) from the basal part of the sedimentary sequence exposed at Pietraszyn 49a, underlying the main archaeological find layer, is comparable to the previous TL ages from Pietraszyn 49. Hence, the high TL ages from Pietraszyn 49 might be explained by contamination of the dated sedimentary units by middle Pleistocene slope deposits. It is important to note, that at site Pietraszyn 49a, almost all of the artefacts (ca. 10k pieces) were found in the layer dated to MIS4/MIS3 (see Section 6.2).

Nevertheless, the new proposal of age assessment of Pietraszyn 49 and 49a does not reject the hypothesis regarding the appearance of asymmetric bifacial tools at the end of the middle Pleistocene in central Europe (Kozłowski, 2014, 2016). Their presence has been confirmed within the layers of MIS 7 and MIS 6 at the Biśnik Cave site (Cyrek et al., 2014).

6.2. An organisation of manufacture, behaviour and mobility of CEM groups

Studies from Pietraszyn 49a deepened our understanding of the process of tool shaping and operational chain economy. Firstly, Pietraszyn 49a shows the phenomenon of individualised treatment of raw materials in the early stages linked to the choice of a particular techno-functional unit sensu E. Boëda (2001), such as the back, playing the role of the prehensile part (Jöris, 2001, 2006; Veil et al., 1994). We noticed that, in some cases, the isolation of the back was integrated with the function of a striking platform, which was used for the detachment of large and flat flakes from the opposite side of the designed working edge of a tool. This idea is well expressed by group Ptr-4. However, these rules were not followed consistently. If there were no conditions for the organisation of such a striking platform, knappers decided to start shaping other parts of the block, for example, from the most distal zones. Secondly, the data also shed light on the question of flexible reaction to some unexpected technical problems caused by unpredictable damage. This behaviour is demonstrated by group Ptr-1 (Fig. 10).

Finally, in the case of Pietraszyn 49a, we are dealing with the technological plano-convex cross-section

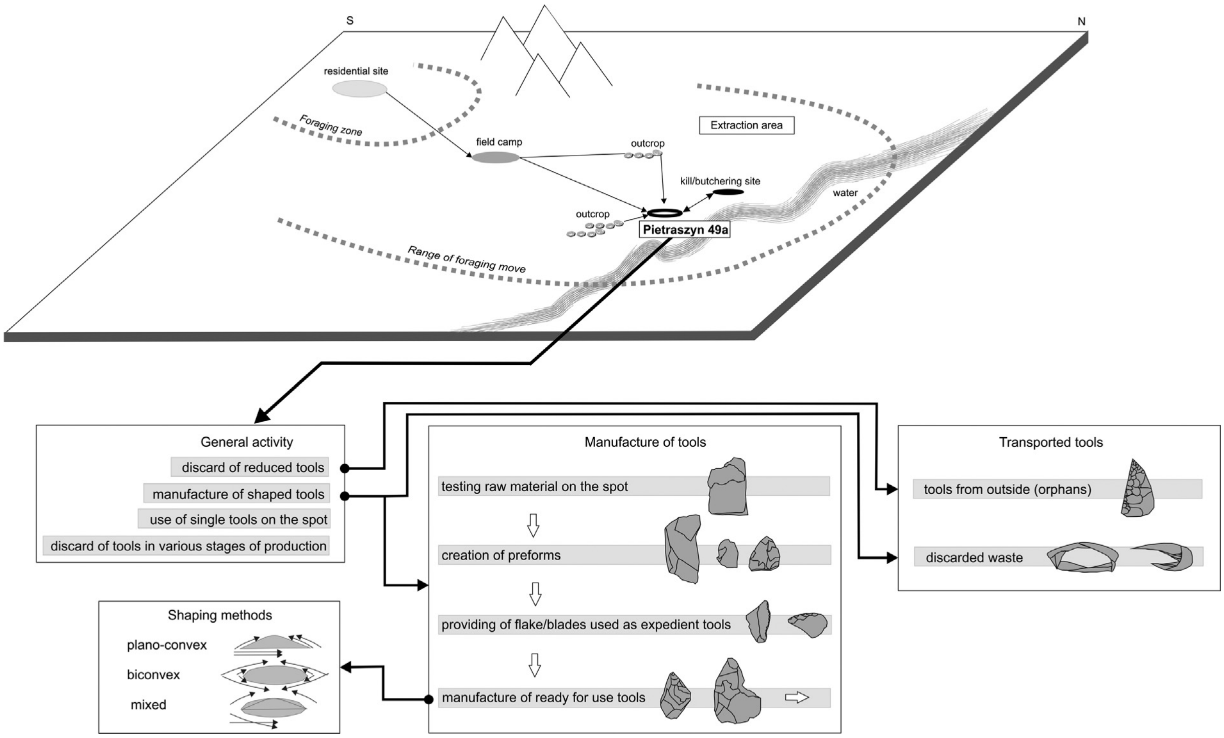

Fig. 15. Settlement and technological pattern related to the site Pietraszyn 49a (SW Poland): top, schematic representation of the spatial organization of the human groups having occupied Moravian Gate and its surrounding; bottom, activity within the workshop and main operational sequences with technical pattern concerning cross-section of shaped tools.
Fig. 15. Schéma d'implantation et d'organisation spatiale des activités techniques du site de Pietraszyn 49a (Sud-Ouest de la Pologne) : en haut, représentation schématique de l'organisation spatiale des groupes humains occupant la Portes de Moravie et ses environs ; en bas, activité au sein de l'atelier et principales chaînes opératoires, avec les schémas techniques relatifs à la section des outils façonnés.

concept. Refits enabled to reconstruct the sequence of shaping operations. It seems that giving the shape to a flat side was an initial stage of shaping. Only thereafter, the convex side was shaped (e.g., Ptr-1 group). Such a way of tool shaping is in line with the idea of renewing, which is the principle for the concept of an instrument used outside of workshops (Iovita, 2014; Uthmeier, 2016).

It should be noted that the use of the plano-convex strategy frequently relates to the basal and middle parts of the tools, while for the tips and distal posterior edge, a biconvex strategy was applied (Fig. 8: 3). At this time, we can only speculate on the reasons behind using mixed strategies. However, based on our observations, we cannot exclude that the use of mixed strategies was connected with attempts to adapt to a particular block shape or even the personal style of tool shaping.

Technological organisations cannot be fully characterised without the assessment of scale of tool production. The number of tools potentially produced in Pietraszyn 49a can be assessed based on the study of Acheulean bifaces from Red Barns (Wenban-Smith et al., 2000, p. 239) and Micoquian bifaces from Kabazi V/Crimea, layer III (Veselsky, 2008). For the Acheulian, the average blank ($\geq$20 mm)-to-biface ratio is 60:1, while the average blank ($\geq$30 mm)-to-biface ratio is 51:1 for the East European Micoquian. Hypothetically, a blank ($\geq$20 mm)-to-biface ratio of 38:1 can be assumed for the Pietraszyn 49a site in this context.

The next issue concerns the direction of production. Many CEM assemblages can be characterised by two lines of manufacture, i.e. a core reduction for flake/blade tools and tool shaping based on nodules or chunks and flakes (Boëda, 1997; Boëda et al., 1990; Bourguignon et al., 2006; Frick, 2016; Richter, 1997; Weißmüller, 1995). In Pietraszyn 49a, the flake/blade blanks of tools were obtained during tool shaping. This hypothesis is confirmed by the presence of a refitted group containing flakes and sidescrapers. As noted above, in Pietraszyn 49a, we did not record any core. This feature makes the complex from Pietraszyn 49a similar to the eastern Micoquian sites in Crimea (Demidenko, 2015; Uthmeier, 2016), as well as individual sites from central Europe (Mańka et al., 2006; Veil et al., 1994). This option seems to be a constant element of the operational chain of tool shaping in the CEM. From the perspective of ethnoarchaeological studies, the use of expedient flakes during stone tool production is not surprising. There have been many examples showing that such blanks served to solve "some technical problems" (McCall, 2012, p. 174).

Although discoveries from the Pietraszyn 49a site have been partially moved by slope processes, it is reasonable to question the number of individuals involved in the tool production process. Considering the large number of finds, as well as nodules or chunks, used during manufacture, it seems that we are dealing with remnants of more than one person. Interestingly, the range of technical activities related to the production of end products was quite uniform. They are represented by shaped tools "equipped" with one or two working edges, a point, a back, and a base.

We believe that this behaviour could be the result of integrating of various technological tasks, which lead to the reconstruction of mobile toolkits. Integration of tasks was observed within modern groups of hunters-gatherers similarly extracting the landscape (Kaplan et al., 2009). Until now, this type of behaviour was mostly considered in the context of residential camps or hunting/butchering sites and workshops in quarries (Hoffecker, 2002; Shipton and Nielsen, 2015; Vaquero et al., 2004).

The case of Pietraszyn 49a raises the question of the relationships of workshops to other places in the late Neanderthal's foraging system. It is generally accepted that shaped tools such as handaxes or knives played an essential role in butchering practices (Claud, 2014; Finkel and Barkai, 2018; Giria, 2004; Jöris, 2006; Pope and Roberts, 2005; Rots, 2009; Veil et al., 1994). The notion that such places were functionally linked with an area of game capture and disarticulation of carcasses was also supported by microscopic studies of individual tools from Pietraszyn 49a.

Finally, in this part, we discuss issues connected to the provisioning system. At Pietraszyn 49a, discarded waste from the manufacture of shaped tools prevails over flake tools and other examples of shaped tools brought from outside (i.e. orphans; see Morrow, 1996). This scenario clearly indicates that, in the excavated part of site Pietraszyn 49, the production of transportable personal gear (i.e. formal tools) occurred (Binford, 1979; Kuhn, 1995, pp. 22–24). However, it is difficult to assess the scale of transport. We cannot exclude that some shaped tools produced in the workshop could have been used and abandoned in the proximity. Such a scenario reflects the presence of several bifacial tools spread over the area of the Troja River valley (Fajer et al., 2001a; Kozłowski, 1964; Wiśniewski, 2006).

To conclude, the site Pietraszyn 49a confirmed that late Neanderthals explored the northern parts of their niche using a flexible system. One of the key elements of the structure was an extraction zone covering needs connected to provisioning for food and toolkits (Fig. 15). It is clear that technological activity in the discussed place was part of a subsistence system of late Neanderthals.

Without question, the finds from Pietraszyn 49a constitute a special functional part of the land-use system. The structure of finds from Pietraszyn 49a calls to mind some camps (type A) from Crimea, indicating that a similar organisation was applied by Neanderthals over vast areas (Chabai and Uthmeier, 2006, pp. 306–307; Uthmeier and Chabai, 2010, p. 208). However, the existence of such places as workshops does not determine which mobility system prevailed at that time in front of the Moravian Gate.

7. Conclusions

The foregoing studies attempted to examine the role of a provisioning zone existing within the foraging system of late Neanderthals, identified within the central European Micoquian. Our conclusions are based on results of lithic assemblage analysis on material recovered from site Pietraszyn 49a in southwestern Poland, radiometrically dated back to MIS 4/MIS 3. The assemblage provided unique evidence of the early steps of roughing-out and shaping of bifacial tools using local glacial erratic flints. Numerous refits allowed us to reconstruct methods and techniques applied during the manufacturing of tools. Careful studies have shown that Neanderthals used a wide range of technological strategies to obtain sets of shaped tools transported as personal gear outside the site. Functional examination of the finds from Pietraszyn 49a led us to infer that the workshop could be linked to places of game capture or disarticulation of carcasses. It is valid to speculate that Pietraszyn 49a and its proximity played roles in foraging areas likely visited routinely by groups of Neanderthals.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.crpv.2019.01.003.

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