Beyond the caves : stone artifact analysis of late Middle Paleolithic open-air assemblages from the European Plain

Weiss, M.

Author: Weiss, M.
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Chapter V: Conclusion

5.1 Aims and Relevance

The aim of the present thesis is to quantitatively analyze factors that drive late Middle Paleolithic stone artifact variability within and between open-air assemblages of the European Plain.

Currently, the late Middle Paleolithic record of central Europe is characterized by a patchwork of typo-technological archaeological entities (e.g. Kozłowski, 2014, fig. 16). They are either defined by the presence of certain bifacial tools, e.g. *Micoquian* (Bosinski, 1967; Kozłowski, 2014), *Micoquo-Prondnikien* (Chmielewski, 1969), *Prądnik cycle* (Krukowski, 1939-1948) or *Keilmessergruppen* (e.g. Veil et al., 1994; Mania, 2002), by the absence of bifacial tools together with Levallois blank production, e.g. *Mousterian* (e.g. Bosinski, 1967; Kozłowski and Kozłowski, 1996), or by artifact size, e.g. *Taubachian* (Collins, 1968; Valoch, 1971, 1977, 1984, 1988, 2003). A more recent approach suggested a synthesis of Mousterian and Micoquian assemblages, interpreting them as parts of a single unit, the "Mousterian with Micoquian Option" or MMO (e.g. Richter, 1997, 2000, 2001, 2002, 2012, 2016). Variability within this concept is then caused by factors like land use, site function, occupation duration or seasonality.

Some of these typo-technological entities or technocomplexes are defined by rather arbitrary, subjective means (Monnier and Missal, 2014; Shea, 2014). Thinking in these categories while interpreting and comparing stone artifact assemblages might lead researchers to overlook important factors that drive stone tool variability that connects or disconnects certain assemblages and thus hamper efforts to answer important questions about human behavior (Monnier and Missal, 2014; Shea, 2014). Therefore, the work presented here attempts to rely on standardized, more objective quantitative methods to analyze late Middle Paleolithic stone tool variability across techno-complexes. Artifact assemblages and individual stone tools where analyzed based on a detailed attribute analysis and quantitative attributes where compared using multivariate methods, like Principal Component Analysis (hereafter PCA; Hotelling, 1933) and Nonmetric Multidimensional Scaling (hereafter: NMDS; Kruskal, 1964; Kruskal and Wish, 1983). Additionally, methods from 3D geometric morphometrics where applied for the analysis of some individual tool types.

The quantitative methods applied in this dissertation revealed some new results or ideas about the structure of stone artifact variability. These results are a first step and with a larger, more diverse dataset in the future, they may help to answer broader archaeological questions about human behavior. For example, it is necessary to understand how late Middle Paleolithic variability is structured if we like to interpret technological changes in the stone tool record of central Europe during the Middle to Upper Paleolithic transition. As an example, this may directly influence our interpretation of the emergence of the transitional Lincombian-Ranisian-Jerzmanowician ("LRJ", Chmielewski, 1961; Kozłowski, 1983; Desbrosse and Kozłowski, 1988; Flas, 2006, 2011, 2013, 2014). This single archaeological phenomenon spanned from Poland across the European Plain to Great Britain and is interpreted as having developed from the local late Middle Paleolithic (Flas, 2006, 2011, 2013, 2014; see also Hublin, 2015). As it geographically overlaps with the late Middle Paleolithic of central Europe, a better understanding of late Middle Paleolithic variability may contribute in the future to the discussion of the LRJ emergence, i.e. if it developed from one of the defined techno-typological entities, if it the LRJ was intrusive, or if the late Middle Paleolithic record was in fact as 'uniform' as the subsequent LRJ, indicating a linear development. Some hypotheses will be discussed below.

Furthermore, a better understanding of the structure of late Middle Paleolithic stone artifact variability between Marine Isotope Stage (MIS) 5a (~ 82 ka (Lisiecki and Raymo, 2005)) and early MIS 3 (57 ka to 43 ka (Lisiecki and Raymo, 2005; Richter, 2016)) may also contribute to discussions about late Neanderthal population dynamics. The cold MIS 4 is currently interpreted as a bottleneck for Neanderthal populations in Europe and local extinctions or population movements to refuge areas are discussed (see e.g. Jöris, 2004; Hublin and Roebroeks, 2009; Roebroeks et al., 2011). Therefore, in revealing factors that drive Middle Paleolithic variability, we may also better understand the presence and/or absence of chronological variability between MIS 5a to early MIS 3 and relate that to Neanderthal population dynamics.

5.2 Material Selection

The three studies of this thesis are based on MIS 5a to MIS 3 open-air stone tool assemblages from the European Plain: Königsaue (Mania and Toepfer, 1973; Mania, 2002) and Pouch (Weiss, 2015) from Saxony-Anhalt, central Germany, Wrocław-Hallera Av. (Wiśniewski et al., 2013) from southwestern Poland, and Khotylevo I-6-2 (Ocherednoi et al., 2014a, 2014b, 2015; Vishnyatsky et al., 2015) located in western Russia. The most important criterion in selecting these sites was to have sites attributed to different typo-technological or archaeological entities:

the lower assemblage of Wrocław-Hallera Av. and Königsaue B (e.g. Mania, 2002) are interpreted as Mousterian, and Königsaue A, C (e.g. Mania, 2002), Pouch and Khotylevo I-6-2 can typologically be classified as Micoquian. Additionally, both assemblages from Wrocław-Hallera Av. are interpreted as Taubachian due to their small artifact size (Valde-Nowak et al., 2016; Alex et al., 2017).

The thesis focusses on open-air sites, as the selected research area is rich in late Middle Paleolithic open-air sites, but up to now they are lacking detailed quantitative comparisons between them. Furthermore, they are interpreted to be mostly less time-averaged than assemblages from cave sites or rock shelters, and short-term occupations may be preserved (see e.g. Isaac, 1981; Roebroeks, 1988; Roebroeks et al., 1992; Roebroeks and Tuffreau, 1999; Enloe, 2006; Bailey and Galanidou, 2009 and references cited therein; Picin, 2016). Whereas time averaged assemblages provide important data on rather long-term processes in human history and behavior (Bailey, 2007; De Lange, 2008; Bailey and Galanidou, 2009), the short-term occupations of the sites included in this study are well suited for isolating factors that drive stone tool variability on a smaller scale. However, stone artifact variability needs to be understood also on a broader scale. Therefore, the time and space perspectives (Bailey, 2008) were adjusted in a subsequent step and the assemblages were compared to different occupations at each site and to the other assemblages across the European Plain (Chapter III). This was done to analyze archaeological entities or tool concepts and to reveal broader patterns of variability.

To cover a large part of the European Plain the assemblages were selected from three separated regions: central Germany, southwestern Poland and the western Russian Plain. The spatial distribution of the sites accounts for highly mobile Neanderthal groups (e.g. Roebroeks and Tuffreau, 1999) roaming in the vast geographical area of central Europe, as suggested by Neanderthal energetics (e.g. Sorensen and Leonard, 2001; Steegmann et al., 2002; Aiello and Wheeler, 2003; Weaver and Steudel-Numbers, 2005; Verpoorte, 2006; MacDonald et al., 2009; Roebroeks et al., 2011) and raw material transports (Féblot-Augustins, 1993, 1999, 2009; Floss, 1994). In other words, when taking into account the low estimated population density (see Roebroeks et al., 2011 and citations therein; Prüfer et al., 2017) together with the highly mobile lifeway of late Neanderthals, it can be expected that the individual groups and their associated stone tool assemblages covered a large territory during, for example, the cycle of a year.

5.3 Outline of the Thesis and Results

This thesis is based on the late Middle Paleolithic stone artifact assemblage of Pouch-Terrassenpfeiler (hereafter: Pouch), Saxony-Anhalt/Germany, which was excavated by the Landesamt für Denkmalpfelge und Archäologie Sachsen-Anhalt – Landesmuseum für Vorgeschichte in 2002. As this material was not published entirely before (see the preliminary report by Seiler and Runck, 2003), the thesis starts with a presentation of the material and a discussion of the assemblage within its central German context (Chapter II). The second study (Chapter III) tries to put the assemblage of Pouch into the context of late Middle Paleolithic assemblages across a broad region. This involves comparisons with several assemblages from central Germany, southwestern Poland and the western Russian Plain. Thereby, assemblage variability is assessed with the application of multivariate methods. In the third part of the study (Chapter IV), tools from Pouch form the baseline for the analysis of the most diagnostic tool type of the central and eastern European Micoquian, the bifacial backed knife or Keilmesser. With the application of 3D geometric morphometrics and thickness distribution mapping of 3D scans, together with a multivariate analysis of tool attributes, the study tackles the question of whether the functional and morphological concept underlying the bifacial Keilmesser was as well applied to simple edge retouched and unifacially shaped tools.

The first paper serves as the baseline for the subsequent studies and presents the assemblage of Pouch. The study was complemented by the presentation of late Middle Paleolithic MIS 3 finds from the vicinity of the site, collected from the last glacial Lower Terrace sequence of the river Mulde. With prepared core and Levallois blank production, bifacial tools like Keilmesser and bifacial scrapers, as well as a variety of unifacially shaped and simple scrapers, Pouch yielded an assemblage typical for the central and eastern European Micoquian or Keilmessergruppen. Luminescence and radiocarbon dates of about 46 ka for the find layers re-enforce the attribution of the assemblage to the late Middle Paleolithic. The paper discusses further some observations about stone tool variability in Pouch. The components underlying the morphological concept of the bifacial Keilmesser, a base and a back opposite a sharp cutting edge and a retouched tip, could be observed as well on simple edge retouched and unifacially shaped tools. This observation formed the baseline for the subsequent study of Keilmesser-like tools in paper three (Chapter IV). Related to that, the tools of Pouch possess in general a variety of backs opposite a sharp working edge. This morphological feature could be traced as well in other central German assemblages. Examples are natural backs, retouched backs ("backed"), and platforms or core edges that form backs. This finding suggests that a handle or prehensile part played a major role in the conceptualization of these late Middle Paleolithic tools. Whether some of those backs, like blunted, backed edges or thinned backs, served for the hafting of a separate handle, should be a subject of future work.

The second study has some implications for assemblage variability and typologically defined late Middle Paleolithic entities. Micoquian assemblages are differentiated from Mousterian assemblages mainly by the presence of bifacial tools. Therefore, assemblages were analyzed without focusing on type fossils, e.g. certain diagnostic tool types like the bifacial Keilmesser. Multivariate methods based on attribute analysis were applied to the flake assemblages. Flakes were chosen, because they represent the most numerous artifact category in each assemblage. The assumption here was that influences resulting from technologies as well as raw material characteristics are coded in the combination of certain flake attributes. Multivariate methods were then applied to analyze and compare the combination of flakes for each assemblage, assuming that more similar assemblages regarding technology and raw material will produce comparable assemblages of flakes. To interpret the results of the multivariate plots, a subsequent analysis of the influence of raw materials, blank production and tool production on the individual flake variables was conducted. The results showed that assemblages classified as Mousterian and Micoquian in fact share one larger cluster of variability in the multivariate analysis of flake attributes. Within this larger cluster, the Königsaue (Saxony-Anhalt/Germany) assemblages show a tight relationship throughout all analytical methods applied. Besides showing similarities concerning technological flake attributes, the Königsaue assemblages show the lowest share of cortex on their flakes. This may be the result of similar raw material treatment strategies, where already pre-shaped nodules might have been transported to the place where they were knapped. On the other hand, one outlier of the larger cluster of flake assemblage variability was observed in all multivariate results. This assemblage from the upper layer of Wrocław-Hallera Av. is distinct from all the other sites, although it shares the same small raw material characteristics with the lower layer from the same site. In fact, the difference observed here must be a result of different technologies, as indicated by a very low share of Levallois methods in the upper assemblage. In general, the variability observed in the record is not related to techno-typological classification, it shows, despite Wrocław-Hallera Av. upper assemblage, no chronological differences, and it is not necessarily site-specific nor geographical. Variability can be related to raw material, but it can also be related to the varying application of similar methods in blank and tool production. Setting aside type fossils and given the facets of variability we documented, these assemblages cannot be readily placed into typo-technological entities defined by the presence/ absence of bifacial tools and/or blank production methods or by artifact size.

Conceptually contrasting with the approach in the second paper, the third study focusses on one of the late Middle Paleolithic type fossils of central and eastern Europe, the bifacial backed knife or Keilmesser. The aim here was to analyze tool variability on a regional sample of early MIS 3 tools from roughly the same paleo-environment. Based on observations on the material of Pouch, the third paper examines whether the concept underlying the bifacial Keilmesser (e.g. Jöris, 2001, 2006, 2012) may as well have been applied to simple edge retouched and unifacially shaped tools. The basic assumption of the study is that similar tools with comparable edge modifications had similar functionality. Based on the functional/morphological components defined for the Keilmesser (e.g. Jöris, 2001, 2006, 2012), additional non-Keilmesser tools were divided into several prehensile and active areas (e.g. Boëda, 1997, 2001; Soressi, 2002; Soressi and Hays, 2003). The study used then a set of varying quantitative analytical methods to analyze aspects of variability from several angles. These aspects represent variability in shape related to the single components, thickness distribution in relation to the active and prehensile parts, and attributes like overall flatness, elongation, edge angles and retouch intensity. The results showed that the artifacts in question might indeed share a comparable function but that they vary regarding shape and symmetry, blank type and retouch intensity. The tool concept formerly restricted to bifacial Keilmesser may in fact be applied to unifacially shaped and simple edge retouched scrapers as well. Thereby, simple scrapers with a Keilmesser-like morphology represent potentially the most simplistic variant of Keilmesser, where the morphology of the blank almost already fulfilled the functional requirements of the tool. Handaxes, on the other hand may represent a functionally related but slightly different tool concept with a more symmetric morphology. For this latter tool type, however, the sample size in relation to late Middle Paleolithic handaxe diversity (see e.g. Bordes, 1961; Bosinski, 1967) was quite small, and it would now be interesting to look more in depth at this tool with a larger sample.

5.4 Discussion and Relevance of the Results for broader archaeological Discussions

5.4.1 Implications for the Understanding of late Middle Paleolithic Variability

The results presented in this thesis suggest that the assemblages included in the analysis represent a single phenomenon of a shared material culture with an inherent range of variability. This material culture-package extends from the northern central European lowlands to the western Russian plain, and probably beyond. The most prominent examples beyond the scope of this thesis might be the Sesselfelsgrotte in Bavaria/ southern Germany (e.g. Richter, 1997), the Kůlna cave in Moravia/ Czech Republik (Valoch, 1988; e.g. Boëda, 1995; Moncel and Neruda, 2000), Suchaja Mečetka at the Wolga river/ Russia (Zamiatnin, 1961; Praslov, 1984), the sites of the Crimean Micoquian (e.g. Chabai et al., 2004; Uthmeier and Demidenko, 2013; Stepanchuk et al., 2015) or Mezmaiskaya Cave (see Golovanova et al., 2016 for the latest work and citations therein) and the Il'Skaya site in the northwestern Caucasus (Scelinski, 1998; Bosinski and Scelinski, 2001).

The studies presented here imply that we should be cautious with the traditional typological classifications of the central and eastern European late Middle Paleolithic. The second study (Chapter III) showed that assemblage variability is structured differently when the type fossils are removed and only the flakes are considered. Other factors, like raw material conditions and management, as well as varying frequencies of tool and blank production methods within each assemblage could lead to assemblage variability and confusion regarding their classification into traditional techno-complexes. The third study (Chapter IV) implies that we have to re-think our concepts of the type fossils themselves and that we should work on more flexible tool definitions in the future. Additionally, it can be inferred from that study that the type fossil itself may be absent at a site but the specific tool concept may still be present. This may also lead to confusion regarding assemblage classification based on type fossils alone.

Taken all together, we can interpret the late Middle Paleolithic stone tool record as uniform from one perspective, as across the study area and based on the assemblages analyzed here, Neanderthals had a flake-based stone tool industry, with prepared core blank production, as well as simple, unifacially shaped, and bifacial tool manufacture. But from another perspective, Neanderthals were as well very flexible regarding blank and tool production. The sites have the same types but varying frequencies of blank production strategies or bifacial tools. Certain tool concepts, like the Keilmesser-concept, were applied to different blanks, causing variability in the record. Additionally, the thesis has shown (Chapter III) that Neanderthals were as well very flexible regarding raw material management. Whether the described facets of flexibility were caused by local environmental conditions, distinct Neanderthal groups (e.g. Ruebens, 2013), mobility of human groups (Picin, 2016), seasonality, site function or occupation duration (e.g. Richter, 1997, 2000, 2001, 2002, 2012, 2016), is beyond the scope of this thesis but should be the subject of future late Middle Paleolithic research of the European Plain.

The thesis contributed as well to the ongoing discussion about whether or not to drop named stone tool entities ("NASTIES"; Shea, 2014). The results imply that names like Mousterian, Micoquian or Taubachian might indeed not be very meaningful for answering behavioral questions. For example, it is not clear whether distinguishing the Königsaue assemblages into Mousterian and Micoquian by typo-technological means and attributing them to distinct human groups (Mania and Toepfer, 1973; Mania, 2002) will yield a coherent interpretation of the late Middle Paleolithic. With this traditional approach, dissimilarities are already assumed and built into the structure of the analysis. Thereafter there is less room for potential similarities when interpreting the archaeological record. But if we drop the techno-complex names and apply consistent and objective techniques of analysis across larger groups of assemblages, we may see, for instance, that they had a persistent raw material pre-treatment behavior over (potentially) generations (Chapter III). Although we still do not know if the assemblages from Königsaue were produced by different human groups, we learned something important about human behavior, persistent in a specific region over a certain amount of time. In other words, we are far from understanding what factors drive variability in the late Middle Paleolithic record, and we need to find more objective ways of analyzing the archaeological record to isolate and trace these factors. If we understand how variability is structured, we can start to build entities that classify the archaeological record in ways that are potentially more behaviorally meaningful. Besides the work of this thesis, a first step towards that goal was to construct entities like the MMO (e.g. Richter, 1997, 2000, 2001, 2002, 2012, 2016). The MMO places certain NASTIES as components of one system and includes factors like land use, site function, occupation duration or seasonality as agents that drive variability. Following Richter (2016), we do not necessarily have to drop names like Keilmessergruppen, Micoquian or Mousterian. They are still valid units to name certain assemblages with specific characteristics. We just have to be aware that they might be part of a broader unit, expressions of variability caused by factors like raw material, site function, land use, environment, seasonality or human behavior. The results from the assemblages analyzed here support the idea of the MMO (e.g. Richter, 1997, 2000, 2001, 2002, 2012, 2016), where a technological baseline (e.g. prepared core blank production in varying frequencies) connects different assemblage types. The latter are then characterized by varying frequencies of bifacial tools or artifact size, among others.

5.4.2 Implications for late Middle Paleolithic Chronology and Neanderthal Population Dynamics

The number of sites included in the present analysis is generally too small to interpret late Middle Paleolithic chronology and Neanderthal population dynamics between MIS 5a and MIS 3. Therefore, it is problematic to discuss southwards movements (e.g. Jöris, 2004) or potential local extinctions of northern Neanderthal populations (e.g. Hublin and Roebroeks, 2009;

Roebroeks et al., 2011) during the cold stage of MIS 4, based on the results of this thesis. An additional issue is the dating uncertainty of some of the assemblages. Two of the sites included in this thesis are problematic in this respect, namely Königsaue and Khotylevo. It is still debated whether Königsaue dates to MIS 5a or MIS 3 (Mania and Toepfer, 1973; Mania, 2002; Jöris, 2004, but see Hedges et al., 1998; Picin, 2016). Whereas the sequence of the silt and peat deposits together with the pollen stratigraphy favors a MIS 5a age (Mania and Toepfer, 1973; Mania, 2002; Jöris, 2004), the radiocarbon dating indicates an early MIS 3 age for the site (Hedges et al., 1998; Picin, 2016). Likewise, the radiocarbon ages of Khotylevo favor, at first glance, an early MIS 3 age. But a closer look (Table 1) reveals some uncertainties: the calibrated radiocarbon dates for CH 1 (Cultural Horizon) range from outside the limits of the calibration curve (IntCal 13) to ~27.000 calBP (1σ). Similar uncertainties exist for CH 2 which dates from 49.000 calBP (1σ) and 'out of range' (2σ) to 40.000 calBP (1σ). The uncertainties of the radiocarbon dating, together with the assemblages embedded in several humic beds or paleosols formed under temperate conditions, do not exclude a potential MIS 5a age for the site. To clarify the chronology of the site, new radiocarbon and luminescence dating is currently ongoing. Beyond the scope of this thesis, reliable dated assemblages are generally rare in the European Plain. For example, the sites Salzgitter and Lichtenberg in Lower Saxony reveal comparable dating uncertainties, related to either radiocarbon (Salzgitter, Pastoors, 2001) or thermoluminescence dating (Lichtenberg, Veil et al., 1994). Therefore, their chronological attribution to MIS 5a, MIS 4 or MIS 3 has at least to be considered as uncertain (Veil et al., 1994; Pastoors, 2001, 2009; Jöris, 2004).

Besides the chronological uncertainties for the archaeological record of the research area, two different models for the chronostratigraphy of the late Middle Paleolithic in central and western central Europe have been proposed. Jöris (2004) proposed a model of a "long chronology" of the Keilmessergruppen. He interprets the sites with dating uncertainties mentioned above (Königsaue, Salzgitter-Lebenstedt and Lichtenberg) as part of the Keilmessergruppen-A (KMG-A) inventories. Jöris (2004) puts more emphasis on the stratigraphy and geological aspects of the sites. Together with common typological aspects, e.g. Keilmesser with convex cutting edges, the occurrence of handaxes, and prepared core blank production, he places these inventories into late MIS 5. KMG-A assemblages should be distributed primarily in the northern European lowlands. The subsequent KMG-B1 inventories are placed by Jöris into the early MIS 4. They are characterized by the frequent application of the Prądnik para-burin technique and seem go occur on the northern border of the low mountain ranges. KMG-B2 is not present in central Europe during MIS-4. Jöris (2004) tries to track these facies in southern refuge areas, e.g. based on some occurrences of Keilmesser within the MTA in France (see argumentation and references in Jöris, 2004). Finally, the KMG-C facies, distributed in the southern low mountain ranges, is placed into MIS 3, e.g. with the G-Layers of the Sesselfelsgrotte/ Bavaria, Germany (Richter, 1997). Technologically, these assemblages show a sequence of Quina blank production followed by Levallois techniques (Richter, 1997). The dates for the latter site (Richter, 2002) led Richter (e.g. Richter, 2002, 2016) to the formulation of a contradicting chronological model of the MMO. He proposes the short chronology for the MMO and places all the assemblages, including the problematic sites from the European Plain mentioned above, into the early MIS 3 between ~60.000 and ~43.000 years ago (Richter, 2016).

With the dating uncertainties of the sites from the European Plain, the question of the chronology of the late Middle Paleolithic in central Europe cannot be solved. Furthermore, as long as we don´t have a clear chronological model for the time period between MIS 5a and MIS 3, it is impossible to answer the question whether late Neanderthal populations of the European plain moved southwards during MIS 4 or whether they became locally extinct. More fieldwork and reliable dating with new and advanced radiometric techniques is needed. However, some preliminary inferences about late Middle Paleolithic chronology and late Neanderthal population dynamics in western central Europe can be drawn. Although they cannot generally be applied to the entire European Plain, they illustrate several possible scenarios.

The technological attributes of Pouch and the collections from the surroundings (Chapter IV) contradict the exclusive attribution of KMG-A assemblages to late MIS 5 as proposed by Jöris (Jöris, 2004): Pouch, Löbnitz and Goitzsche are reliably dated to MIS 3 (Chapters II and IV). They can be characterized as KMG-A inventories, as prepared core techniques are the main methods of blank production and Keilmesser with convex cutting edges as well as handaxes are present. Technologically, the analysis in Chapter III revealed that Pouch (MIS 3) is also closely related to Khotylevo (MIS 5a/ MIS 3?) and Königsaue (MIS 5a/ MIS 3?). The latter, more specific Königsaue-A, was attributed by Jöris (2004) to KMG-A and the analysis in Chapter III confirms a technological relationship of these sites and a KMG-A interpretation of Pouch. On the other hand, Wrocław-Hallera Av. lower layer (MIS 5a) shows differences in raw material but is technologically still more closely related to the other assemblages than to the upper layer of Wrocław-Hallera Av. dated to MIS 3. In this respect, Wrocław-Hallera Av. is the only evidence within the dataset for chronological changes in blank production methods (e.g. as proposed by Richter, 1997, 2016; Jöris, 2004). The ages of Khotylevo and Königsaue have several interesting implications for late Middle Paleolithic chronology and Neanderthal population dynamics:

(1) If Königsaue and Khotylevo both have a MIS 5a age, this would imply that during that time period the European Plain from Germany to western Russia was inhabited by Neanderthal populations using similar blank and tool production techniques. After the cold MIS 4, central Europe was repopulated by Neanderthals producing comparable assemblages (Pouch). This would favor the interpretation of southwards movement of northern populations during MIS 4, together with a subsequent repopulation by similar groups during the beginning of MIS 3. In terms of the model of long chronology (Jöris, 2004), this would suggest that KMG-A inventories existed in MIS 5 and MIS 3 in central Europe.
(2) If only one of the sites – either Khotylevo or Königsaue – has an MIS 5a age this would imply the same as (1).
(3) If both of the sites have an MIS 3 age, the situation is more difficult to interpret. Then we would have a rather uniform stone tool industry across the European Plain during MIS 3 with the exception of Wrocław-Hallera Av. upper layer. The evidence from MIS 5a is then rather limited as only a single assemblage from the lower layer of Wrocław-Hallera Av. represents this time period in the dataset. Still, the dating for the latter to MIS 5a would contradict the short chronology model as proposed by Richter (2002, 2016).

If we now only consider the reliably dated assemblages from Wrocław-Hallera Av. and Pouch, the picture is more complex. As mentioned above, the MIS 5a assemblage from Wrocław-Hallera Av. lower layer is statistically and technologically more closely related to the MIS 3 assemblage of Pouch than to the MIS 3 assemblage of Wrocław-Hallera Av. upper layer. This implies that during MIS 3, the area around Pouch was repopulated by Neanderthals using comparable blank and tool production strategies, like in Wrocław-Hallera Av. lower layer. In contrast, the site Wrocław-Hallera Av. itself was potentially repopulated during MIS 3 with a different population. Although they were confronted with similar raw material constrains (e.g. small nodule size), they used different blank production strategies.

The examples described here illustrate that the depopulation during MIS 4 and the repopulation during MIS 3 of the northern and central European Plain seems to have been a rather complex process. Generally, local extinctions cannot be ruled out, but the same is true for the southward movement of Neanderthal groups with a subsequent repopulation during MIS 3. Further, the evidence presented here – at least with the dates for Wrocław-Hallera Av. – favors rather a model of long chronology, from late MIS 5 to early MIS 3 for the late Middle Paleolithic of the European Plain. Contradicting the model for the long chronology proposed by Jöris (2004), the dates for Pouch suggest that KMG-A inventories might also have been present during MIS 3 in central Europe.

These preliminary interpretations based on the results of this thesis are promising, but they imply that a broader database and more reliable dating is needed for future discussions.

5.4.3 Implications for the Middle to Upper Paleolithic Transition in central Europe

As an example of the relationship between late Middle Paleolithic and transitional industries in central Europe, the case of the Lincombian-Ranisian-Jerzmanowician (LRJ) is worth examining (Chmielewski, 1961; Kozłowski, 1983; Desbrosse and Kozłowski, 1988; Flas, 2006, 2011, 2013, 2014). This technocomplex largely overlaps in the northwestern part of the European Plain with the assemblages analyzed in this thesis and is interpreted as having developed from the local late Middle Paleolithic (Flas, 2006, 2011, 2013, 2014; see also Hublin, 2015). Although it still lacks precise dating, it most probably occurs around 40.000 calBP (for summary see e.g. Hublin, 2015). However, the dataset of this thesis is too limited to reconstruct the formation of the LRJ, and this was done already elsewhere (Flas, 2006, 2011, 2013, 2014; see also e.g. Richter, 2008-2009). Nevertheless, some thoughts based on the late Middle Paleolithic variability present here and their implications on the formation of the LRJ can be brought forward.

The late Middle Paleolithic in the scope of this thesis can be described as a rather uniform material cultural package covering the European Plain, which was flexibly applied based on local environmental circumstances, site functions and needs. The technology consists of a flake based blank production systems with varying frequencies of prepared core techniques within the individual assemblages (Chapter III). The tool repertoire consists of varying degrees of bifacial tools, which are dominated by asymmetric knives (e.g. bifacial backed knives or Keilmesser) accompanied by leaf-shaped scrapers and handaxes (e.g. Veil et al., 1994). These asymmetric tool concepts, often consisting of a back opposite a sharp cutting edge and a pointed tip, are found equally in bifacial and unifacial tools (Chapter II and Chapter IV). Beyond the framework of this thesis, there exist also late Middle Paleolithic open-air assemblages with exclusively bifacial reduction, e.g. Lichtenberg, Lower Saxony/ Germany (Veil et al., 1994) and Pietraszyn 49a, Poland (pers. communication Andrzej Wiśniewski, excavator of the site).

For the LRJ, instead, flake production methods have not been found in this technocomplex (Flas, 2011). The most prominent tool type of the LRJ is the Jerzmanowice point manufactured on blades from bidirectional cores, with partial dorsal and ventral retouch. Furthermore, although less numerous, some Upper Paleolithic tool types occur: pointed blades, retouched blades, endscrapers and burins (Flas, 2011). Besides Jerzmanowice points, bifacial leaf-points manufactured on natural flat pieces or large flakes occur in some assemblages. They are less frequent than Jerzmanowice points except at the central German cave site Ranis/Thuringia (Hülle, 1977; Flas, 2011).

It is evident that the main difference between the two entities – late Middle Paleolithic and LRJ – are the Jerzmanowice blade points and the associated blank production technique. Blade production on bidirectional cores was not observed in the late Middle Paleolithic assemblages analyzed here. Furthermore, other studies suggest that late Neanderthals within the scope of the present research area where not "interested" in the manufacture of blades (e.g. Pastoors, 2009). Additionally, standardized symmetric blade points where not observed in the analyzed assemblages, where rather asymmetric tools manufactured on natural pieces or flakes prevail. Based on this, there are two ways to interpret the emergence of these specific blade points and the associated blank production strategy: either they were a new innovation or they were intrusive.

On the one hand, the flexible application of known techniques and tool concepts seems to leave room for new innovations. But seen from a different angle, the rather uniform Middle Paleolithic techno-tradition across time and space can also be interpreted as a kind of technological conservativism that, instead, prevents entirely new innovations. Generally, the late Middle Paleolithic described here is rooted in a long Middle Paleolithic tradition lasting for at least 250.000 years (e.g. Hérisson et al., 2016; Richter, 2016; Lauer and Weiss, 2018). Flake based blank production systems on prepared cores exist during the entire Middle Paleolithic, although there exist some attribute based chronological differences between MIS 7 to MIS 3 central German assemblages (Weiß and Weber, 2019, in press). Even handaxes and asymmetric tool concepts were already present in central Europe at the onset of the Middle Paleolithic about 300.000 years ago (see e.g. the site of Eythra/Saxony, Germany Rudolph et al., 1995; Lauer and Weiss, 2018). However, blade production methods also existed in central and northwestern central Europe during the course of the Middle Paleolithic (for a summery see Richter, 2016), for example at the MIS 7 site Rheindahlen B1/North Rhine-Westphalia, Germany (Ikinger,

2002) or the early Weichselian site Tönchesberg 2B/Rhineland-Palatinate, Germany (Conard, 1992). But their occurrence was rather occasional (for a summery see Richter, 2016) and, as mentioned above, sophisticated blade production is not an aspect of the central European assemblages analyzed here. Additionally, in the case of the Jerzmanowice points, it is a special, new and innovative blank production method for the purpose of producing a specific tool type that - in this standardized way - did not exist in the late Middle Paleolithic assemblages of the European Plain analyzed here. Other assemblages from this geographical region show as well no evidence for this technology (e.g. Tode, 1982; Veil et al., 1994; Pastoors, 2001, 2009; Schild, 2005; Laurat and Brühl, 2006; Valde-Nowak et al., 2016). Therefore, the results of this thesis concerning late Middle Paleolithic variability may argue rather for an origin of the Jerzmanowice blade points that lies outside the late Middle Paleolithic technological repertoire. As currently no human remains are clearly associated with the LRJ, the question of whether these blade points where manufactured by *Homo sapiens* has to remain open.

The bifacial leaf-points on the other hand point to a connection of the LRJ to the late Middle Paleolithic. As they are mostly found in the assemblage of Ranis (see e.g. Flas, 2011), archaeological horizon "Ranis 2", I will use this leaf-point assemblage as an example to discuss a potential late Middle Paleolithic relationship. Unfortunately, no reliable date for the assemblage is currently available as the animal bones from the original excavation associated with the LRJ layer reveal large dating uncertainties (M.Grünberg, 2006; Higham et al., 2007). The assemblage Ranis 2 (Hülle, 1977) was found in the so-called grey layer (Layer X, "Graue Schicht") and consists of 24 Jerzmanowice blade points (including fragments) and 19 bifacial leaf-points (including fragments). Additionally, late Middle Paleolithic tool types, like leaf-shaped bifacial scrapers and (bifacial) scrapers are present in the assemblage. One of the bifacial scrapers seems to be in the morphological variation of Keilmesser (Hülle, 1977, Plate 36:2,72). The inventory contains no flakes or cores, suggesting that the tools where not produced and maintained at the site.

The bifacial leaf-points from Ranis 2 show strong parallels to the late Middle Paleolithic (MIS 3, for age estimations see Uthmeier, 2002; Richter, 2008-2009) 'Altmühlian' leaf-points (Bohmers, 1951; Bosinski, 1967; Richter, 2008-2009) from Bavaria, Germany. Besides leaf-points, the most prominent assemblage, Weinberghöhlen Zone 4, Mauern/Bavaria, Germany (Bohmers, 1951; Zotz, 1955) also contains Middle Paleolithic tool types, like Keilmesser and scrapers. Therefore it is currently interpreted as a facies of the Bavarian late Middle Paleolithic (Uthmeier, 2002; Richter, 2008-2009). Additionally, most of the leaf-points are rather asymmetric and are therefore interpreted as leaf-shaped knives (Kot and Richter, 2012). Similar, asymmetric bifacial leaf-points are present within the assemblage of Ranis (Hülle, 1977, Plate 21: 2,52) and they occur in the assemblage of Königsaue A as well (Mania and Toepfer, 1973, Plate 27:1). This indicates a strong relationship between the leaf-points from Ranis and the late Middle Paleolithic analyzed in the present work, as the asymmetric tool concept was typical for the late Middle Paleolithic in central Germany (Chapters II and IV).

Another important evidence for the connection to the late Middle Paleolithic of the bifacial leaf-points of Ranis 2 is related to the raw material. The bifacial leaf-points are made of high quality Baltic flint which was brought to central Germany by the northern ice advances during the major glaciations in MIS 12 and MIS 6 (Lauer and Weiss, 2018). However, the glaciers never reached the area of Ranis and stopped about 30 km to the north. This marks the minimum distance for the origin of the raw material. It was even suggested that the large nodules necessary for the manufacture of the rather large leaf-points might have been only available in the river terraces of the Leipzig lowlands (Weber, 1990). This is supported by the large estimated nodule size for Pouch described in Chapter III. This would imply the transport of Baltic flint or the finished tools from 30 km to 200 km to the north. Furthermore, this suggests connections to the area of the late Middle Paleolithic assemblages analyzed here, like Pouch and Königsaue. What is even more interesting is one fragment of a bifacial leaf-point (Hülle, 1977, Plate 37:2,77): it was not manufactured on Baltic flint but instead on Bavarian Hornstein (chert), the same raw material that was used in the Altmühlian, more specifically the Weinberghöhlen Zone 4, Mauern/Bavaria (Weber, 1990). This is a direct evidence of the relatedness of the two sites, of long-distance travel of more than 200 km between them and strong evidence for the Middle Paleolithic origin of the Ranis bifacial leaf-point assemblage.

In conclusion, the results for late Middle Paleolithic variability presented in this thesis, together with results from other studies have the following implications for the origin of the LRJ: (1) the suggested uniformity of the late Middle Paleolithic of the European Plain between MIS 5a and MIS 3 (Chapter III) favors the formation of a uniform LRJ technocomplex overlapping in the same region. (2) On the other hand, within the late Middle Paleolithic analyzed here there is no evidence for bidirectional blade production with the purpose of the manufacture of a specific type of blade point. To the contrary, with the flake based blank production system based on simple and prepared flake cores (Chapter III), the Middle Paleolithic of the European Plain seems rather conservative through space and time (Chapter III), which might hamper an entirely new innovation or a linear development. (3) The bifacial part of the LRJ assemblages seems to have a Middle Paleolithic origin. Asymmetric bifacial tool concepts as described in Chapter IV are as well found in the bifacial component of the Ranis 2 LRJ assemblage. Additionally, a comparable 'leaf-knife' was found in the assemblage of Königsaue. Asymmetric bifacial leaf-shaped knives are also part of the late Middle Paleolithic Altmühlian assemblage of Mauern. To both regions, Bavaria and central Germany, Ranis 2 is connected by the raw material used for the manufacture of the bifacial leaf-points and other bifacial tools.

Following from what was described above, we end up in a dilemma: the results of the analysis of the late Middle Paleolithic of central Europe suggest an intrusive character of the Jerzmanowice blade points and the related blank production methods. On the other hand, the bifacial part of the assemblage reveals strong affiliations to the late Middle Paleolithic in central Europe as well as the late Middle Paleolithic in Bavaria. There are at least two possible explanations:

(1) The inferences drawn above based on the current dataset are not valid and late Neanderthals did in fact invent and/or incorporate a blade based point manufacture strategy in their technological repertoire.
(2) The assemblage from Ranis is a result of several short-term stays of different hominin groups. In other words, the makers of the Jerzmanowice blade points where not the same as the ones who manufactured the bifacial part of the assemblage. That the mix of archeological material from two hominin groups in a single layer can be a possible scenario was recently suggested by Gravina et al. (Gravina et al., 2018) for the Châtelperronian layer of La Roche-à-Pierrot, Saint-Césaire. Their new analysis has shown that the layer is comprised of a rather limited number of artifacts that can be attributed to Châtelperronian lithic technology. Contrarily, most artifacts seem to be of a Middle Paleolithic character and no evident association of Neanderthals and the Châtelperronian could be shown.

With the data presented here, it is not possible to solve the dilemma. Although, based on the evidence discussed here, there is a tendency towards the second explanation. New fieldwork in Ranis is currently ongoing and might help to solve the problematic.

5.5 Future Work

The methodology presented here, as well as the theories formulated within this thesis, pave the way for new ideas and subjects of future research on late Middle Paleolithic variability. It was demonstrated that multivariate analytical methods, like Principal Component Analysis (PCA) and Nonmetric Multidimensional Scaling, based on an attribute analysis, are suitable to trace factors that drive stone artifact assemblage variability. Especially PCA, a linear method for the reduction of the dimensionality of a dataset, is able to show the influence of each variable in the final result. This statistical approach can help to find the most important variables influencing variability. The subsequent analysis then focuses on how factors like raw material, blank production and tool manufacture influence the results of the multivariate analyses and introduced a new way of analyzing map-like configurations of certain groups in multivariate plots (for examples without this kind of analysis in the past see e.g. Schäfer, 1993; Weber, 1995; Golovanova et al., 2016). The thesis contributed, therefore, to showing an extended way for the application of these methods, perhaps opening new ways for the analysis of stone tool assemblage variability.

3D geometric morphometrics as well as the Thickness Mapping of 3D scans were demonstrated here to be suitable methods for the analysis of stone tools in new ways. Although this has already been applied several times in the past (e.g. Archer et al., 2015, 2016), the combination of analytical methods applied in this thesis has shown that there might be many more interesting applications of these methods for future stone tool analysis. In applying this set of techniques, the thesis has shown that we might start to re-think some of our fundamental ways of classifying stone tools. I am referring here especially to categories like bifacial and unifacial tools. Realizing certain conceptualizations of tools independent from blanks and in a rather flexible way might more closely match how ancient human knappers thought about their stone tools.

However, following from what I described in the chapters about late Middle Paleolithic variability, the population dynamics and the transition above, more work is needed to understand the variability of the late Middle Paleolithic stone tool record. It is hoped that the dataset built in this thesis as well as the methodology presented here can serve as a baseline for subsequent studies. Some ideas and future projects are outlined below.

The attribute analysis used to build the dataset for this thesis was based on the attribute lists of Weber (1986) and Schäfer (e.g. 1993). As this list is very detailed, more attributes on flakes, tools and cores have been recorded here than were used for the studies presented in this thesis.

Therefore, this dataset will be used in the future to identify more and other attributes that may trace factors of variability within the late Middle Paleolithic stone tool record. Besides flake analysis, the various attributes collected on the cores and tools are planned to be analyzed in the near future to learn more about the variation of late Middle Paleolithic blank and tool production strategies across the European Plain.
Another planned step is the continuous enlargement of the dataset. Besides the inclusion of other "general" assemblages of the European Plain, like e.g. Suchaja Mečetka at the Wolga river/ Russia (Zamiatnin, 1961; Praslov, 1984), more assemblages with known specialized site functions will be added to the dataset. Two examples are the sites of Lichtenberg, Lower Saxony/ Germany (Veil et al., 1994), and Pietraszyn 49a, Poland (pers. communication Andrzej Wiśniewski, excavator of the site). Both assemblages yielded no traces of core reduction. All flakes found within these assemblages are the result of late Middle Paleolithic bifacial tool production. Except for (potentially) Königsaue B, which has no or only limited bifacial tool reduction, the assemblages incorporated within the present thesis have always both core and bifacial tool reduction. There might be an issue that some flakes produced during bifacial tool production bear similar attributes to flakes that were detached from prepared cores. This may complicate the differentiation between assemblages with varying numbers of flakes resulting from both methods and this can be interpreted as a weakness of the quantitative methods presented here. But adding Lichtenberg and Pietraszyn 49a to the dataset and comparing them to assemblages like Königsaue B may improve the methodology and lead to a better way of detecting differences in flake attributes and flake assemblages resulting from bifacial shaping and prepared core blank production.

The enlargement of the dataset will include as well chronologically different assemblages (as first attempt resulting from this thesis see Weiß and Weber, 2019, in press). Here, the future focus lies on the incorporation of transitional assemblages from the central European Szeletian (Allsworth-Jones, 1990, 2004; Bolus, 2004; Neruda and Nerudová, 2013; Mester, 2014) and the Lincombian-Ranisian-Jerzmanowician (Chmielewski, 1961; Kozłowski, 1983; Desbrosse and Kozłowski, 1988; Flas, 2006, 2011, 2013, 2014) from the European Plain. These assemblages are of special interest as they are interpreted as having been developed from the central and northwestern European late Middle Paleolithic (see e.g. Flas, 2006, 2011, 2013, 2014; Neruda and Nerudová, 2013; see also Hublin, 2015). For the interpretation of these transitional industries and their relation to late Neanderthal stone tool industries (see above) it will be interesting to know to what degree in the multivariate analysis their flake assemblages share similarities or dissimilarities with the late Middle Paleolithic assemblages. This future step of the multivariate analysis will also benefit from the incorporation of some central European Initial Upper Paleolithic assemblages, e.g. the Bohunician of Moravia (Svoboda and Škrdla, 1995; Škrdla, 2003, 2017; Tostevin and Škrdla, 2006; Richter et al., 2008; Valoch, 2008).

The combination of analytical methods presented in paper three has shown that 3DGM together with Thickness Mapping based on 3D models and multivariate analysis of conventional attributes is able to trace similarities and dissimilarities between bifacial, unifacially shaped and simple tools. These similarities and dissimilarities are the result of functionality, blank selection, shaping and conventional typological criteria. As we control for geographic origin, paleoenvironment and chronology, we reduce factors of variability driven by those aspects. This resulted in a better comparability of the stone tools. However, the downside is that it also resulted in a low sample size. Therefore, the third study can be understood as a pilot study to test the methodology for analyzing morphological and functional tool variability. The next step will be the inclusion of additional late Middle Paleolithic tools from other assemblages to design a large-scale comparison. Simple edge retouched and unifacially shaped scrapers with Keilmesser-like morphologies have been observed in other central German Keilmessergruppen assemblages, like Lichtenberg Lower Saxony/ Germany (Veil et al., 1994), Salzgitter-Lebenstedt (Pastoors, 2001) and Königsaue (Mania and Toepfer, 1973). It would be interesting to see if they are similarly related to bifacial Keilmesser as observed for tools from the assemblage of Pouch. Moreover, it is planned to include Keilmesser sub-types (see e.g. Bosinski, 1967; Jöris, 2006) in the study to learn more about how bifacial Keilmesser variability is structured.

Another application of the methodology presented in paper three will be a broad analysis of late Middle Paleolithic handaxes across Europe. In terms of the diversity of late Middle Paleolithic handaxes in Europe (see e.g. Bordes, 1961; Bosinski, 1967; Ruebens, 2012) the sample size of handaxes included in this thesis was very low. Therefore, a future study would benefit from the inclusion of different handaxe types - e.g. MTA handaxes or other Micoquian handaxes - to analyze morphological and functional similarities and dissimilarities between the different types as well as their relation to other late Middle Paleolithic bifacial tools. It is considered as well to include in this study some early Middle Paleolithic handaxes from the site of Eythra, Saxony/ Germany that have an age of about 280.000 years (Lauer and Weiss, 2018). These handaxes could possibly serve as an outgroup to the late Middle Paleolithic handaxes and/or help to answer the question of in which way the Middle Paleolithic handaxes changed over time.

Lastly, with respect to the discussions about the bifacial component of the LRJ outlined above, it would also be good to include the bifacial symmetric and asymmetric leaf-points from Ranis 2 and Mauern into the current dataset with a subsequent 3DGM analysis of their relation to each other and to asymmetric Keilmesser.

5.6 References

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