Beyond the trenches: a landscape-oriented chronostratigraphic approach to MIS 5 Middle Paleolithic open-air sites on the European Plain : case studies from Lichtenberg and Khotylevo I

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CHAPTER I: INTRODUCTION

1.1 CONTRIBUTION OF LANDSCAPE RESEARCH FOR UNDERSTANDING NEANDERTHAL BEHAVIOR

Gaining knowledge on past human behavior is arguably the essence of archaeological research (Rapoport, 2008; Reid et al., 1974). In the Middle Palaeolithic period – in Europe solely associated with Neanderthals (Conard, 2001) – behavioral mannerisms are mainly concluded from archaeological remains, particularly from lithic artifacts due to their good preservation. Even though huge progress has been made in the field of computational artifact analysis in recent years (Archer, 2016; Delpiano and Uthmeier, 2020; Presnyakova et al., 2015; Weiss, 2020), which furthered our understanding of their manufacture and usage, the explanatory power of stone tools is limited, eventually. Thus, they represent biased, i.e. not fully representative records for human behavior. Apart from lithics, human behavior can also be inferred from other objects of the material culture. Depending on the site preservation, there is evidence for wooden tools/weapons (Thieme, 2007), intentional bone cut marks and bone tools (Culotta, 1999; Gaudzinski, 1999; Van Kolfschoten et al., 2015) or hearth features (Goldberg et al., 2012; cf. Pop et al., 2016) from Lower and Middle Palaeolithic sites in Central Europe. Rare - and strongly debated - are hints that point towards symbolic or even 'artistic' behavior (Hoffmann et al., 2018; Leder et al., 2021). Possible funeral practices (Dibble et al., 2015) as well as aspects of mobility and sustenance can furthermore be inferred from occasional skeletal finds (Germonpré et al., 2013; Hublin, 1984) and the anatomic, isotopic or genetic analysis on those (Bocherens, 2011; Hublin and Roebroeks, 2009; Pereira-Pedro et al., 2020; Vernot et al., 2021; Weyrich et al., 2017). While these records can cover important facets of behavioral traits, they need to be put in context of their timing and contemporaneous natural environments in order to identify possible adaptations or socially induced decision-making (cf. Goldberg and Macphail, 2006; Locht et al., 2016; Pederzani et al., 2021). This shall be demonstrated by the definition of the term behavior as used in this thesis:

DEFINITION OF "behavior": The term 'behavior' could be defined as a range of actions and habits displayed by individual organisms or groups in response to internal and external stimuli, i.e. in conjunction with themselves and their **physical environments** (cf. Hull, 1951; Minton and Kahle, 2013).

This definition inevitably leads to the concept of landscapes as manifestations of these physical environments that are related to human behavior.

Definition of "landscapes": Landscapes are the results and the expressions of the lithosphere, atmosphere, hydrosphere, biosphere, and **anthroposphere** mutually influencing and interpenetrating each other to form highly complex (semi-)open systems of these connected components (Fergusson and Bangerter, 2015; Neef, 1967; Simensen et al., 2018).

Firstly, that makes landscapes vaguely delimited entities of the physical environments within a certain area. Secondly, and most crucially, it represents the notion that landscapes do not exist independently of their observers and users, meaning that '**environments**' become '**landscapes**' in the human presence (Kühne et al., 2019; Richter, 2006). Because the two terms are so intimately linked, they will be used synonymously in this thesis. There are three conceivable dimensions to the human-landscape relationship in the Middle Palaeolithic period, as landscapes can (i) affect, (ii) be subject to, and (iii) archive human behavior:

(i) Landscapes provide the context and scenery for human occupation. They were used to procure food, water, raw material, and shelter. The availability and quality of these resources is influenced by complex and sometimes antithetic fluctuations, mainly governed by climate changes. Partly because of this complexity, the knowledge of Neanderthal habitat preference, i.e. the balance of push and pull factors for occupation and migration is still incomplete (Nielsen et al., 2019). For instance, the temperate and fully-forested landscapes of the Eemian Interglacial (~MIS 5e), and the cold tundra steppes of the Early Pleniglacial (~MIS 4) have both variously been regarded as too unfavorable for Neanderthal presence by different authors (cf. Defleur and Desclaux, 2019; Hublin and Roebroeks, 2009). In contrast, the longstanding Neanderthal colonization of the European Plain (>300 ka), indicates a high ecological tolerance and a wide range of exploited environments (Hérisson et al., 2016; Roebroeks et al., 1992) (see 1.3.3).

(ii) Human activities and the exploitation of their environments might have intentionally or incidentally changed landscape segments in terms of faunal or floral composition, which in turn, would have affected the sedimentary and hydrological regimes, as well (cf. Piacente, 1996). This concerns for instance the promotion or suppression of select plant and animal species that were part of the Neanderthal diet or not. As an example of how dramatically the introduction of such a top predator can alter ecosystems may serve the well-documented rewilding of the wolf in Yellowstone National Park, USA. Wolves created an "ecology of fear" that changed behavioral patterns among their prey and led to various ripple effects and feedback mechanisms. Thus, only a few years after the wolf resettled the park, a substantial raise in biodiversity and increased fluvial dynamics had taken place (Beschta and Ripple, 2016). Possible Neanderthal effects on landscapes also concern the obscure topic of Neanderthal fire use. It is still a matter of debate, whether Middle Palaeolithic people could start a fire, but they were surely capable of occasional and opportunistic wildfire management/scavenging (Allué et al., 2022; Pop et al., 2016; Roebroeks et al., 2015; Sandgathe et al., 2011). As ethnographic studies demonstrate, hunter-gatherers use fire not only for cooking and warmth, but also for protection, communication and as a means for hunting (Scherjon et al., 2015). This includes driving game with fire or attracting it by fire-stimulated plant growth. Moreover, the use as a kind of landscape engineering tool is often documented, e.g. to clear pathways or prepare the ground when re-visiting ephemeral sites (ibid.). Furthermore, Neanderthal birch-tar production as an adhesive for hafted tools is well-established and related to controlled fire use (Kozowyk et al., 2017). Although it is still challenging to distinguish natural from anthropogenic fires in the sedimentary records (e.g. Dibble et al., 2018), the mere notion of it is intriguing (cf. Bowman et al., 2013; Roos et al., 2014). Large-scale intentional burning of landscapes would have had significant repercussions on geo-ecological systems and would have turned landscape segments into artifacts, informative of human behavior. With the current state of knowledge, however, the general Neanderthal ecological footprint is hard to account for.

(iii) Because sediments in certain geomorphic positions store the occupational remains, landscapes serve as important repositories for human behavior. Widely acknowledged for that are e.g. loess plains (Chu and Nett, 2021; Locht et al., 2016; Valde-Nowak and Łanczont, 2021), riverine landscapes (Antoine et al., 2007; Basell et al., 2011; Vandenberghe, 2015; Weber and Beye, 2015), but on the northern European Plain especially lakelands (Kindler et al., 2020; Thieme and Veil, 1985). Deciphering the (syn-/non-/post-) depositional developments on sites and their surroundings – including pedogenic, hydromorphic, cryogenic, and biogenic processes – is invaluable to assess the integrity of an artifact assemblage and the choice of 'settlement' location. And it is also an indispensable requirement for establishing a luminescence-based chronological framework. Comprehension of off-site processes is just as important because they can *inter alia* provide information on a potential an occupational hiatus in the archaeological sequence due to extensive erosion or cryoturbation disturbances (Vandenberghe, 2013).

It has been shown here that palaeoenvironments have played an important role in Neanderthal behavioral patterns. However, the low resolution and paucity of ecological, chronological and archaeological data (Chapter 1.3) often still precludes well-founded conclusions on adaptations or cultural and biological evolution (e.g. Discamps et al., 2011). To unlock the full potential of Neanderthal records, an integrative combination of archaeological and geoscientific research and precise dating is needed (cf. Goldberg and Macphail, 2006). This is the intention of the present thesis, dedicated to the chronology of landscape conditions and processes at or around open-air sites, using case studies in Lichtenberg, N-Germany and Khotylevo I, W-Russia (cf. detailed research objectives in Chapter 1.5).

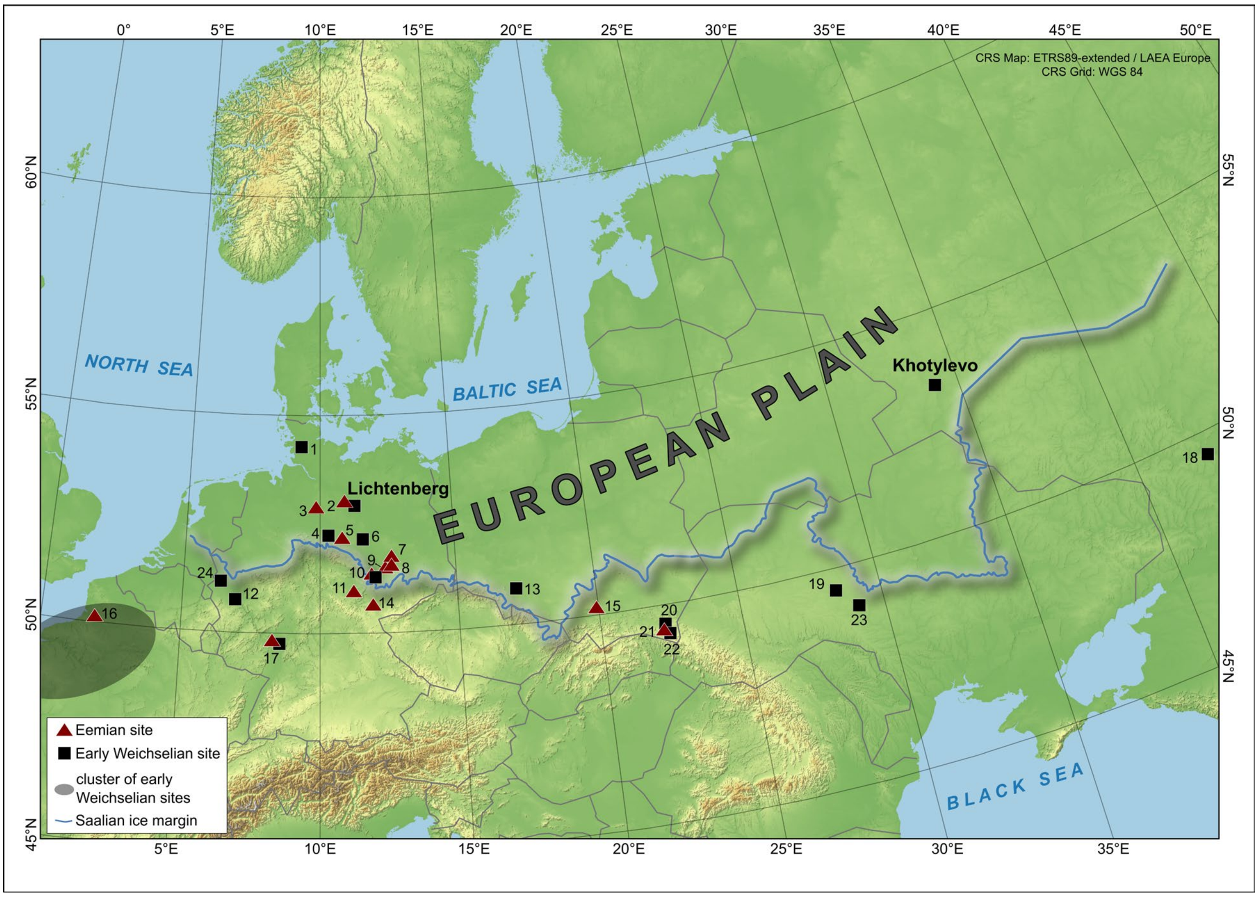

Figure 1: Map of the European Plain and the Middle Palaeolithic archaeological sites mentioned in the text, presumed to be Eemian and/or Early Weichselian. 1 – Schalkholz, 2 – Woltersdorf, 3 – Lehringen, 4 – Salzgitter Lebenstedt, 5 – Steinmühle/Veltheim, 6 – Königsaue, 7 – Gröbern, 8 – Grabschütz, 9 – Rabutz, 10 – Neumark Nord, 11 – Burgtonna, 12 – Tönchesberg, 13 – Wrocław Hallera Av., 14 – Weimar Parktravertin and Taubach, 15 – Kraków-Zwierzyniec, 16 – Caours, 17 – Wallertheim, 18 – Sukhaya Mechetka, 19 – Moldova, 20 – Pikulice, 21 – Orzechowce, 22 – Nehrybka, 23 – Vykhvatinskiy naves, 24 – Rheindahlen Westwand (B1). Study sites Lichtenberg and Khotylevo I are labelled, instead of numbered. Digital Elevation model based on SRTM-data (downloaded from https://earthexplorer.usgs.gov/), national borders obtained from Eurostat (https://ec.europa.eu/eurostat/de/web/gisco/geodata/reference-data). Maximum Saalian glacier extent after Ehlers et al. (1984), Matoshko (2011) and Velichko et al. (2006) (see Chapter 3).

1.2 CHOICE OF STUDY SITES AND SPATIO-TEMPORAL SCOPE

The European Plain (henceforth: EP) is widely regarded as one of the Earth's largest expanses of uninterrupted lowlands, but there is no general agreement on its actual extent (cf. Encyclopædia Britannica). For the purposes of this study, the European Plain is determined as the area largely congruent with the Saalian ice-sheet cover in MIS 6, stretching from the lowlands of the Benelux in the west to the Ural Mountains in the east (Figure 1). From a pre-LGM Weichselian point of view, the EP with its rather homogeneous topographies and recent glacio-geological history, represented an uninterrupted biome, that facilitated lateral exchanges of the faunal and floral elements (see 1.3.2). This is also reflected in the Middle Palaeolithic archaeological remains of this area, which are very similar across the vast dimensions of the EP (Weiss, 2019). The choice of study areas takes this fact into account by selecting the open-air sites Khotylevo I-6-2 at the eastern and Lichtenberg at the western periphery of the EP (Figure 1). Contrasting with the distance that separates them (ca. 1,800 km), these two sites share an astonishing number of similarities (Otcherednoi et al., 2014; Veil et al., 1994):

(i) Both are located at approx. 53° N and are among the northernmost undisputed Middle Palaeolithic sites of their major regions and of the entire European Plain, respectively (see 1.3.3). This northerly latitudinal location was another key criterion for choosing these sites. Given the geographic distribution of known Neanderthal occupations, it seems to be the general consensus that the tentative northern margin of the Neanderthal habitat was at 55° N, even during times of ameliorating climates (Hublin and Roebroeks, 2009). In that regard, the present author fully agrees with Nielsen et al. (2017) about the potential of this extreme boundary to reveal crucial information on Neanderthal resilience or constraints towards changing environmental conditions. This kind of information is usually obtained from combining environmental, chronological, and archaeological findings, the latter mainly being based on lithic artifacts.

(ii) Both sites in question show a very consonant and distinctly rich Middle Palaeolithic stone tool assemblage, associated with the *Keilmessergruppen* (see 1.3.3).

(iii) Both occupational layers have been numerically dated to MIS 3; Khotylevo I-6-2 by means of radiocarbon (Otcherednoi et al., 2014) and Lichtenberg using thermoluminescence on sediments (Veil et al., 1994) (see the particular discussions in Chapters 2 and 4).

(iv) In both cases, there are thick and highly-resolved sediment sequences available, either directly on site or in the immediate vicinity. These are key-archives for the reconstruction of Early Weichselian environments.

(v) This supplemental stratigraphic and environmental data could at both sites justify to rather assign the occupations to MIS 5, which has indeed previously been suggested for both sites (Jöris, 2004; Velichko, 1988).

In concurrence with these plausible stratigraphic arguments, the MIS 5, i.e. the last interglacial and subsequent early glacial is the temporal scope of this thesis. For all those aforementioned similarities, it shall not be concealed that Khotylevo I-6-2 and Lichtenberg differ in two important respects, namely (1) the raw material procurement for lithic production and (2) bone preservation: (1) In Khotylevo, along the valley of the River Desna, Cretaceous chalks and marls crop out that hold primary, high-quality tabular flints (see Chapter 2). This ubiquity does not exist in Lichtenberg. Middle Palaeolithic people there had to rely on Baltic flint diluted within the containing Saalian glacial deposits. Thus, they were likely depending on sediment (re)depositions providing fresh material (see Chapter 4). (2) Whereas in Khotylevo, the occupation layer produced a decent faunal spectrum due to good bone preservation in the contact zone with Cretaceous chalk (Chubur, 2013), in Lichtenberg, evidence for animal remains is missing so far from the respective layers.

1.3 NEANDERTHALS IN THEIR ENVIRONMENTS DURING THE LAST INTERGLACIAL/GLACIAL CYCLE

1.3.1 Climatic development inferred from global palaeoclimate archives

Marine cores

Interpretations of North Atlantic marine palaeoclimate records have substantially furthered our understanding of how sensitive global climate responded to orbital changes with different cyclicities between ca. 1,000 and 100,000 years. Based on the oxygen isotope ratio ($\delta^{18}O$) of the calcite shells in benthic foraminifera, alternating warmer and colder intervals in Earth's palaeoclimate can be inferred from successive layers in marine sediment cores. Dating of these sequences is provided by radiocarbon in the upper section <40 ka, correlation with better-dated palaeoclimate archives (e.g., speleothems and ice cores), and tuning to global orbital changes (Lisiecki and Stern, 2016). The established Marine isotope stages (MIS) timescale assigns an odd number to warm and an even number to cold phases, starting with number 1 for the Holocene and covering >>100 stages (Emiliani, 1955). Within the Pleistocene, the cycles of this record were found to be linked with evidence for terrestrial glacials and interglacials (Shackleton, 1967), making the (globally stacked) benthic $\delta^{18}O$ records perhaps the most prominent chronological reference point in Quaternary research, *sensu lato*, over the last decades (esp. Lisiecki and Raymo, 2005). Stage 5 in the MIS record, dated to 130 ka - 71 ka (Lisiecki and Raymo, 2005), was divided into 5 substages by Shackleton (1969; Shackleton et al., 2002), realizing that only the first part of this marine interglacial corresponds to terrestrial ones on the continents. He assigned MIS 5e to the Eemian Interglacial, whereas MIS 5c and 5a represent subsequent warm intervals, and MIS 5d and 5b cooler intervals, respectively. For Substages 5e to 5a no clearly defined boundaries exist, but their maximum $\delta^{18}O$-values are ascribed to ages of 123 ka (5e), 109 ka (5d), 96 ka (5c), 87 ka (5b), and 82 ka (5a) (Lisiecki and Raymo, 2005)(Figure 2). In the course of MIS 5, rather temperate conditions prevailed, with an overall and gradual cooling tendency. This trend was interrupted by brief colder spells that did not, however, regularly reach values indicative of glacial conditions, such as in the neighboring Stages MIS 4 and 6 (Lisiecki and Stern, 2016). The timing of MIS 5 is regarded as broadly equivalent to the cumulative Eemian and Early Weichselian, which is the period under consideration for this thesis.

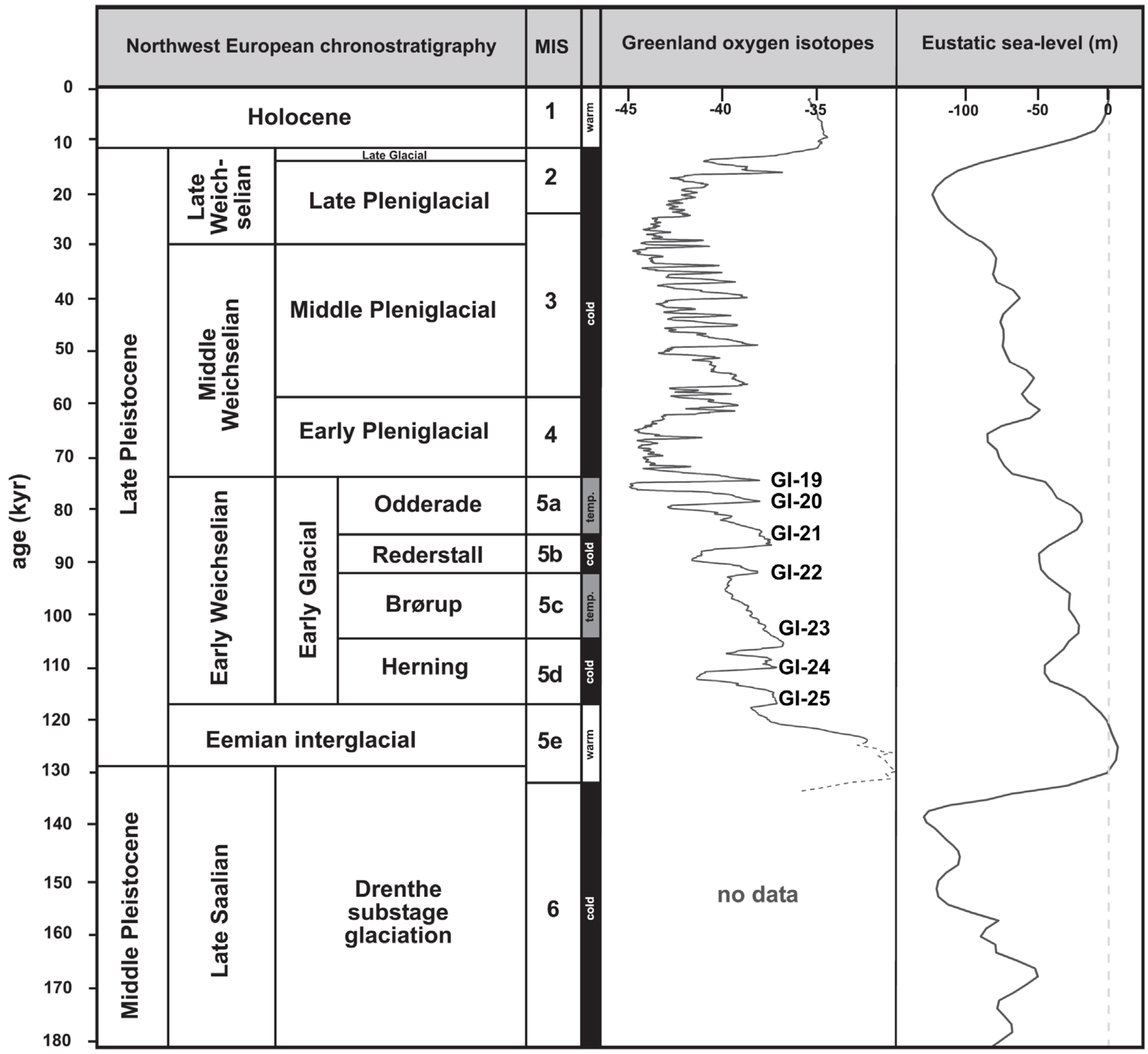

Figure 2: Climato-stratigraphic subdivision of the last interglacial/glacial cycle in Central and Western Europe (modified after Peeters et al., 2015).

Greenland ice cores

Another outstanding and extensive palaeoclimatic record is provided by several long cores, such as GISP, GISP2, GRIP, NEEM, and NGRIP, drilled at the polar ice-cap of Greenland to depths of up to 3 km and covering the last interglacial/glacial cycle (Rasmussen et al., 2014). The three ice cores GRIP, GISP2, and NGRIP were correlated by volcanic and chemo-stratigraphic matching, i.e., comparing tephras, peaks in the sulfur concentrations (SO_4^{2-}), dust input (Ca^{2+}), and biomass burning events (NH_4^+). The chronology relies on known ages of the contained tephras and on annual layer countings for certain sections in the different cores (Seierstad et al., 2014). Temperature reconstructions are based on $\delta^{15}N$ measurements on air bubbles, entrapped within the glacier and on $\delta^{18}O$-values of the ice (Kindler et al., 2014). Within this record, millennial-scale climatic fluctuations between stadial and interstadial conditions were detected, known as Dansgard-Oeschger (D-O) events. Every such event cycle is asymmetric in nature and consists of abrupt warming followed by a gradual decrease in temperature (Dansgaard et al., 1982). Numbering starts with 1 for the last pre-Holocene cycle (Younger Dryas) and numbers increase consistently with growing age up to 26. Later, a revised scheme was proposed, maintaining the numeration but dividing each D-O cycle into the initial warm and the successive cold phase, i.e., into a Greenland Interstadial (GI) and a Greenland Stadial (GS) (Rasmussen et al., 2014). It remains unclear, how these events are triggered (Sánchez Goñi, 2020). However, they seem to be closely corresponding to changes in strength and a southward shift of the AMOC (Atlantic meridional overturning circulation, *vulgo:* Gulf Stream) and likely also the ITCZ (Intertropical Convergence Zone) (Kindler et al., 2014). The overall climatic trends for the northern hemisphere are similar to the MIS patterns (see above), but the ice core records exhibit a distinctly better resolution, because of higher accretion rates, negligible bioturbation, and a more precise dating (Aitken and Stokes, 1997). Therefore, they are much more sensitive to those short-term events (D-O/GI, GS). Relevant to the timescale in question for this thesis is the period from Greenland Stadial GS-26 (starting at 119 ka) to Greenland Interstadial GI-19 (ca. 71 ka), which altogether relates to the Early Weichselian, whereas for the last interglacial, no Greenland Interstadial is assigned (Rasmussen et al., 2014) (Figure 2).

These global or hemispherical palaeoclimate records provide an eminently valuable reference system for palaeoenvironmental and archaeological research in the Late Pleistocene. However, those macro-climatic findings cannot directly be transferred to terrestrial conditions because of complex ecological and meso-climatic responses at the continental scales (e.g. Shackleton et al., 2003). For that reason, it is inevitable to include terrestrial archives in order to examine the relationship of global climatic trends and continental developments, and to provide local environmental context for archaeological sites.

1.3.2 Terrestrial/continental evolution of palaeoenvironments on the European Plain

Preliminary remarks

It is important to note that the functioning of these former, Late Pleistocene ecosystems is not easily compared to present-day equivalents. Their compartments had unusual (non-analog) associations and characteristics, resulting from individualistic and unexpected responses to repeatedly changing climates (cf. Guthrie, 2001). This has long been realized for the fauna (Bolland et al., 2021; Graham, 2005; Stewart, 2005), vegetation (Chytrý et al., 2019; Pross et al., 2000), and their mutual relationship. It led *inter alia* to the introduction of the "steppe-tundra" or "mammoth-steppe" concept for the Weichselian Pleniglacial (Guthrie, 1990; Zimov et al., 2012). But also soil formations differed from current counterparts in terms of thickness, typology and associated pedogenic processes (Meszner and Faust, 2018; Stremme et al., 1982; cf. Velichko and Morozova, 2010). While this was undoubtedly co-determined by climatic variations, palaeoclimate *itself* might be regarded as non-analog: Considerable fluctuations in sea levels, the AMOC, ice extents, and insulation affected the European Plain in various ways and combinations (e.g. Salonen et al., 2013). And lastly, CO_2 concentrations of c.280 ppm have been measured for the last interglacial, decreasing to <200 ppm in late MIS 5 (Fischer et al., 1999). Hence, CO_2 values for most of MIS 5 would have been significantly lower than the ditto 280 ppm in pre-industrial times of the Holocene (Monnin et al., 2001). Lower atmospheric CO_2 concentrations would have had negative physiological effects on plant growth due to reduced photosynthesis and increased transpiration. It would have also affected floristic compositions, as CO_2 depletion seems to constrain trees stronger than herbaceous plants (Harrison and Bartlein, 2012). This non-exhaustive compilation of non-analog conditions is not meant to overemphasize these factors, but nor should they be carelessly disregarded when investigating and interpreting palaeoenvironmental processes.

Overarching characteristics of the Eemian Interglacial and Early Weichselian Glacial

Information on the Eemian and Early Weichselian palaeoenvironments and -climates are to a large extent derived from abundant palaeolake basins whose formation is associated with the Saalian glaciation (Caspers et al., 2002; Helmens, 2014). Apart from these lacustrine archives, access to meaningful data is very much restricted to coastal areas (Höfle et al., 1985; Marks et al., 2014) and loess/riverine landscapes which tend to preserve respective palaeosols and deposits (Antoine et al., 2016; Fuchs et al., 2013; Turner, 2000; Vandenberghe, 2015). And additionally, deposits of that period can be found in zones of tectonic subsidence (Knipping, 2008; Schokker et al., 2004). From these archives it is known, that roughly in congruence with the North Atlantic data (see 1.3.1), the European Plain saw frequent and high-amplitude climatic changes during MIS 5. The terrestrial information, mainly based on palynology, reveals rapid warming in the Early Eemian Interglacial and then an overall deteriorating climate from the Mid-Eemian to the onset of the first glacial maximum in MIS 4. This is chiefly expressed by increasing continentality with strong shifts in winter temperatures and precipitation (Salonen et al., 2013). The general cooling trend in the period in question was superimposed all across the European Plain by three fully-forested intervals: the Eemian Interglacial, the Brörup Interstadial, and the Odderade Interstadial (~MIS 5e, 5c and 5a). These were separated by two cooler phases with more open vegetation: the Herning and Rederstall Stadials (~MIS 5d and 5b) (Behre, 1989; Caspers and Freund, 2001). This variation had significant and poorly understood geo-environmental effects. It necessitated repeated reconfigurations and redistributions of the vegetation and fauna but and also similar adjustments within the sedimentary and hydrographic systems (e.g. Pecl et al., 2017). However, such responses often lagged behind the climatic development and also differed spatially (cf. Brauer et al., 2007; Sier et al., 2015). Within the former vegetation, there is a general trend, that steppic floral elements increase toward the east, (sub-)arctic elements enlarge toward the north, and the continentality gradient was more enhanced in colder stages than in warmer intervals (Caspers and Freund, 2001; Emontspohl, 1995; Helmens, 2014; Velichko et al., 2005; Yelovicheva and Sanko, 1999, see also below).

Without much systematic research on landscape dynamics in this period (i.e. on geomorphic activity and stability phases) and a scarcity of numerical ages, our comprehension of how terrestrial sediment systems adjusted to these climatic changes remains vague. Usually, for the Eemian, stable surfaces are assumed, enabling soil formation on well-drained positions and humus accumulation in waterlogged basins (e.g. Menke, 1992). In one of the few studies that cover this topic, Schokker et al. (2004), confirm this notion for the Eemian optimum, but report increased clastic sediment redeposition in the early and late phases of the interglacial. This is in agreement with the ubiquitous occurrence of truncated (i.e. partially eroded) Eemian palaeosols in the loess belt (Antoine et al., 2016; Jary and Ciszek, 2013; Lehmkuhl et al., 2016). For the Early Weichselian in NW Germany, Lade and Hagedorn (1982) developed a depositional model that encompasses soil formation/humus accumulation in the warmer interstadials and slopewash/solifluction in the colder stadials. Although this model is not based on numerical dating, it seems to hold true for the loess areas, as well (e.g. Chu and Nett, 2021; Lehmkuhl et al., 2016). Likewise, the temporal and spatial coupling of landscape dynamics in the hinterlands and fluvial discharge/aggradation patterns in the river valleys remains vastly unexplored for MIS 5 (but see Panin et al., 2020; Winsemann et al., 2015). Even so, such knowledge could vastly enhance our understanding and interpretation of artifact scatters in secondary contexts of fluvial gravels (Bridgland et al., 2006).

Fluvial dynamics of this period are not easy to assess. Changes in the sedimentary budget of rivers (i.e. incision/aggradation) usually occur in transitional phases from warm to cold or *vice versa*, when the fluvial systems need to rearrange toward a new equilibrium (Bridgland and Westaway, 2008). However, the specific behavior of any given river in any given time is highly individual. Fluvial reactions are non-linear and governed by the interplay of a whole set of influencing factors, such as longitudinal gradient, sediment supply, and discharge. All of these influences are themselves depending on various aspects (climate, vegetation, sea level, tectonics) (Vandenberghe, 2015). During the Eemian, stable floodplains with meandering or anastomosing rivers are assumed, characterized by low overbank aggradation rates (Gao and Boreham, 2011). Subsequently, at the Eemian-Weichselian transition (~MIS

5e/5d), many European rivers in Germany, Belgium, Northern France, and Britain responded in the form of incision. This eradicated much of the previous Eemian floodplain along with potential Neanderthal occupation traces within the valley (Antoine et al., 2007; De Clercq et al., 2018; Gibbard and Lewin, 2002; Winsemann et al., 2015). For the Russian Plain, no numerical dates have been obtained yet, but a coincidental development could be assumed because Eemian deposits are extremely rare in the fluvial archives there (Panin et al., 2017). For the Early Weichselian, chronological information is on thin ground, but Winsemann et al. (2015) reconstructed incision events during MIS 5d and the MIS 5c for the German Weser-Leine catchment. In the paleo-Scheldt valley in N-Belgium and the Lower Rhine valley, stable conditions prevailed throughout the Early Weichselian (Busschers et al., 2007; De Clercq et al., 2018), but were likely influenced by near-coastal conditions. At the same time, incipient aggradation occurred in Russia (Panin et al., 2017). Lastly, the major climatic shift at the MIS 5a/4 transition was accompanied by roughly simultaneous incisions of the Lower Rhine (Peeters et al., 2015), many smaller rivers in the Netherlands and Poland (various authers cited in Mol et al., 2000), and the Weser river in Northern Germany (Winsemann et al., 2015). Again, this fluvial erosion likely compromised *in situ* archaeological records of the Early Weichselian in the valleys (cf. Bridgland et al., 2006).

Similarly, the reconstruction of specific faunal elements suffers from low spatio-temporal resolution and a shortage of reliable data (Finlayson and Carrión, 2007). In the Eemian, a warm-adapted forest fauna was present, including large species such as straight-tusked elephant (*Elephas antiquus*), the narrow-nosed rhinoceros (*Stephanorhinus hemitochus*), and the giant deer (*Megaloceros*), but also woodland ungulates, such as red and fallow deer (*Cervus elaphus* and *Dama dama*) and aurochs (*Bos primigenius*). The widest spectrum of this Eemian fauna was obtained at the archaeological sites of Neumark Nord (Kindler et al., 2020; Strahl et al., 2010), Gröbern (Litt and Weber, 1988), and Lehringen (Thieme and Veil, 1985). This warm fauna disappeared from the European Plain before the end of the Early Weichselian. As to when that happened there is no real consensus. This transition process might have started as early as the Mid-Eemian (Richter, 2016) and was definitely completed before the onset of the Pleniglacial (~MIS 4) (Defleur and Desclaux, 2019; Finlayson and Carrión, 2007). In the cooler spells of the Early Weichselian, a less varied spectrum of cold-adapted open woodland and steppe fauna surfaced and later on dominated. It was characterized by reindeer (*Rangifer tarandus*), steppe bison (*Bison priscus*) and horse (*Equus*) (Finlayson and Carrión, 2007; Locht et al., 2014; Roebroeks et al., 1992). Finally, by no later than MIS 5a, the woolly mammoth (*Mammuthus primigenius*) and woolly rhinoceros (*Coelodonta antiquitatis*) appear in the sequences (Chubur, 2013; Richter, 2016). This cold-adapted faunal association prevailed through much of the later Weichselian as an inseparable part of the mammoth steppe biome (Guthrie, 2001).

Eemian Interglacial (~MIS 5e)

For the Eemian Interglacial a typical vegetation succession can be observed throughout the European Plain (Turner, 2002; Velichko et al., 2005) and in southern Scandinavia (Björck et al., 2000; Salonen et al., 2013). The uniformity of the diagnostic tree species development in the area allows for low-effort correlations between several archives. In Northern Germany, according to the dominant arboreal taxa, the Eemian is subdivided into seven pollen assemblage zones, PAZ E1 to E7 (Caspers et al., 2002; Menke and Tynni, 1984). The succession is as follows: birch → pine/birch → thermophilous mixed oak forests → admixture of hazel-yew-lime → hornbeam-spruce → boreal type forests with pine-spruce-fir → pine. For neighboring regions, such as France, the Netherlands, Poland, and Russia, very similar and correlatable classification schemes exist (de Beaulieu and Reille, 1992; Grichuk, 1961; Mamakowa, 1989; Zagwijn, 1961). This progression is descriptive of a rapid warming period followed by an extensive thermal optimum and finally a temperature deterioration towards the end of the interglacial.

The rather small longitudinal variation in the floral compositions of different regions was facilitated by a more oceanic climate even in Eastern Europe. This effect is connected to the generally higher eustatic sea levels in the Mid-Eemian, which surpassed the current stands by 5 to 9 meters (Dutton and Lambeck, 2012). More regionally, these raised levels caused the separation of the Jutland peninsula from the

Central European landmass and also formed a direct connection between the Baltic and the White Sea through Karelia (Miettinen et al., 2014).

Palaeoclimatic parameters, derived from pollen, botanical macro remains, but also from different faunal assemblages (Behre et al., 2005; Caspers et al., 2002; Kühl et al., 2007; Kupryjanowicz et al., 2018; Russell Coope, 2000; Zagwijn, 1996) indicate that the temperatures were similar or up to 2-3 degrees higher than today in the Eemian optimum all across the European Plain. Especially the winter temperatures exceeded present-day values by several degrees. Notably, in different studies, there are contradictory gradients of continentality towards south-eastern Europe (Brewer et al., 2008; Kaspar, 2005). Precipitation values are even more difficult to reconstruct but assumed to be comparable to, yet more variable than today, especially in the eastern region (Pidek et al., 2021).

Recently, there is a lot of debate on the duration and timing of the Eemian. Traditionally, the Eemian is correlated with MIS 5e and thought to have lasted from 128 to 117 ka (cf. Tzedakis, 2003). This was in good agreement with varve countings at the site of Bispingen (Northern Germany) that implied a duration of 10,000 to 11,000 years (Müller, 1974). However, marine cores off the coast of Iberia suggested a considerable time offset between MIS 5e and the terrestrial interstadial (Shackleton et al., 2003). For Central Europe, Sier et al. (2015, 2011) recognized a delayed onset of the Eemian with respect to MIS 5e by as much as 10,000 years. Conversely, Brauer et al. (2007) determined a simultaneous beginning with MIS 5e but a much longer duration of 17,000 years, based on varves in Southern Italy. This diachroneity indicates a time-transgressive onset of the Eemian throughout Europe with a noticeable delay in Central Europe. The discussion of possible reasons for that is not within the scope of this thesis. However, these seemingly contradicting estimates for the Eemian chronology point out, that caution should be exercised when interpreting MIS 5e-equivalent numerical ages in the absence of biostratigraphical control.

Early Weichselian (~MIS 5d – 5a)

Herning Stadial (WF I): Temperatures dropped after the Eemian (mean of 10°C and -15°C for July and January) and low sea levels (ca. 40m lower than today) caused a higher continentality (Helmens, 2014; Zagwijn, 1983). Therefore, most tree taxa had retreated to the south, and open vegetation, comprised of heath (*Calluna vulgaris*) and grasses (Poaceaea) dominated on the European Plain, with some admixture of juniper (*Juniperus*) (Behre, 1989; Helmens, 2014). Much of the European Plain was likely situated in the forest/tundra ecotone, a transitional zone between tundra and taiga, where boreal tree pollen amount to max. 50% (Emontspohl, 1995).

Brörup Interstadial (WF II): The Herning was followed by a climatic amelioration. Mean July and January temperatures increased to 15 to 19°C and -8 to -14°C, respectively (Caspers and Freund, 2001; cf. Kühl et al., 2007). Compared to the Eemian, this development shows the advancing degree of continentality, comprising low winter temperatures and low precipitation values, due to much lower sea levels. According to Behre (1989) and Caspers and Freund (2001), this distinct seasonality is the major reason, why temperate forests species did not fully re-immigrate during the Early Weichselian interstadials on the European Plain. Instead, this interval saw the dominance of birch and pine forests, with the admixture of spruce, larch, and alder. Birches were determining the first half (WF IIa) and pines were more abundant in the second half (WF IIb) of the Brörup Interstadial. To the north, the forest/tundra ecotone was situated approximately in central Jutland (Björck et al., 2000; Caspers and Freund, 2001; Emontspohl, 1995). To the east, tree species composition remained similar to Central Europe, only the abundance of moisture-loving taxa decreased (e.g. *Calluna vulgaris, Sphagnum*), while the percentage of steppe species was higher (e.g. *Artemisia, Chenopodiaceae*) (Helmens, 2014). Also, the values for the relatively thermophilous deciduous trees, such as alder (*Alnus*) seem to be even lower in Eastern Europe (Caspers and Freund, 2001; Yelovicheva and Sanko, 1999). By contrast, in the western part of the European Plain (e.g. Amersfoort, NL), oceanic conditions have fostered higher *Alnus*-, *Calluna*- and *Sphagnum*-percentages and even the more demanding oaks, that did not clearly colonize Central and Eastern Europe (Emontspohl, 1995; Zagwijn, 1989). Based on annual varves in the diatomite at the Rederstall site, a duration of 5,800 to 10,500 years was estimated for the Brörup Interstadial (Grüger, 1991). This appears too short in comparison with the North Atlantic palaeoclimate records, which seem to suggest a time interval closer to 15,000 years (see below).

Rederstall Stadial (WF III): Rederstall deposits only occur infrequently, especially pollen-bearing sequences. This is why, only the beginning and end of this stadial are usually documented, if at all (Caspers and Freund, 2001). The records indicate open heliophile vegetation, dominated by Poaceaea, steppe taxa and *Juniperus* (juniper) (Behre, 1989; Helmens, 2014). Thicker sediments and first evidence of (discontinuous) permafrost imply a stronger climatic deterioration than in the Herning (Caspers, 1997). Even so, fossil beetle evidence indicates comparable temperatures to the Herning Stadial (-9 to -12°C and 11°C for January and July) (Walkling, 1997). Furthermore, an increased seasonality compared to the Herning is inferred from the more western distribution pattern of *Artemisia* (Emontspohl, 1995; Helmens, 2014).

Odderade Interstadial (WF IV): The Odderade Interstadial is considered more or less analogous to the Brörup regarding vegetation patterns and their distribution (Behre, 1989; Zagwijn, 1989). As a slight difference to this previous interstadial, boreal pine-birch forests did not reach as far north and *Alnus* is generally less represented. Both indicates marginally cooler and more continental conditions (cf. Emontspohl, 1995; Zagwijn, 1989). Mean temperatures of 12 to 17°C and -11 to -22°C have been established for summer and winter in this period (Helmens, 2014; Kühl et al., 2007). Quick readvances of forests after the Rederstall suggest, that the boreal tree species survived the preceeding stadial phases in the wider region and/or in favorable topographic positions (Caspers and Freund, 2001). In the absence of varved sediments, the duration of the Odderade has been assessed to 5,000 and 10,000 years, leaning on the sediment thickness and the general comparability with the Brörup Interstadial (Behre and van der Plicht, 1992). After the Odderade and before the onset of the first glacial maximum, there are one or two short climatic amelioration phases, in which boreal forests briefly reappeared in France and the Alpine Foreland in Germany and Switzerland (de Beaulieu and Reille, 1992; Müller and Sánchez Goñi, 2007). For the European Plain, there is no palynological evidence for such fluctuations in this transitional period, so far (see Chapter 4).

The timing of the Early Weichselian Interstadials is not officially determined. Conventionally, Brörup and Odderade are correlated with MIS 5c and 5a, respectively (Behre and van der Plicht, 1992) and with GI-23/22 and 21 (Rasmussen et al., 2014;

Richter, 2016). Accordingly, the Herning and Rederstall Stadials are assigned to MIS 5d and 5b (Behre and van der Plicht, 1992). In the Alpine Foreland and the loess belt of central and western Europe, this congruence has been confirmed (Antoine et al., 2016; Boch et al., 2011, see also discussion in Chapter 4), whereas in the type region of these (inter)stadials – the NW European Plain – no conclusive chronology has been established, yet.

1.3.3 Neanderthal population dynamics

In the foregoing sections, palaeoclimatic and palaeoenvironmental background information was provided which may serve as a mental framework to assess Neanderthal occupation on the European Plain in the Late Pleistocene. In this section, the focus lies on the geographical distribution of archaeological remains in different temporal phases and some aspects of subsistence. It is not within the scope of this thesis to review and address specific tool production methods or nomenclatorial, typological, or even "cultural" issues. For an overview of these complex and in some cases ambiguous questions, see e.g., Rolland & Dibble (1990), Soressi (2005), Jöris (2006), and Richter (2016).

The geographic map of the Middle Palaeolithic ecumene in the Eemian and Early Weichselian is rather vague and low in content, and it suffers from **(1)** a research bias and **(2)** a geological or preservation bias (cf. Nielsen et al., 2017).

(1) Conceivably, just a very low percentage of human occupations through time has been discovered yet (cf. Roebroeks, 2014; Speleers, 2000). Sites seem to cluster in regions, where artificial exposures of the aggregate industry enabled regular surveys (Kels and Schirmer, 2011; Richter, 2016; Valde-Nowak and Łanczont, 2021) or where rescue excavations related to large-scale construction and infrastructure projects have been conducted, e.g. in northern France (Locht et al., 2016, 2014). Apart from that, systematic search for new sites has been rather patchy, and only recently, commendable endeavors to locate unknown occupations have started in the form of geodata-based predictive modeling (Nielsen et al., 2019, for SW-Scandinavia). Furthermore, the sites that exist mostly lack a precise dating (e.g. Wiśniewski et al., 2019), so that their chronological allocation often remains disputable (Jöris, 2004; cf. Richter, 2016).

(2) Following the disintegration of the Saalian ice sheet, natural processes have been persistently working towards a leveling of the undulating late glacial landscape, employing erosion and deposition (e.g. Fränzle, 1988; Zagwijn and Paepe, 1968). These processes are bound to have jeopardized the archaeological record, especially in (but not restricted to) sloping positions. Since the geomorphological dynamics of the period in question are also largely unspecified (see 1.3.2), the extent of the occupational records being endangered or eradicated cannot even be estimated. To give an example, numerous sedimentary archives across the European Plain bear witness to an extensive and severe erosion event at the late Eemian/Early Weichselian transition (see 1.3.2). In loess-palaeosol sequences, the uppermost ~50 cm, i.e. the E-horizons of the Eemian luvisol soils are always missing (e.g. Antoine et al., 2016 see also above), so likewise is the entire Eemian occupation surface (cf. Uthmeier et al., 2011). As already mentioned, in river valleys, more often than not, fluvial downcutting at the Eemian-Weichselian transition has caused the predominant eviction of the previous Eemian sediment suites (Ehlers, 1990; Gibbard and Lewin, 2002; Vandenberghe, 2015; Winsemann et al., 2015). During the following stadials Herning and Rederstall (~MIS 5d and 5b), increased slope erosion has to be assumed on account of lighter vegetation cover (Lade and Hagedorn, 1982). Posterior cryoturbation mainly in MIS 4 and 2 would have had additional disturbing effects on the stratigraphic integrities in shallow sediment suites (e.g. Bertran et al., 2014). This leaves us with topographic depressions as reliable repositories for human occupation in that period (esp. palaeolake basins, see 1.3.2). These special geomorphological situations inhibit erosion and can preserve Eemian and Early Weichselian deposits, and – by extension – also the archaeological remains. So if a large share of the MIS 5 sites on the European Plain is associated with palaeolakes of various dimensions (see below), it is difficult to decide, whether this is due to the selective preservation of these (closed-depression) landforms or rather the attraction of the former watering places.

Eemian (~MIS 5e)

For the Eemian Interglacial, sites are overall very sparse on the European Plain, except for a cluster in Germany, which displays a considerable record compared to the neighboring regions (see Wenzel, 2007 for a compiled map). Among those sites are Lehringen (Thieme and Veil, 1985), Neumark-Nord 2/2 (Kindler et al., 2020), Gröbern (Mania et al., 1990), Grabschütz, and Rabutz (Weber, 1990) all discovered in open-cast mines for lignite or aggregates and preserved in palaeolake basins associated with the Saalian Glaciation (cf. Chapter 3). A rather unknown site in Woltersdorf (ca. 3 km from Lichtenberg) falls in the same category as the artifacts are contained in a mid/late Eemian peat of a small palaeolake (Breest, 1992). Furthermore, some sites are preserved in travertines, e.g. Steinmühle/Veltheim, Burgtonna, Weimar Parktravertin (Wenzel, 2007), and Taubach (Bratlund, 1999), or more rarely in fluvial sediments, e.g. Wallertheim (Adler et al., 2003). In adjacent Northern France, although many decades of intensive research in the loess area were carried out, only a handful of sites has been discovered from that time period (Locht et al., 2014). And in the loess belt of Southern Poland, just the two sites of Orzechowce and Kraków-Zwierzyniec are tentatively assigned to the Eemian for stratigraphical reasons (Valde-Nowak and Łanczont, 2021). In SW Scandinavia (Jutland) and on the British Isles, confirmed occupations lack altogether (Lewis et al., 2011; Nielsen et al., 2017), in spite of climatically favorable conditions (see 1.3.2). Similarly, from the vast Russian Plain, no Eemian sites have been reported so far (Velichko, 1988).

The low number of sites resulted in the assumption of particularly low population densities in the Eemian (e.g. Roebroeks et al., 1992). This decline is attributed to rather challenging environmental conditions in the densely-forested landscapes with a presumed lower carrying capacity (esp. abundance) for ungulate biomass compared to open landscapes (Hublin and Roebroeks, 2009). Coupled with the higher energetic costs of Neanderthals for sustenance and mobility (Roebroeks and Soressi, 2016) this could have led to dietary stress compromising human reproduction, and even to Neanderthals resorting to cannibalism in the interglacial (Defleur and Desclaux, 2019 present evidence from the Moula Guercy cave in S-France). However, it is highly probable that the number of currently known sites is far from representing a realistic record for the actual Neanderthal occupation (cf. Locht et al., 2014), so that the causal reasoning of Defleur and Desclaux (2019) might be premature.

Alternatively, the geographic asymmetry and also the general scarcity of Eemian sites are possibly best explained by different research histories/intensities and geological or topographical factors (e.g. Speleers, 2000). Examples for the latter would be marine channels barring the dispersal to Britain and Scandinavia, or the large-scale erosion after the Eemian, or the scarcity of accommodating landforms outside of the Saalian Glaciation area (cf. Nielsen et al., 2019).

Eemian sites are commonly described as short-term but occasionally recurring occupations relating to lithic production, hunting, and butchering, indicating a highly mobile land use strategy (Wenzel, 2007). However, for Neumark-Nord 2/2 it could be shown that this high mobility is rather local compared to mobility in open landscapes, inferred from the more locally roaming prey. This led to frequent and repeated site occupations and intensive site use (Kindler et al., 2020). Humans exploited ungulates like aurochs (*Bos primigenius*) and cervids (*Cervus elaphus* and *Dama dama)* as well as big game, such as rhino (*Dicerorhinus kirchbergensis*) and elephant (*Palaeoloxodon antiquus*) (Kindler et al., 2020). Lithic assemblages are dominated by small-sized, discoid and levallois artifacts, produced on simple blanks, whereas bifacial technology is rare (Pop, 2014; Richter, 2016; Wenzel, 2007). Therefore, an opportunistic, rather unselective raw material procurement and exploitation from local sources were proposed, presumably constrained by the limited accessibility of flint on the densely-vegetated and stable surfaces (Locht et al., 2014; cf. Pop and Bakels, 2015; Richter, 2016).

Early Weichselian (~MIS 5d – 5a)

Just like for the Eemian, there is merely a very small number of open-air sites from the Early Weichselian on the European Plain (Figure 1). In Germany, only four sites seem to be uncontested: (1) Tönchesberg 2B, thought to correspond to MIS 5d or 5c (Conard, 1992; Roebroeks et al., 1992), (2) Wallertheim D, E, F, correlated with MIS 5c (Conard and Adler, 1997), (3) Rheindahlen-Westwand B1, stratigraphically related to the Early Weichselian (Bosinski, 2008; Schmitz and Thissen, 1998), and (4) Neumark Nord 2/0

(Laurat and Brühl, 2021; Richter and Krbetschek, 2014), dated to MIS 5c or 5a based on luminescence dating. Apart from that, Middle Palaeolithic artifacts at the site of Schalkholz on the Jutland peninsula are contained within a peat deposit from the Brörup Interstadial (~MIS 5c) (Arnold, 1978; Nielsen et al., 2017). In Southern Poland, the two sites of Pikulice (dated to MIS 5c) and Nehrybka (associated with Early Weichselian soil formation) fall in this time period (Valde-Nowak and Łanczont, 2021). On the Russian Plain, a couple of sites have the potential to be of Early Weichselian antiquity for their stratigraphic situation, such as Sukhaya Mechteka, Khotylevo I, Vykhvatinskiy naves, and Moldova I and V (Velichko, 1988) (Figure 1), but reliable numerical dates have not yet been obtained.

This shortage of sites is in stark contrast to the neighboring region of northern France where numerous occupations (n > 40) from the Early Weichselian have been discovered in recent decades in the course of targeted infrastructure activities (Locht et al., 2016). This contrast suggests, that just like for the Eemian, a pronounced research bias exists that strongly distorts the occupation geography (cf. Nielsen et al., 2017). Another important point is the vagueness of chronologies for the majority of Middle Palaeolithic sites: In contrast to the MIS 5 record, there is an unevenly larger share of Middle Palaeolithic occupations on the European Plain that is placed into MIS 3, but mainly due to typological considerations and not based on numerical dating. This is particularly true for assemblages of the *Keilmessergruppen* (Mania et al., 1990; Veil et al., 1994), also called MMO-assemblages (Mousterian with Micoquian Option) (Richter, 2016, 1997). However, at least for a couple of these sites, there are good (bio-)stratigraphic arguments to assign them to MIS 5a, instead of MIS 3 (e.g. Jöris, 2004; contra Richter, 2016). This applies, for instance, for the sites of Königsaue (Mania, 2002), Lichtenberg (Veil et al., 1994) and Salzgitter Lebenstedt (Hublin, 1984; Pastoors, 2001; Tode, 1982). The present author fully endorses this alternative notion after reviewing the published environmental information (Mania and Toepfer, 1973; Pfaffenberg, 1991; Veil et al., 1994). Therefore, these three sites appear in Figure 1 tagged as "Early Weichselian", acknowledging that the occupations of Salzgitter Lebenstedt and Lichtenberg might even have happened at the MIS 5a/4 transition (cf. Jöris, 2004). For the period of this MIS 5a/4 boundary, elsewhere also the site of

Wrocław Hallera Av., Complex B, Poland (Wiśniewski et al., 2013) and more than 10 sites in Northern France have been documented (Locht et al., 2016).

The artifacts of Early Weichselian sites are usually contained within shallow colluvial or solifluction sediments (Locht et al., 2016; Valde-Nowak and Łanczont, 2021), limnic/peaty deposits at palaeolake shores (Caspers and Freund, 2001; Laurat and Brühl, 2021), or fluvial deposits (Wiśniewski et al., 2013). In the Central European assemblages, a certain typological continuity from the Eemian is displayed (Laurat and Brühl, 2006; Locht et al., 2016; Richter, 2016), with "microlithic" tools made on Levallois or - less frequently - discoidal blanks. In some assemblages occur small blades with backed or retouched points (Hublin and Roebroeks, 2009). Especially sites west of the Rhine, like Tönchesberg 2B, Wallertheim D, and Rheindahlen B1 have a large blade component. Contemporaneous Early Weichselian blade assemblages are also known from sites in northwestern France and Belgium (Bosinski, 2008; Conard, 2012; Locht et al., 2016). As a tendency, more diversified reduction strategies with co-existing systems can be observed. Compared to the Eemian, this relative diversification implies a slightly improved, but still difficult raw material procurement, with less dense forests allowing some minor sediment redeposition and better access to lithic resources (Locht et al., 2014). If the mentioned *Keilmessergruppen* sites are considered to be (late) MIS 5a, then at the end of the Early Weichselian, a clear shift in the assemblages has to be noted towards larger, bifacial, and less variable tools made from large-sized, high-quality raw material (Keilmesser, handaxes, leaf-shaped scrapers) (Weiss, 2019; Weiss et al., 2018). Interestingly, this typological shift would have happened in parallel with the gradual disappearance of the woodland fauna and the emergence of the steppe species (cf. Locht et al., 2014; Richter, 2016).

Pleniglacial (~MIS 4 and early MIS 3)

During the first glacial maximum of the Weichselian (~MIS 4), Neanderthals seem to have avoided the European Plain, i.e., the "northern" realms of Europe, where periglacial conditions prevailed (Richter, 2016; Wiśniewski et al., 2013). Hublin and Roebroeks (2009) make a convincing point, that this apparent desertion might have been caused by regional extinction, rather than migrations to the south. Either way, after this void, a recolonization can be observed, starting from the more southern parts of the European Plain and neighboring areas in late MIS 4 (Locht et al., 2014; Wiśniewski et al., 2019). Albeit, there are two notable exceptions to this pattern: (1) The Garzweiler open-cast mine in western Germany yielded numerous artifacts and as many as eight sites in the MIS 4 loess, thought to relate to gelic Gleysols (Kels and Schirmer, 2011; Uthmeier et al., 2011). (2) The site of Havrincourt in N-France features an occupation associated with an arctic brown soil that can credibly be correlated with GI-18 (ca. 64 ka) in mid-MIS 4 (Antoine et al., 2014; Guérin et al., 2017; Locht et al., 2016). This evidence sheds new light on the MIS 4 'settlement' geography. At least in the western part of the European Plain and the adjoining northern France region, the more oceanic conditions seem to have allowed for ephemeral occupations. Hence, these landscapes were possibly "far away from being […] hostile cold desert(s)" (Uthmeier et al., 2011). Further claims for MIS 4 occupations in northern France and thus a relative settlement continuity cannot be chronostratigraphically substantiated yet in the present author's opinion (Banks et al., 2021; Locht et al., 2016).

The assemblages of early MIS 3 all across the European Plain constitute the richest Middle Palaeolithic ecumene and are mostly assigned to the *Keilmessergruppen/MMO* (Richter, 2016). Only recently, increased efforts have been made to gradually establish chronologies for these open-air records (Weiss, 2019, 2015; Winsemann et al., 2015; Wiśniewski et al., 2019). Yet, with many sites remaining undated and a large share of surface finds with ambiguous stratigraphic context, an uncertain portion of these occupations could likely have occurred in MIS 5a, as well (see Jöris, 2004; cf. Richter, 2016, for discussions on the "long" vs. "short" chronology of the *Keilmessergruppen*).

1.4 METHODS

In the following section, the main methods of palaeoecological and chronological analysis used for this work are described with respect to the gain of knowledge they can provide. More detailed technical aspects and also archaeological methods in a stricter sense can be found in the respective paragraphs of Chapters 2 to 4 and the related supplementary information.

Apart from the methods outlined below, the present author also actively took part in sampling and discussion of the results for micromorphology and phytolith analysis (Chapter 4). Sampling and interpretation of values for soil organic carbon and total nitrogen has been done by the author, and he was an integral part in the seismic measurements and their interpretation (Chapter 3). Furthermore, he jointly planned, organized and conducted the excavations in Lichtenberg with Dr. Marcel Weiss, i.a. operating the mechanical excavator (Chapter 4).

The only aspects, the present author did not directly contribute to, are the preliminary statistical analysis of the Lichtenberg lithic artefacts and the traceology on this material (Supplementary Information 1 for Chapter 4).

1.4.1 Prospection and Fieldwork

Particular emphasis was put on the geomorphological and stratigraphic settings of the two sites investigated. Prior to fieldwork, a simple GIS-based terrain analysis has been conducted, in order to preliminarily assess the temporal relationship of different depositional processes and to better locate positions for future fieldwork (cf. Cook et al., n.d.; Garrison, 2016). This analysis encompassed topographical, geological and historical maps, as well as aerial photographs and digital elevation models (DEMs) in horizontal resolutions between 25 and 1 m (cf. Otto et al., 2018) (see supplementary information for Chapter 3). For Khotylevo, this was only possible to a limited extent, unfortunately, as high-resolution data were more difficult to access. Building on this, artificial exposures of the study region were examined, and for Lichtenberg, an extensive coring campaign was planned and carried out. The latter started with dispersed probing in the wider area to gain a profound overview of the depositional variety and it led to the targeted coring transect across the excavation site as reported in Chapters 3 and 4. Mechanical coring using a motor hammer and open gouges is a versatile and well-established prospection method, both in geomorphology and archaeology and it allows for quick and cost-effective stratigraphic assessment and correlation. Therefore, coring can serve to localize unknown occupations or give environmental context for find layers (Canti and Meddens, 1998; Frew, 2014). With that kind of stratigraphic knowledge, more costly coring activity with truck-mounted systems could be arranged in good conscience. The results of which have already been partly incorporated into this thesis (Chapter 3). Again, because of logistic reasons, in this case, retrieving cores was not feasible for Khotylevo - nor was it strictly necessary. Huge natural exposures and large-scale Paleolithic excavations on the raised bank of River Desna provided a satisfactory insight into the regional sediment suites even beyond the investigated site (Gavrilov et al., 2015; Otcherednoi et al., 2014). All available stratigraphies on- and off-site were described in the field according to German soil mapping standards (AG Boden, 2005), comprising texture, color, bedding, admixtures, as well as carbonate and organic matter contents. Special care was taken to identify disconformities, as well as pedogenic and cryogenic features (Vandenberghe, 2013a). Descriptions of lacustrine and organic sediments followed Meier Uhlherr et al. (2015). That way, the *qualitative* understanding of sedimentary processes and even a notion of their spatial distribution preceded any *quantitative* analysis. In fact, the present author considers this kind of comprehension a prerequisite for establishing the sampling design for any further palaeoenvironmental method.

1.4.2 Luminescence dating

Constraining the ages of deposits and identifying the sequence of events driving archaeological site formation and landscape development is essential for the study of palaeoenvironments and Palaeolithic occupations alike. Numerical dates are utilized to establish and to test theoretical models and concepts (cf. Garrison, 2016; Richter and Wagner, 2015). With the Middle Palaeolithic period being mostly outside of the radiocarbon range (< ca. 50 ka) (Wood, 2015), luminescence techniques are frequently chosen for chronological control. Luminescence dating can estimate the time that has elapsed since a burning event or the burial of sediment (Aitken, 1998). While the application of luminescence on heated artifacts is constantly evolving and returns remarkable results (e.g. Richter et al., 2017), the scope for this thesis only comprises sedimentation events. The basic principle relies on the phenomenon that certain minerals (called "dosimeters", esp. quartz and feldspar), due to defects in their crystal lattice, can store energy produced by omnipresent ionizing background radiation within the sediment and from cosmic rays (Aitken, 1998).

Upon stimulation of the mineral by light or heat, the accumulated energy therein is released as luminescence, i.e. visible light. In nature, this procedure of *resetting* the dosimeters (called "bleaching") is activated by exposure to sunlight during sediment transport, whereby different transportation processes have disparate bleaching potentials (Murray et al., 2012; Wallinga, 2002). After deposition and burial of the mineral grains, energy accumulation starts again, only discontinued by the sampling and measuring activity. In the laboratory, resetting is achieved by stimulating the grains with artificial light at specific wavelengths under above-ambient temperature conditions. The resulting *natural luminescence* signal is detected and documented. In a following sequence of applying known radiation doses and measuring the respective luminescence intensities, the distinct radiation dose value is estimated, required to evoke a luminescence intensity, which is equivalent to the measured natural one (Murray and Wintle, 2003). Hence, this value is called *equivalent dose,* with the SI unit *Gy*. To calculate the burial age, the equivalent dose is divided by the energy deposited in the mineral per year owing to background radiation, expressed as the *dose rate* (Gy/a):

$$\text{Age (a)} = \frac{\text{Equivalent dose (Gy)}}{\text{Dose rate (Gy a}^{-1}\text{)}}$$

The amount of energy that can possibly be stored in the minerals is obviously not indefinite which sets the upper limit to the ages that can be obtained. The actual point of *saturation* is specific to the type of dosimeter. Quartz is reported to have average saturation values of ca. 150 Gy (Wallinga and Cunningham, 2014; Wintle, 1997), which depending on the dose rates usually correspond to ages of <150,000 years. Feldspar saturates at higher doses of up to 1,000 Gy and is therefore particularly attractive for older deposits of up to 600 ka (Buylaert et al., 2012). Additional benefits and drawbacks of using quartz or feldspar are e.g. summarized in Preusser et al. (2008). Luminescence dating has been successfully applied to Neanderthal sites and a wide range of settings and palaeoenvironments, which are time-equivalent to the Middle Palaeolithic (Bateman and Van Huissteden, 1999; Fuchs et al., 2013; Guérin et al., 2015; Lauer et al., 2020; Mercier et al., 2003; Strahl et al., 2010; Thrasher et al., 2009; Wiśniewski et al., 2019).

For the research within this thesis, the luminescence signal of quartz could not be exploited. Pre-tests had shown that the quartz at both study sites either saturates too early to give a reliable account of the depositional ages (Khotylevo), or has unpredictable luminescence characteristics (Lichtenberg). Instead, dating was based on potassium feldspar, using state-of-the-art protocols and methods (Buylaert et al., 2012; Thiel et al., 2011). The present author conducted sampling, equivalent dose estimation, as well as calculation and interpretation of the ages at the Max Planck Institute for Evolutionary Anthropology. The dose rates were determined for all samples by D. Degering at the VTKA laboratory in Dresden. In cases of very thin sediment layers, additional in-situ measurements took place, using a portable high-resolution germanium gamma spectrometer (Arnold et al., 2012).

1.4.3 Grain size analysis

Sediments are traditionally regarded as the most integral and thus most informative element of landscapes. Their deposition and alteration processes are linked to climate, biological factors, as well as geological, hydrological, and geomorphological dynamics (Blott and Pye, 2001; Folk and Ward, 1957). During their entrainment, transport and aggradation, sediments are affected by the energy and the endurance of their transporting media – such as wind, water or glaciers – resulting in characteristic grain-size distributions. These distributions, in turn, can be used to infer transport processes (e.g. fluvial, aeolian, limnic, glacial) and distances, but also source areas and post-depositional modifications by pedogenic, cryogenic or biogenic factors (Cordier et al., 2012; Farrell et al., 2012; Flemming, 2007; King et al., 1998; Meszner et al., 2014; Vandenberghe, 2013b). Classically, three major grain size classes or fractions - sand, silt and clay - were distinguished, divided into 'coarse', 'medium' and 'fine' subfractions, respectively. They were formed through mechanical sieving and sedimentation from a suspension (Beuselinck et al., 1998). With the more recent advent of laser diffractometry, high-resolution (>100 fractions) measurements on large sample sets became possible. This enabled the enhanced identification of multiple, overlapping transportation processes and complex scenarios of redeposition (Dietze and Dietze, 2019; Vandenberghe et al., 2018), reinforcing and renewing the worth of the method. Thus, in their function as key properties of soils, deposits and entire environments, grain size distributions are among the standard analyzed parameters in various disciplines, studying the subsurface of the Earth (e.g. quaternary geology, geomorphology, sedimentology, pedology, and palaeoenvironmental research). But also in archaeology, grain size analysis is increasingly acknowledged as a valuable tool and applied in various contexts (Antoine et al., 2016; Garrison, 2016; Goldberg and Macphail, 2006). Lastly, pore water content and the depositional process are indispensable information for luminescence dating. Since these sediment properties can be derived from grain size distributions, their analysis also supports the correct interpretation of luminescence ages (Nelson and Rittenour, 2015).

The present author conducted sampling and is responsible for processing, interpretation and discussion of the results. Measurements were done by S. Riemenschneider at the Leibniz Institute for Applied Geophysics in Hannover.

1.4.4 Palynological analysis

The analysis of pollen and spores (palynomorphs) is one of the most widely-applied methods in quaternary science and palaeoecology (e.g. Beug, 2004). This is due to their abundance, explanatory power, and preservation (Behre, 1989; Faegri et al., 1989; Moore et al., 1991): Palynomorphs are the most frequent botanical remains in quaternary deposits. Grains differ in shape, size, surface features, and concerning the position and number of apertures (=germination openings, only in pollen grains). The different combinations of these main characteristics result in a large number of pollen and spore types. Up to which taxonomic rank the palynomorphs can be determined, varies substantially. For some types, only the identification of the family is possible (e.g. Chenopodiaceae, Poaceae), whereas the great majority of types allow the determination of the genus (e.g. *Pinus*, *Corylus*). Only in exceptional cases, differentiation of single species is feasible (e.g. *Sanguisorba officinalis*, *Myriophyllum alterniflorum*). In spite of their minuscule sizes (ca. 2-100 µm), pollen and spore grains preserve exceptionally well over millions of years (e.g. Labandeira et al., 2007). This is because their cell walls contain sporopollenin, one of the most chemically inert biological substances on Earth (Brooks and Shaw, 1978). Preservation is particularly good under anoxic conditions (peat, lake deposits), while palynomorphs tend to decompose much quicker in better-aerated sediments and soils, except for very acidic members (Dimbleby, 1961; Havinga, 1968). Pollen and spores are used to draw conclusions about former vegetation conditions and -developments. Typical time sequences can be correlated between different archives to create supra-regional pollen zones (e.g. Zagwijn, 1989), making palynology a powerful biostratigraphic tool especially in periods of sparse numerical age information (Velichko et al., 2005). For that reason, the whole stratigraphic framework of the last interglacial and early glacial on the European Plain largely relies on pollen zones (Caspers and Freund, 2001; Helmens, 2013), whereby type localities of pollen archives lend their names to specific intervals. For example, the Eemian, the Brörup and the Odderade are named after locations in the Netherlands, Denmark and N-Germany, respectively (Menke, 1976; Sier et al., 2015). Apart from its undisputed biostratigraphic value for the subdivision of the Quaternary, palynology is also a *quantitative* tool for palaeoclimatic reconstructions (Kühl et al., 2007; Pidek et al., 2021; Salonen et al., 2013). Several existing techniques to deduce former temperature and precipitation on a site level, based on known climate sensitivities of plant species and associations are summarized in Chevalier et al. (2020). Furthermore, their worldwide prevalence makes pollen and spores important proxies for understanding global climate dynamics (Masson-Delmotte et al., 2013).

Both sites presented in this thesis have been sampled for palynological analysis. However, due to poor preservation, the samples from Khotylevo could not be reliably interpreted, whereas the palynological results for Lichtenberg can be found in Chapters 3 and 4 and their respective supplementary information. The samples were prepared and analysed by B. Urban at the Institute of Ecology at the Leuphana

University Lüneburg. The present author conducted sampling and shared the interpretation and discussion of the results with B. Urban.

1.5 RESEARCH OBJECTIVES

Problem statement

Using this set of methods, the overall aim of this thesis is to contribute to a better understanding of Neanderthal behavior. To facilitate that understanding, numerous case studies investigating diachronic occupational environments, manifested in palaeo-landscapes, are required. The foregoing sections, however, illustrate (i) various biases impeding this objective and (ii) a general scarcity of sites, at which the availability of reliable chronological and palaeoenvironmental data coincides. This results i.a. in (iii) many undated or unsatisfyingly dated Neanderthal open-air sites, especially in sequences or areas where stratigraphic marker horizons, such as palaeosols or tephras, are ambiguous or missing. On a methodological level, this is vastly caused by the facts, that:

1. Most open-air Neanderthal occupations may have occurred at a time-period outside of the radiocarbon dating range.

2. At many sites, state of the art luminescence dating techniques have not yet been applied.

3. Depositional environments at open-air sites may be challenging for luminescence dating, because of poor bleaching, redeposition and deformation of sediments, especially in non-aeolian settings. Thus, these sediments can hardly be unraveled on a site-level alone. However, the surrounding landscapes are often not incorporated into the research protocol, by default. This situation can affect the quality of luminescence dating and the understanding of site-formation, alike.

Approach of the research

Therefore, this thesis is aiming at the improvement of the standard research design, applied at Middle Palaeolithic open-air sites (see Figure 3), using Khotylevo I and Lichtenberg as case studies, and eventually increasing the chronostratigraphic robustness. This is trying to be achieved by:

- Extending the investigations of the sites to a landscape-level utilizing Digital Elevation Models, geophysics and all available outcrops within the closer area and/or auxiliary sediment cores to better understand the sediment dynamics and fluxes than can be done on a site-level. This may also help to competently determine the locality of an excavation. Detailed off- and on-site macroscopic sediment descriptions, supported by on-site micromorphological and grain size analyses can further promote the comprehension of depositional environments and site-formations, but may also provide evidence as to the choice of site locations.

- Taking the obtained knowledge on depositional environments and sediment characteristics into account for luminescence dating. This encompasses: (i) a more educated identification of optimal sampling locations, (ii) taking a comparably high number of samples, (iii) using very small aliquot sizes of 0.5 mm with 10 to 100 individual grains per aliquot retrieved from the dominant grain size fraction, so as to better resolve the equivalent dose distribution within each sample (for more details and potential drawbacks, see Chapter 5.2.1), and (iv) choosing the equivalent dose with the highest likelihood to refer to the depositional process (also Chapter 5.2.1).
- Using landscape-level stratigraphic findings to better assess the position of the closest related off-site archive for palaeoecological information (esp. pollen), if on-site preservation does not allow for a direct determination. Moreover, stratigraphic relationships in the surroundings of a site may help to assign definite biostratigraphic units. For instance, the pollen zones of the late Eemian, as well as the Brörup and Odderade Interstadial have similar pollen spectra, so that disjoint samples can be difficult to classify. However, in many cases, certain options can reliably be ruled out due to the stratigraphic position of the samples (more details in Chapter 5.2.1). Furthermore, lithostratigraphic information on a landscape level can hold evidence for sediment reworking, which is relevant for palynological interpretation, but this evidence can also be provided in the opposite direction.
- Amalgamating the biostratigraphic and palaeoenvironmental data with the obtained sedimentary and chronological information, and putting the resulting framework in a wider (supra)regional chrono-/climatostratigraphic context to test for possible coincidences or discrepancies.

In turn, the obtained findings of these more detailed analyses can then be used to enhance the comprehension of the landscape-scale processes (Figure 3). The present author believes that this top-down, integrative and eventually iterative, landscape-oriented approach can result in improved chronostratigraphies, where the precision and robustness of the luminescence ages may be less affected by the error ranges of the dating method.

Chronostratigraphic robustness is considered here as the concurrence and mutual support of chronological and palaeoenvironmental data, creating an added value for both individual contributors and the overall framework. What degree of robustness and precision can be achieved, depends on respective site conditions and applicable methods. In any case, this framework is intended to offer a solid foundation for future investigations and findings at those sites.

Benefit for archaeological research

The field of Middle Palaeolithic archaeology can profit from establishing a firm chrono-, bio- and lithostratigraphic structure at and around occupational sites in multiple ways. Knowledge on the timing of occupations allows for synchronizing archaeological remains with climatic and environmental data – the latter is partly also provided by the research approach delineated above – in order to investigate possible technological and/or behavioral adaptations to changing conditions. Additionally, if robust chronostratigraphies become increasingly available in the spatial dimension, this will facilitate comparisons and correlations of occupations over longer distances. And it also enables theoretical models on migration and population geographies to be (re)formulated and tested. As a concrete application example, which is also an important subject of the thesis, the *Keilmessergruppen* shall serve here. Evidence for their occurrence is spread all across Central and Eastern Europe. Yet their temporal emergence and duration remain as unclear as the catalyst for their technology (cf. Jöris, 2006; Richter, 2016). Conceivably, this can best be resolved with a concerted synopsis of sedimentological, palaeoenvironmental and chronological methods, applied at and around the individual sites.

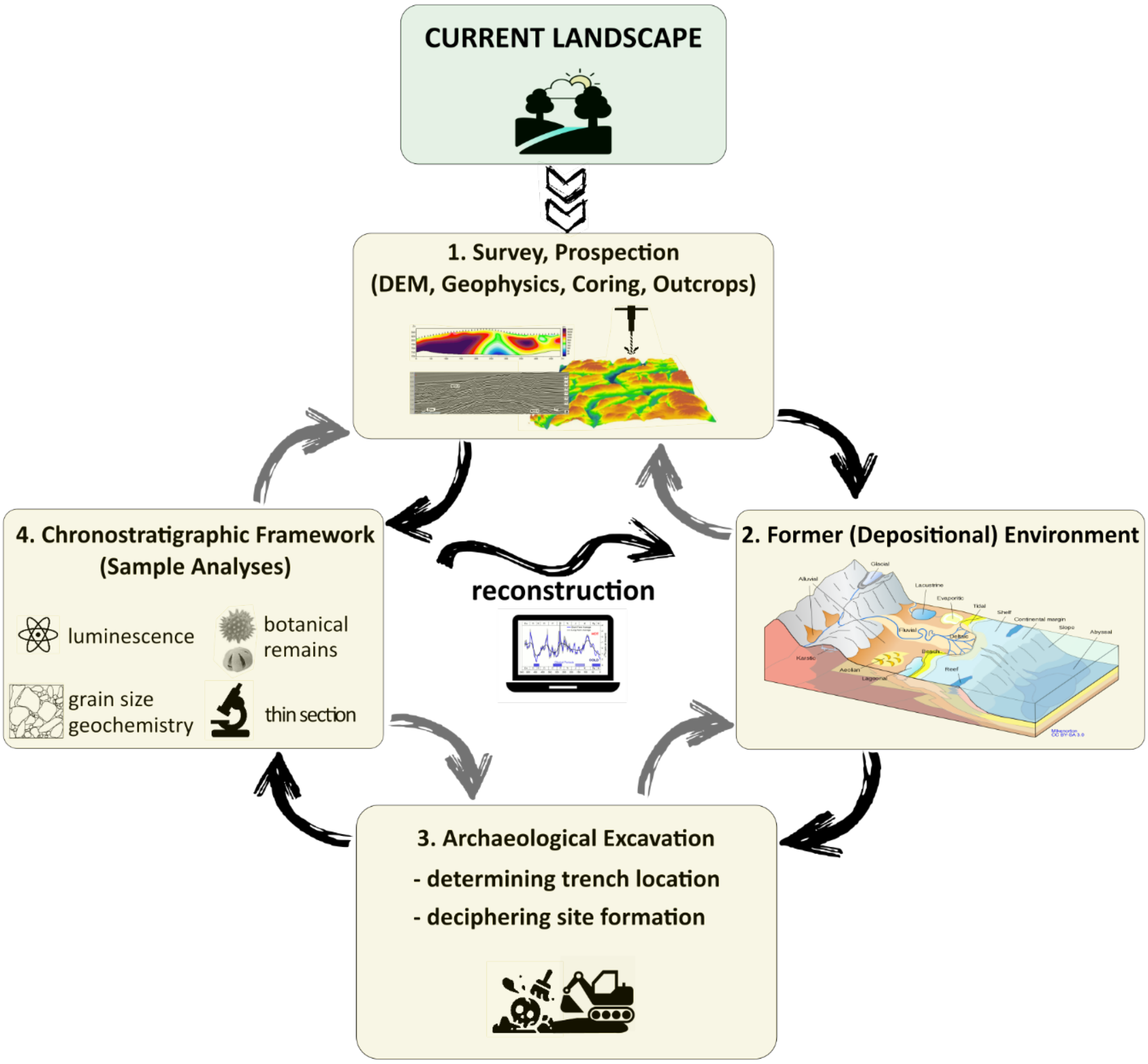

Figure 3: Stepwise and iterative, landscape-oriented research approach to increase chronostratigraphic robustness at Middle Palaeolithic open-air sites. Consecutive numbering of the working steps in the graph does not directly relate to the bullet points given in the text above.

Research questions

In the subsequent Chapters 2 to 4, the outlined approach and methods will be applied to the two Middle Palaeolithic open-air sites Khotylevo I in western Russia and Lichtenberg in northern Germany. The investigations were broadly oriented towards the following research questions (RQ):

RQ 1: ***Is the inclusion of investigations within the surroundings of the sites a helpful tool to strengthen the chronostratigraphies and obtained palaeoenvironmental data of the occupational layers, and to improve the understanding of site formation processes?***

RQ 2: ***Can the previous numerical dates at both sites and their correlation with MIS 3 be confirmed? Or will the results show that the occupations rather occurred at an earlier period (e.g., MIS 5), as already suggested by some authors?***

RQ 3: ***Is the short or the long chronology for the Keilmessergruppen (sensu Jöris, 2004) to be favored, based on the findings of the investigations?***

RQ 4: ***Can a systematic landscape-oriented and chronostratigraphic approach, even for a few consecutive years, support the discovery of new Middle Palaeolithic occupations?***

1.6 REFERENCES

Adler, D.S., Prindiville, T.J., Conard, N.J., 2003. Patterns of spatial organization and land use during the Eemian Interglacial in the Rhineland: New data from Wallertheim, Germany. Eurasian Prehsitory 1, 25–78.

AG Boden, 2005. Bodenkundliche Kartieranleitung KA5, 5. Aufl. ed. Ad-hoc-Arbeitsgruppe Boden (German Soil Mapping Manual).

Aitken, M.J., 1998. An introduction to optical dating: The dating of Quaternary sediments by the use of photon-stimulated luminescence, Oxford science publications. https://doi.org/10.1002/(SICI)1520-6548(200001)15:1<81::AID-GEA5>3.3.CO;2-Y

Aitken, M.J., Stokes, S., 1997. Climatostratigraphy, in: Chronometric Dating in Archaeology. Springer US, Boston, MA, pp. 1–30. https://doi.org/10.1007/978-1-4757-9694-0_1

Allué, E., Mallol, C., Aldeias, V., Burguet-Coca, A., Cabanes, D., Carrancho, Á., Connolly, R., Leierer, L., Mentzer, S., Miller, C., Sandgathe, D., Stahlschmidt, M., Théry-Parisot, I., Vaquero, M., 2022. Fire among Neanderthals, in: Updating Neanderthals. Elsevier, pp. 227–249. https://doi.org/10.1016/B978-0-12-821428-2.00014-7

Antoine, P., Coutard, S., Guerin, G., Deschodt, L., Goval, E., Locht, J.-L., Paris, C., 2016. Upper Pleistocene loess-palaeosol records from Northern France in the European context: Environmental background and dating of the Middle Palaeolithic. Quat. Int. 411, 4–24. https://doi.org/10.1016/j.quaint.2015.11.036

Antoine, P., Goval, E., Jamet, G., Coutard, S., Moine, O., Hérisson, D., Auguste, P., Guérin, G., Lagroix, F., Schmidt, E., Robert, V., Debenham, N., Meszner, S., Bahain, J.-J., 2014. Les séquences loessiques pléistocène supérieur d'Havrincourt (Pas-de-Calais, France) : stratigraphie, paléoenvironnements, géochronologie et occupations paléolithiques. Quaternaire 321–368. https://doi.org/10.4000/quaternaire.7278

Antoine, P., Limondin Lozouet, N., Chaussé, C., Lautridou, J.-P., Pastre, J.-F., Auguste, P., Bahain, J.-J., Falguères, C., Galehb, B., 2007. Pleistocene fluvial terraces from northern France (Seine, Yonne, Somme): synthesis, and new results from interglacial deposits. Quat. Sci. Rev. 26, 2701–2723. https://doi.org/10.1016/j.quascirev.2006.01.036

Archer, W., 2016. What is Still Bay ? Human behavioural variability and biogeography reflected in southern African Middle Stone Age bifacial points. Leiden University.

Arnold, L.J., Duval, M., Falguères, C., Bahain, J.-J., Demuro, M., 2012. Portable gamma spectrometry with cerium-doped lanthanum bromide scintillators: Suitability assessments for luminescence and electron spin resonance dating applications. Radiat. Meas. 47, 6–18. https://doi.org/10.1016/j.radmeas.2011.09.001

Arnold, V., 1978. Neue Funde aus der Steinzeit Ditmarschens. Dithmarschen 3, 57–65.

Banks, W.E., Moncel, M.-H., Raynal, J.-P., Cobos, M.E., Romero-Alvarez, D., Woillez, M.-N., Faivre, J.-P., Gravina, B., D'Errico, F., Locht, J.-L., Santos, F., 2021. An ecological niche shift for Neanderthal populations in Western Europe 70,000 years ago. Sci. Rep. 11, 5346. https://doi.org/10.1038/s41598-021-84805-6

Basell, L., Brown, A.G., Hosfield, R., Toms, P.S., 2011. The geoarchaeology of Palaeolithic rivers of southwest Britain. Geol. Soc. Am. Spec. Pap. 476, 23–36.

Bateman, M.D., Van Huissteden, J., 1999. The timing of last-glacial periglacial and aeolian events, Twente, eastern Netherlands. J. Quat. Sci. 14, 277–283.

Behre, K.-E., 1989. Biostratigraphy of the last glacial period in Europe. Quat. Sci. Rev. 8, 25–44. https://doi.org/10.1016/0277-3791(89)90019-X

Behre, K.-E., Hölzer, A., Lemdahl, G., 2005. Botanical macro-remains and insects from the Eemian and Weichselian site of Oerel (northwest Germany) and their evidence for the history of climate. Veg. Hist. Archaeobot. 14, 31–53. https://doi.org/10.1007/s00334-005-0059-x

Behre, K.-E., van der Plicht, J., 1992. Towards an absolute chronology for the last glacial period in Europe: radiocarbon dates from Oerel, northern Germany. Veg. Hist. Archaeobot. 1, 111–117. https://doi.org/10.1007/BF00206091

Bertran, P., Andrieux, E., Antoine, P., Coutard, S., Deschodt, L., Gardère, P., Hernandez, M., Legentil, C., Lenoble, A., Liard, M., Mercier, N., Moine, O., Sitzia, L., Van Vliet-Lanoë, B., 2014. Distribution and chronology of Pleistocene permafrost features in France: Database and first results. Boreas 43, 699–711. https://doi.org/10.1111/bor.12025

Beschta, R.L., Ripple, W.J., 2016. Riparian vegetation recovery in Yellowstone: The first two decades after wolf reintroduction. Biol. Conserv. 198, 93–103. https://doi.org/10.1016/j.biocon.2016.03.031

Beug, H.-J., 2004. Leitfaden der Pollenbestimmung für Mitteleuropa und angrenzende Gebiete. Germania 87, 542.

Beuselinck, L., Govers, G., Poesen, J., Degraer, G., Froyen, L., 1998. Grain-size analysis by laser diffractometry: comparison with the sieve-pipette method. CATENA 32, 193–208. https://doi.org/10.1016/S0341-8162(98)00051-4

Björck, S., Noe-Nygaard, N., Wolin, J., Houmark-Nielsen, M., Jørgen Hansen, H., Snowball, I., 2000. Eemian Lake development, hydrology and climate: a multi-stratigraphic study of the Hollerup site in Denmark. Quat. Sci. Rev. 19, 509–536. https://doi.org/10.1016/S0277-3791(99)00025-6

Blott, S.J., Pye, K., 2001. GRADISTAT: a grain size distribution and statistics package for the analysis of unconsolidated sediments. Earth Surf. Process. Landforms 26, 1237–1248. https://doi.org/10.1002/esp.261

Boch, R., Cheng, H., Spötl, C., Edwards, R.L., Wang, X., Häuselmann, P., 2011. NALPS: a precisely dated European climate record 120–60 ka. Clim. Past 7, 1247–1259. https://doi.org/10.5194/cp-7-1247-2011

Bocherens, H., 2011. Diet and Ecology of Neanderthals: Implications from C and N Isotopes, in: Conard, N.J., Richter, J. (Eds.), Neanderthal Lifeways, Subsistence and Technology. Springer, Dordrecht, pp. 73–85. https://doi.org/10.1007/978-94-007-0415-2_8

Bolland, A., Kern, O.A., Allstädt, F.J., Peteet, D., Koutsodendris, A., Pross, J., Heiri, O., 2021. Summer temperatures during the last glaciation (MIS 5c to MIS 3) inferred from a 50,000-year chironomid record from Füramoos, southern Germany. Quat. Sci. Rev. 264, 107008. https://doi.org/10.1016/j.quascirev.2021.107008

Bosinski, G., 2008. Urgeschichte am Rhein, Tübingen Publications in Prehistory & Tübinger Monographien zur Urgeschichte. Kerns Verlag, Tübingen.

Bowman, D.M.J.S., O'Brien, J.A., Goldammer, J.G., 2013. Pyrogeography and the Global Quest for Sustainable Fire Management. Annu. Rev. Environ. Resour. 38, 57–80. https://doi.org/10.1146/annurev-environ-082212-134049

Bratlund, B., 1999. Taubach revisited. Jahrb. des Römisch-Germanischen Zentralmuseums 46, 61–114.

Brauer, A., Allen, J.R.M., Mingram, J., Dulski, P., Wulf, S., Huntley, B., 2007. Evidence for last interglacial chronology and environmental change from Southern Europe. PNAS 104, 450–455. https://doi.org/doi.org/10.1073/pnas.0603321104

Breest, K., 1992. Neue Einzelfunde des Alt- und Mittelpaläolithikums im Landkreis Lüchow-Dannenberg. Die Kd. N.F. 43, 1–23.

Brewer, S., Guiot, J., Sánchez-Goñi, M.F., Klotz, S., 2008. The climate in Europe during the Eemian: a multi-method approach using pollen data. Quat. Sci. Rev. 27, 2303–2315. https://doi.org/10.1016/j.quascirev.2008.08.029

Bridgland, D., Westaway, R., 2008. Climatically controlled river terrace staircases: A worldwide Quaternary phenomenon. Geomorphology 98, 285–315. https://doi.org/10.1016/j.geomorph.2006.12.032

Bridgland, D.R., Antoine, P., Limondin-Lozouet, N., Santisteban, J.I., Westaway, R., White, M.J., 2006. The Palaeolithic occupation of Europe as revealed by evidence from the rivers: data from IGCP 449. J. Quat. Sci. 21, 437–455. https://doi.org/10.1002/jqs.1042

Brooks, J., Shaw, G., 1978. Sporopollenin: A review of its chemistry, palaeochemistry and geochemistry. Grana 17, 91–97. https://doi.org/10.1080/00173137809428858

Busschers, F.S., Kasse, C., van Balen, R.T., Vandenberghe, J., Cohen, K.M., Weerts, H.J.T., Wallinga, J., Johns, C., Cleveringa, P., Bunnik, F.P.M., 2007. Late Pleistocene evolution of the Rhine-Meuse system in the southern North Sea basin: imprints of climate change, sea-level oscillation and glacio-isostacy. Quat. Sci. Rev. 26, 3216–3248. https://doi.org/10.1016/j.quascirev.2007.07.013

Buylaert, J.P., Jain, M., Murray, A.S., Thomsen, K.J., Thiel, C., Sohbati, R., 2012. A robust feldspar luminescence dating method for Middle and Late Pleistocene sediments. Boreas 41, 435–451. https://doi.org/10.1111/j.1502-3885.2012.00248.x

Canti, M.G., Meddens, F.M., 1998. Mechanical Coring as an Aid to Archaeological Projects. J. F. Archaeol. 25, 97–105. https://doi.org/10.1179/jfa.1998.25.1.97

Caspers, G., 1997. Die eem- und weichselzeitliche Hohlform von Groß Todtshorn (Kr. Harburg; Niedersachsen) - Geologische und palynologische Untersuchungen zu Vegetation und Klimaverlauf der letzten Kaltzeit. Schriftenr. der Dtsch. Geol. Gesellschaft 4, 7–59.

Caspers, G., Freund, H., 2001. Vegetation and climate in the Early- and Pleni-Weichselian in northern Central Europe. J. Quat. Sci. 16, 31–48. https://doi.org/10.1002/1099-1417(200101)16:1<31::AID-JQS577>3.0.CO;2-3

Caspers, G., Merkt, J., Müller, H., Freund, H., 2002. The Eemian Interglaciation in Northwestern Germany. Quat. Res. 58, 49–52. https://doi.org/10.1006/qres.2002.2341

Chevalier, M., Davis, B.A.S., Heiri, O., Seppä, H., Chase, B.M., Gajewski, K., Lacourse, T., Telford, R.J., Finsinger, W., Guiot, J., Kühl, N., Maezumi, S.Y., Tipton, J.R., Carter, V.A., Brussel, T., Phelps, L.N., Dawson, A., Zanon, M., Vallé, F., Nolan, C., Mauri, A., de Vernal, A., Izumi, K., Holmström, L., Marsicek, J., Goring, S., Sommer, P.S., Chaput, M., Kupriyanov, D., 2020. Pollen-based climate reconstruction techniques for late Quaternary studies. Earth-Science Rev. 210, 103384. https://doi.org/10.1016/j.earscirev.2020.103384

Chu, W., Nett, J.J., 2021. The past in dust: current trends and future directions in Pleistocene geoarcheology of European loess. J. Quat. Sci. https://doi.org/10.1002/jqs.3388

Chubur, A.A., 2013. Theriofauna of the paleolithic location Khotylevo 1 (Bryansk Region). Int. J. Appl. Fundam. Res. 3, 122–124.

Chytrý, M., Horsák, M., Danihelka, J., Ermakov, N., German, D.A., Hájek, M., Hájková, P., Kočí, M., Kubešová, S., Lustyk, P., Nekola, J.C., Pavelková Řičánková, V., Preislerová, Z., Resl, P., Valachovič, M., 2019. A modern analogue of the Pleistocene steppe-tundra ecosystem in southern Siberia. Boreas 48, 36–56. https://doi.org/10.1111/bor.12338

Conard, N.J., 2012. Klingentechnologie vor dem Jungpaläolithikum, in: Floss, H. (Ed.), Steinartefakte Vom Altpaläolithikum Bis in Die Neuzeit, Tübingen Publications in Prehistory. Kerns Verlag, Tübingen, pp. 245–266.

Conard, N.J. (Ed.), 2001. Settlement dynamics of the Middle Paleolithic and Middle Stone Age. Kerns Verlag, Tübingen.

Conard, N.J., 1992. Tönchesberg and its Position in the Paleolithic Prehistory of Northern Europe., Monographien des RGZM. Mainz.

Conard, N.J., Adler, D.S., 1997. Lithic reduction and hominid behavior in the Middle Paleolithic of the Rhineland. J. Anthropol. Res. 53, 147–175.

Cook, S.J., Clarke, L.., Nield, J.M. (Eds.), n.d. Geomorphological Techniques (Online Edition). British Society for Geomorphology, London.

Cordier, S., Lauer, T., Harmand, D., Frechen, M., Brkojewitch, G., 2012. Fluvial response to climatic and anthropogenic forcing in the Moselle drainage basin (NE France) during historical periods: Evidence from OSL dating. Earth Surf. Process. Landforms 37, 1167–1175. https://doi.org/10.1002/esp.3236

Culotta, E., 1999. Neanderthals Were Cannibals, Bones Show. Science (80-.). 286, 18–19. https://doi.org/10.1126/science.286.5437.18b

Dansgaard, W., Clausen, H.B., Gundestrup, N., Hammer, C.U., Johnsen, S.F., Kristinsdottir, P.M., Reeh, N., 1982. A New Greenland Deep Ice Core. Science (80-.). 218, 1273–1277. https://doi.org/10.1126/science.218.4579.1273

de Beaulieu, J.-L., Reille, M., 1992. The last climatic cycle at La Grande Pile (Vosges, France) a new pollen profile. Quat. Sci. Rev. 11, 431–438. https://doi.org/10.1016/0277-3791(92)90025-4

De Clercq, M., Missiaen, T., Wallinga, J., Zurita Hurtado, O., Versendaal, A., Mathys, M., De Batist, M., 2018. A well-preserved Eemian incised-valley fill in the southern North Sea Basin, Belgian Continental Shelf - Coastal Plain: Implications for northwest European landscape evolution. Earth Surf. Process. Landforms 43, 1913–1942. https://doi.org/10.1002/esp.4365

Defleur, A.R., Desclaux, E., 2019. Impact of the last interglacial climate change on ecosystems and Neanderthals behavior at Baume Moula-Guercy, Ardèche, France. J. Archaeol. Sci. 104, 114–124. https://doi.org/10.1016/j.jas.2019.01.002

Delpiano, D., Uthmeier, T., 2020. Techno-functional and 3D shape analysis applied for investigating the variability of backed tools in the Late Middle Paleolithic of Central Europe. PLoS One 15, e0236548. https://doi.org/10.1371/journal.pone.0236548

Dibble, H.L., Aldeias, V., Goldberg, P., McPherron, S.P., Sandgathe, D., Steele, T.E., 2015. A critical look at evidence from La Chapelle-aux-Saints supporting an intentional

Neandertal burial. J. Archaeol. Sci. 53, 649–657. https://doi.org/10.1016/j.jas.2014.04.019

Dibble, H.L., Sandgathe, D., Goldberg, P., McPherron, S., Aldeias, V., 2018. Were Western European Neandertals Able to Make Fire? J. Paleolit. Archaeol. 1, 54–79. https://doi.org/10.1007/s41982-017-0002-6

Dietze, E., Dietze, M., 2019. Grain-size distribution unmixing using the R package EMMAgeo. E&G Quat. Sci. J. 68, 29–46. https://doi.org/10.5194/egqsj-68-29-2019

Dimbleby, G.W., 1961. Soil pollen analysis. J. Soil Sci. 12, 1–10. https://doi.org/10.1111/j.1365-2389.1961.tb00891.x

Discamps, E., Jaubert, J., Bachellerie, F., 2011. Human choices and environmental constraints: deciphering the variability of large game procurement from Mousterian to Aurignacian times (MIS 5-3) in southwestern France. Quat. Sci. Rev. 30, 2755–2775. https://doi.org/10.1016/j.quascirev.2011.06.009

Dutton, A., Lambeck, K., 2012. Ice Volume and Sea Level During the Last Interglacial. Science (80-.). 337, 216–219. https://doi.org/10.1126/science.1205749

Ehlers, J., 1990. Untersuchungen zur Morphodynamik der Vereisungen Norddeutschlands unter Berücksichtigung benachbarter Gebiete. Bremer Beiträge zur Geogr. und Raumplan. 19, 166.

Emiliani, C., 1955. Pleistocene Temperatures. J. Geol. 63, 538–578. https://doi.org/10.1086/626295

Emontspohl, A.-F., 1995. The northwest European vegetation at the beginning of the Weichselian glacial (Brørup and Odderade interstadials)—new data for northern France. Rev. Palaeobot. Palynol. 85, 231–242. https://doi.org/10.1016/0034-6667(94)00128-7

Faegri, K., Iversen, J., Kaland, P.E., Krzywinski, K., 1989. Textbook of pollen analysis, 4th ed. John Wiley & Sons Ltd., Chichester.

Farrell, E.J., Sherman, D.J., Ellis, J.T., Li, B., 2012. Vertical distribution of grain size for wind blown sand. Aeolian Res. 7, 51–61. https://doi.org/10.1016/j.aeolia.2012.03.003

Fergusson, L., Bangerter, P.J., 2015. Principles of environmental remediation in open and closed systems. Int. J. Eng. Sci. Res. Technol. 4, 1–16.

Finlayson, C., Carrión, J.S., 2007. Rapid ecological turnover and its impact on Neanderthal and other human populations. Trends Ecol. Evol. 22, 213–222. https://doi.org/10.1016/j.tree.2007.02.001

Fischer, H., Wahlen, M., Smith, J., Mastroianni, D., Deck, B., 1999. Ice Core Records of Atmospheric CO 2 Around the Last Three Glacial Terminations. Science (80-.). 283, 1712–1714. https://doi.org/10.1126/science.283.5408.1712

Flemming, B.W., 2007. The influence of grain-size analysis methods and sediment mixing on curve shapes and textural parameters: Implications for sediment trend analysis. Sediment. Geol. 202, 425–435. https://doi.org/10.1016/j.sedgeo.2007.03.018

Folk, R.L., Ward, W.C., 1957. Brazos River bar [Texas]; a study in the significance of grain size parameters. J. Sediment. Res. 27, 3–26. https://doi.org/10.1306/74D70646-2B21-11D7-8648000102C1865D

Fränzle, O., 1988. Glaziäre, periglaziäre und marine Reliefentwicklung im nördlichen Schleswig-Holstein. Schr. Naturwiss. Ver. Schlesw.-Holst. 58, 1–30.

Frew, C., 2014. Coring Methods, in: Cook, S.., Clarke, L.E., Nield, J.M. (Eds.), Geomorphological Techniques (Online Edition). British Society for Geomorphology, London.

Fuchs, M., Kreutzer, S., Rousseau, D.-D., Antoine, P., Hatté, C., Lagroix, F., Moine, O., Gauthier, C., Svoboda, J., Lisá, L., 2013. The loess sequence of Dolní Věstonice, Czech Republic: A new OSL-based chronology of the Last Climatic Cycle. Boreas 42, 664–677. https://doi.org/10.1111/j.1502-3885.2012.00299.x

Gao, C., Boreham, S., 2011. Ipswichian (Eemian) floodplain deposits and terrace stratigraphy in the lower Great Ouse and Cam valleys, southern England, UK. Boreas 40, 303–319. https://doi.org/10.1111/j.1502-3885.2010.00191.x

Garrison, E., 2016. Techniques in Archaeological Geology, Natural Science in Archaeology. Springer International Publishing, Cham. https://doi.org/10.1007/978-3-319-30232-4

Gaudzinski, S., 1999. Middle Palaeolithic Bone Tools from the Open-Air Site Salzgitter-Lebenstedt (Germany). J. Archaeol. Sci. 26, 125–141. https://doi.org/10.1006/jasc.1998.0311

Gavrilov, K.N., Voskresenskaya, E. V., Maschenko, E.N., Douka, K., 2015. East Gravettian Khotylevo 2 site: Stratigraphy, archeozoology, and spatial organization of the cultural layer at the newly explored area of the site. Quat. Int. 359–360, 335–346. https://doi.org/10.1016/j.quaint.2014.08.020

Germonpré, M., Udrescu, M., Fiers, E., 2013. The fossil mammals of Spy. Anthropol. Præhistorica 123, 298–327.

Gibbard, P.., Lewin, J., 2002. Climate and related controls on interglacial fluvial sedimentation in lowland Britain. Sediment. Geol. 151, 187–210. https://doi.org/10.1016/S0037-0738(01)00253-6

Goldberg, P., Dibble, H., Berna, F., Sandgathe, D., McPherron, S.J.P., Turq, A., 2012. New evidence on Neandertal use of fire: Examples from Roc de Marsal and Pech de l’Azé IV. Quat. Int. 247, 325–340. https://doi.org/10.1016/j.quaint.2010.11.015

Goldberg, P., Macphail, R.I., 2006. Practical and Theoretical Geoarchaeology. Blackwell Publishing Ltd., Malden, MA USA. https://doi.org/10.1002/9781118688182

Graham, R.W., 2005. Quaternary Mammal Communities: Relevance of the Individualistic Response and Non-Analogue Faunas. Paleontol. Soc. Pap. 11, 141–158. https://doi.org/10.1017/S1089332600001297

Grichuk, V.P., 1961. Fossil floras as a paleontological basis of Quaternary stratigraphy., in: Markov, K.K. (Ed.), Relief and Stratigraphy of Quaternary Deposits on the North-West of Russian Plain. USSR Academy of Sciences Press, Moscow, pp. 25–71.

Grüger, E., 1991. Later quaternary stratigraphy in the nordic coutries 150,000 - 15,000 B.P. Striae 34, 7–14.

Guérin, G., Antoine, P., Schmidt, E., Goval, E., Hérisson, D., Jamet, G., Reyss, J.-L., Shao, Q., Philippe, A., Vibet, M.-A., Bahain, J.-J., 2017. Chronology of the Upper Pleistocene loess sequence of Havrincourt (France) and associated Palaeolithic occupations: A Bayesian approach from pedostratigraphy, OSL, radiocarbon, TL and ESR/U-series data. Quat. Geochronol. 42, 15–30. https://doi.org/10.1016/j.quageo.2017.07.001

Guérin, G., Frouin, M., Talamo, S., Aldeias, V., Bruxelles, L., Chiotti, L., Dibble, H.L., Goldberg, P., Hublin, J.-J., Jain, M., Lahaye, C., Madelaine, S., Maureille, B., McPherron, S.J.P., Mercier, N., Murray, A.S., Sandgathe, D., Steele, T.E., Thomsen, K.J., Turq, A., 2015. A multi-method luminescence dating of the Palaeolithic sequence of La Ferrassie based on new excavations adjacent to the La Ferrassie 1 and 2 skeletons. J. Archaeol. Sci. 58, 147–166. https://doi.org/10.1016/j.jas.2015.01.019

Guthrie, R.D., 2001. Origin and causes of the mammoth steppe: a story of cloud cover, woolly mammal tooth pits, buckles, and inside-out Beringia. Quat. Sci. Rev. 20, 549–574. https://doi.org/10.1016/S0277-3791(00)00099-8

Guthrie, R.D., 1990. Frozen fauna of the Mammoth Steppe: the story of Blue Babe. University of Chicago Press, Chicago.

Harrison, S.P., Bartlein, P., 2012. Records from the Past, Lessons for the Future, in: The Future of the World's Climate. Elsevier, pp. 403–436. https://doi.org/10.1016/B978-0-12-386917-3.00014-2

Havinga, A.J., 1968. Some remarks on the interpretation of a pollen diagram of a podsol profile. Acta Bot. Neerl. 17, 1–4. https://doi.org/10.1111/j.1438-8677.1968.tb00058.x

Helmens, K.F., 2014. The Last Interglacial–Glacial cycle (MIS 5–2) re-examined based on long proxy records from central and northern Europe. Quat. Sci. Rev. 86, 115–143. https://doi.org/10.1016/j.quascirev.2013.12.012

Helmens, K.F., 2013. The Last Interglacial-Glacial cycle (MIS 5-2) re-examined based on long proxy records from central and northern Europe.

Hérisson, D., Brenet, M., Cliquet, D., Moncel, M.-H., Richter, J., Scott, B., Van Baelen, A., Di Modica, K., De Loecker, D., Ashton, N., Bourguignon, L., Delagnes, A., Faivre, J.-P., Folgado-Lopez, M., Locht, J.-L., Pope, M., Raynal, J.-P., Roebroeks, W., Santagata, C., Turq, A., Van Peer, P., 2016. The emergence of the Middle Palaeolithic in north-western Europe and its southern fringes. Quat. Int. 411, 233–283. https://doi.org/10.1016/j.quaint.2016.02.049

Hoffmann, D.L., Standish, C.D., García-Diez, M., Pettitt, P.B., Milton, J.A., Zilhão, J., Alcolea-González, J.J., Cantalejo-Duarte, P., Collado, H., de Balbín, R., Lorblanchet, M., Ramos-Muñoz, J., Weniger, G.-C., Pike, A.W.G., 2018. U-Th dating of carbonate crusts reveals Neandertal origin of Iberian cave art. Science (80-.). 359, 912–915. https://doi.org/10.1126/science.aap7778

Höfle, H.-C., Merkt, J., Müller, H., 1985. Die Ausbreitung des Eem-Meeres in Nordwestdeutschland. E&G Quat. Sci. J. 35, 49–60. https://doi.org/10.3285/eg.35.1.09

Hublin, J.-J., 1984. The fossil man from Salzgitter-Lebenstedt (FRG) and its place in human evolution during the Pleistocene in Europe. Z. Morphol. Anthropol. 75, 45–56.

Hublin, J.-J., Roebroeks, W., 2009. Ebb and flow or regional extinctions? On the character of Neandertal occupation of northern environments. Comptes Rendus Palevol 8, 503–509. https://doi.org/10.1016/j.crpv.2009.04.001

Hull, C.L., 1951. Essentials of behavior. Yale University Press.

Jary, Z., Ciszek, D., 2013. Late Pleistocene loess–palaeosol sequences in Poland and western Ukraine. Quat. Int. 296, 37–50. https://doi.org/10.1016/j.quaint.2012.07.009

Jöris, O., 2006. Bifacially backed knives (Keilmesser) in the central European Middle Palaeolithic, in: Goren-Inbar, N., Sharon, G. (Eds.), Axe Age: Acheulian Tool-Making from Quarry to Discard. Equinox Publishing Ltd, London, pp. 287–310.

Jöris, O., 2004. Zur chronostratigraphischen Stellung der spätmittelpaläolithischen Keilmessergruppen: Der Versuch einer kulturgeographischen Abgrenzung einer mittelpaläolithischen Formengruppe in ihrem europäischen Kontext. Bericht RGK 84, 49–153.

Kaspar, F., 2005. A model-data comparison of European temperatures in the Eemian interglacial. Geophys. Res. Lett. 32, L11703. https://doi.org/10.1029/2005GL022456

Kels, H., Schirmer, W., 2011. Relation of loess units and prehistoric find density in the Garzweiler open-cast mine, Lower Rhine. E G Quat. Sci. J. 59, 59–65. https://doi.org/10.3285/eg.59.1-2.05

Kindler, L., Smith, G.M., García Moreno, A., Gaudzinski-Windheuser, S., Pop, E., Roebroeks, W., 2020. The last interglacial (Eemian) lakeland of Neumark-Nord (Saxony-Anhalt, Germany). Sequencing Neanderthal occupations, assessing subsistence opportunities and prey selection based on estimations of ungulate carrying capacities, biomass production and energ. RGZM-Tagungen 37, 67–104.

Kindler, P., Guillevic, M., Baumgartner, M., Schwander, J., Landais, A., Leuenberger, M., 2014. Temperature reconstruction from 10 to 120 kyr b2k from the NGRIP ice core. Clim. Past 10, 887–902. https://doi.org/10.5194/cp-10-887-2014

King, E.L., Haflidason, H., Sejrup, H.P., Løvlie, R., 1998. Glacigenic debris flows on the North Sea Trough Mouth Fan during ice stream maxima. Mar. Geol. 152, 217–246. https://doi.org/10.1016/S0025-3227(98)00072-3

Knipping, M., 2008. Early and Middle Pleistocene pollen assemblages of deep core drillings in the northern Upper Rhine Graben, Germany. Netherlands J. Geosci. - Geol. en Mijnb. 87, 51–65. https://doi.org/10.1017/S0016774600024045

Kozowyk, P.R.B., Soressi, M., Pomstra, D., Langejans, G.H.J., 2017. Experimental methods for the Palaeolithic dry distillation of birch bark: implications for the origin and development of Neandertal adhesive technology. Sci. Rep. 7, 8033. https://doi.org/10.1038/s41598-017-08106-7

Kühl, N., Litt, T., Schölzel, C., Hense, A., 2007. Eemian and Early Weichselian temperature and precipitation variability in northern Germany. Quat. Sci. Rev. 26, 3311–3317. https://doi.org/10.1016/j.quascirev.2007.10.004

Kühne, O., Weber, F., Berr, K., Jenal, C. (Eds.), 2019. Handbuch Landschaft, RaumFragen: Stadt – Region – Landschaft. Springer Fachmedien Wiesbaden, Wiesbaden. https://doi.org/10.1007/978-3-658-25746-0

Kupryjanowicz, M., Fiłoc, M., Kwiatkowski, W., 2018. Was there an abrupt cold climatic event in the middle Eemian? Pollen record from a palaeolake at the Hieronimowo site, NE Poland. Quat. Int. 467, 96–106. https://doi.org/10.1016/j.quaint.2017.04.027

Labandeira, C.C., Kvaček, J., Mostovski, M.B., 2007. Pollination drops, pollen, and insect pollination of Mesozoic gymnosperms. Taxon 56, 663–695. https://doi.org/10.2307/25065852

Lade, U., Hagedorn, H., 1982. Sedimente und Relief einer eiszeitlichen Hohlform bei Krempel (Elbe-Weser-Dreieck). E&G Quat. Sci. J. 32, 93–108. https://doi.org/10.3285/eg.32.1.08

Lauer, T., Weiss, M., Bernhardt, W., Heinrich, S., Rappsilber, I., Stahlschmidt, M.C., von

Suchodoletz, H., Wansa, S., 2020. The Middle Pleistocene fluvial sequence at Uichteritz, central Germany: Chronological framework, paleoenvironmental history and early human presence during MIS 11. Geomorphology. https://doi.org/10.1016/j.geomorph.2019.107016

Laurat, T., Brühl, E., 2021. Neumark-Nord 2 – A multiphase Middle Palaeolithic open-air site in the Geisel Valley (Central Germany). Anthropologie. 102936. https://doi.org/10.1016/j.anthro.2021.102936

Laurat, T., Brühl, E., 2006. Zum Stand der archäologischen Untersuchungen im Tagebau Neumark-Nord, Ldkr. Merseburg- Querfurt (Sachsen-Anhalt) - Vorbericht zu den Ausgrabungen 2003-2005. Jahresschrift für mitteldeutsche Vor. 90, 9–69.

Leder, D., Hermann, R., Hüls, M., Russo, G., Hoelzmann, P., Nielbock, R., Böhner, U., Lehmann, J., Meier, M., Schwalb, A., Tröller-Reimer, A., Koddenberg, T., Terberger, T., 2021. A 51,000-year-old engraved bone reveals Neanderthals' capacity for symbolic behaviour. Nat. Ecol. Evol. 5, 1273–1282. https://doi.org/10.1038/s41559-021-01487-z

Lehmkuhl, F., Zens, J., Krauß, L., Schulte, P., Kels, H., 2016. Loess-paleosol sequences at the northern European loess belt in Germany: Distribution, geomorphology and stratigraphy. Quat. Sci. Rev. 153, 11–30. https://doi.org/10.1016/j.quascirev.2016.10.008

Lewis, S.G., Ashton, N., Jacobi, R., 2011. Testing Human Presence During the Last Interglacial (MIS 5e): A Review of the British Evidence, in: Ashton, N., Lewis, S.G., Stringer, C. (Eds.), The Ancient Human Occupation of Britain. pp. 125–164. https://doi.org/10.1016/B978-0-444-53597-9.00009-1

Lisiecki, L.E., Raymo, M.E., 2005. A Plio-Pleistocene stack of 57 globally distributed benthic [delta]18O records. Paleoceanography 20, PA1003. https://doi.org/10.1029/2004PA001071

Lisiecki, L.E., Stern, J. V., 2016. Regional and global benthic δ 18 O stacks for the last glacial cycle. Paleoceanography 31, 1368–1394. https://doi.org/10.1002/2016PA003002

Litt, T., Weber, T., 1988. Ein eemzeitlicher Waldelefantenschlachtplatz von Gröbern, Krs. Gräfenhainichen. Ausgrab. Funde 33, 181–187.

Locht, J.-L., Goval, E., Antoine, P., Coutard, S., Auguste, P., Paris, C., Hérisson, D., 2014. Palaeoenvironments and prehistoric interactions in northern France from the Eemian Interglacial to the en dof the Weichselian Middle Pleniglacial, in: Foulds, W.F., Drinkall, H.C., Perri, A.R., Clinnick, D.T.G. (Eds.), Wild Things: Recent Advances in Palaeolithic and Mesolithic Research. Oxbow Books, pp. 70–78.

Locht, J.-L., Hérisson, D., Goval, E., Cliquet, D., Huet, B., Coutard, S., Antoine, P., Feray, P., 2016. Timescales, space and culture during the Middle Palaeolithic in northwestern France. Quat. Int. 411, 129–148. https://doi.org/10.1016/j.quaint.2015.07.053

Mamakowa, K., 1989. Late Middle Polish Glaciation, Eemian and Early Vistulian vegetation at Imbramowice near Wroclaw and the pollen stratigraphy of this part of the Pleistocene in Poland. Acta Palaeobot. 29, 11–176.

Mania, D., 2002. Der mittelpaläolithische Lagerplatz am Ascherslebener See bei Königsaue (Nordharzvorland). Praehistoria Thuringica 8, 16–75.

Mania, D., Thomae, M., Litt, T., Weber, T., 1990. Neumark - Gröbern. Beiträge zur Jagd des mittelpaläolithischen Menschen. Veröff. Landesmus. Vor. Halle 43, 321.

Mania, D., Toepfer, V., 1973. Königsaue: Gliederung, Oekologie und Mittelpaläolithische

Funde der letzten Eiszeit. Veröffentlichungen des Landesmuseums für Vorgeschichte in Halle 26, Deutscher Verlag der Wissenschaften, Berlin.

Marks, L., Gałązka, D., Krzymińska, J., Nita, M., Stachowicz-Rybka, R., Witkowski, A., Woronko, B., Dobosz, S., 2014. Marine transgressions during Eemian in northern Poland: A high resolution record from the type section at Cierpięta. Quat. Int. 328–329, 45–59. https://doi.org/10.1016/j.quaint.2013.12.007

Masson-Delmotte, V., Schulz, M., Abe-Ouchi, A., Beer, J., Ganopolski, A., González Rouco, J.F., Jansen, E., Lambeck, K., Luterbacher, J., Naish, T., Osborn, T., Otto-Bliesner, B., Quinn, T., Ramesh, R., Rojas, M., Shao, X., Timmermann, A., 2013. Information from Paleoclimate Archives., in: Stocker, T.F., Qin, D., Plattner, G.-K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V., Midgley, P.M. (Eds.), Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, pp. 383–464.

Meier-Uhlherr, R., Schulz, C., Luthardt, V., 2015. Steckbriefe Moorsubstrate, 2nd. ed. HNE Eberswalde, Berlin.

Menke, B., 1992. Eeminterglaziale und nacheiszeitliche Wälder in Schleswig-Holstein. GLASH 1, 29–101.

Menke, B., 1976. Neue Ergebnisse zur Stratigraphie und Landschaftsentwicklung im Jungpleistozän Westholsteins. E&G Quat. Sci. J. 27, 53–68. https://doi.org/10.3285/eg.27.1.05

Menke, B., Tynni, R., 1984. Das Eeminterglazial und das Weichselfrühglazial von Rederstall/Dithmarschen und ihre Bedeutung für die mitteleuropäische Jungpleistozän-Gliederung . Geol. Jahrb. A 76, 1–120.

Mercier, N., Valladas, H., Froget, L., Joron, J.L., Reyss, J.L., Balescu, S., Escutenaire, C., Kozlowski, J., Sitlivy, V., Sobczyk, K., Zieba, A., 2003. Luminescence dates for the palaeolithic site of Piekary IIa (Poland): Comparison between TL of burnt flints and OSL of a loess-like deposit. Quat. Sci. Rev. 22, 1245–1249. https://doi.org/10.1016/S0277-3791(03)00025-8

Meszner, S., Faust, D., 2018. Paläoböden in den Lössgebieten Ostdeutschlands, in: Handbuch Der Bodenkunde. Wiley, pp. 1–20. https://doi.org/10.1002/9783527678495.hbbk2018002

Meszner, S., Kreutzer, S., Fuchs, M., Faust, D., 2014. Identifying depositional and pedogenetic controls of Late Pleistocene loess-paleosol sequences (Saxony, Germany) by combined grain size and microscopic analyses. Zeitschrift für Geomorphol. Suppl. Issues 58, 63–90. https://doi.org/10.1127/0372-8854/2014/S-00169

Miettinen, A., Head, M.J., Knudsen, K.L., 2014. Eemian sea-level highstand in the eastern Baltic Sea linked to long-duration White Sea connection. Quat. Sci. Rev. 86, 158–174. https://doi.org/10.1016/j.quascirev.2013.12.009

Minton, E., Kahle, L., 2013. Belief Systems, religion, and Behavioral economics. Business Expert Press.

Mol, J., Vandenberghe, J., Kasse, C., 2000. River response to variations of periglacial climate in mid-latitude Europe. Geomorphology 33, 131–148.

Monnin, E., Indermühle, A., Dällenbach, A., Flückiger, J., Stauffer, B., Stocker, T.F., Raynaud, D., Barnola, J.-M., 2001. Atmospheric CO2 Concentrations over the Last Glacial Termination. Science (80-.). 291, 112–114. https://doi.org/10.1126/science.291.5501.112

Moore, P.D., Webb, J.A., Collison, M.E., 1991. Pollen analysis. Blackwell Scientific Publications, Oxford.

Müller, H., 1974. Pollenanalytische Untersuchungen und Jahresschichtenzählungen an der eemzeitlichen Kieselgur von Bispingen/Luhe. Geol. Jahrb. A21, 149–169.

Müller, U.C., Sánchez Goñi, Maria F., 2007. Vegetation dynamics in southern Germany during marine isotope stage 5 (~ 130 to 70 kyr ago), in: Sirocko, F., Claussen, M., Sánchez Goñi, M.F., Litt, T. (Eds.), The Climate of Past Interglacials. (Developments in Quaternary Sciences 7). pp. 277–287. https://doi.org/10.1016/S1571-0866(07)80044-3

Murray, A.S., Thomsen, K.J., Masuda, N., Buylaert, J.P., Jain, M., 2012. Identifying well-bleached quartz using the different bleaching rates of quartz and feldspar luminescence signals. Radiat. Meas. 47, 688–695. https://doi.org/10.1016/j.radmeas.2012.05.006

Murray, A.S., Wintle, A.G., 2003. The single aliquot regenerative dose protocol: potential for improvements in reliability. Radiat. Meas. 37, 377–381. https://doi.org/10.1016/S1350-4487(03)00053-2

Neef, E., 1967. Die theoretischen Grundlagen der Landschaftslehre. Haack, Gotha/Leipzig.

Nelson, M.S., Rittenour, T.M., 2015. Using grain-size characteristics to model soil water content: Application to dose-rate calculation for luminescence dating. Radiat. Meas. 81, 142–149. https://doi.org/10.1016/j.radmeas.2015.02.016

Nielsen, T.K., Benito, B.M., Svenning, J.-C., Sandel, B., McKerracher, L., Riede, F., Kjærgaard, P.C., 2017. Investigating Neanderthal dispersal above 55°N in Europe during the Last Interglacial Complex. Quat. Int. 431, 88–103. https://doi.org/10.1016/j.quaint.2015.10.039

Nielsen, T.K., Kristiansen, S.M., Riede, F., 2019. Neanderthals at the frontier? Geological potential of southwestern South Scandinavia as archive of Pleistocene human occupation. Quat. Sci. Rev. 221, 105870. https://doi.org/10.1016/j.quascirev.2019.105870

Otcherednoi, A., Salnaya, N., Voskresenskaya, E., Vishnyatsky, L., 2014. New geoarcheological studies at the middle paleolithic sites of khotylevo i and betovo (Bryansk oblast, Russia): Some preliminary results. Quat. Int. 326–327, 250–260. https://doi.org/10.1016/j.quaint.2013.11.005

Otto, J.-C., Prasicek, G., Blöthe, J., Schrott, L., 2018. GIS Applications in Geomorphology, in: Comprehensive Geographic Information Systems. Elsevier, pp. 81–111. https://doi.org/10.1016/B978-0-12-409548-9.10029-6

Panin, A., Adamiec, G., Buylaert, J.-P., Matlakhova, E., Moska, P., Novenko, E., 2017. Two Late Pleistocene climate-driven incision/aggradation rhythms in the middle Dnieper River basin, west-central Russian Plain. Quat. Sci. Rev. 166, 266–288. https://doi.org/10.1016/j.quascirev.2016.12.002

Panin, A., Borisova, O., Konstantinov, E., Belyaev, Y., Eremenko, E., Zakharov, A., Sidorchuk, A., 2020. The Late Quaternary Evolution of the Upper Reaches of Fluvial Systems in the Southern East European Plain. Quaternary 3, 31. https://doi.org/10.3390/quat3040031

Pastoors, A., 2001. Die Mittelpaläolithische Freilandstation von Salzgitter-Lebenstedt: Genese der Fundstelle und Systematik der Steinbearbeitung. Archiv der Satdt Salzgitter, Salzgitter.

Pecl, G.T., Araújo, M.B., Bell, J.D., Blanchard, J., Bonebrake, T.C., Chen, I.-C., Clark, T.D., Colwell, R.K., Danielsen, F., Evengård, B., Falconi, L., Ferrier, S., Frusher, S., Garcia, R.A., Griffis, R.B., Hobday, A.J., Janion-Scheepers, C., Jarzyna, M.A., Jennings, S., Lenoir, J., Linnetved, H.I., Martin, V.Y., McCormack, P.C., McDonald, J., Mitchell, N.J., Mustonen, T., Pandolfi, J.M., Pettorelli, N., Popova, E., Robinson, S.A., Scheffers, B.R., Shaw, J.D., Sorte, C.J.B., Strugnell, J.M., Sunday, J.M., Tuanmu, M.-N., Vergés, A., Villanueva, C., Wernberg, T., Wapstra, E., Williams, S.E., 2017. Biodiversity redistribution under climate change: Impacts on ecosystems and human well-being. Science (80-.). 355. https://doi.org/10.1126/science.aai9214

Pederzani, S., Aldeias, V., Dibble, H.L., Goldberg, P., Hublin, J.-J., Madelaine, S., McPherron, S.P., Sandgathe, D., Steele, T.E., Turq, A., Britton, K., 2021. Reconstructing Late Pleistocene paleoclimate at the scale of human behavior: an example from the Neandertal occupation of La Ferrassie (France). Sci. Rep. 11, 1419. https://doi.org/10.1038/s41598-020-80777-1

Peeters, J., Busschers, F.S., Stouthamer, E., 2015. Fluvial evolution of the Rhine during the last interglacial-glacial cycle in the southern North Sea basin: A review and look forward. Quat. Int. 357, 176–188. https://doi.org/10.1016/j.quaint.2014.03.024

Pereira-Pedro, A.S., Bruner, E., Gunz, P., Neubauer, S., 2020. A morphometric comparison of the parietal lobe in modern humans and Neanderthals. J. Hum. Evol. 142, 102770. https://doi.org/10.1016/j.jhevol.2020.102770

Pfaffenberg, K., 1991. Die Vegetationsverhältnisse während und nach der Sedimentation der Fundschichten von Salzgitter-Lebenstedt, in: Busch, R., Schwabedissen, H. (Eds.), Der Altsteinzeitliche Fundplatz Salzgitter-Lebenstedt. Teil II. Naturwissenschaftliche Untersuchungen. Böhlau Verlag, Köln, Weimar, Wien, pp. 183–210.

Piacente, S., 1996. Man as geomorphological agent, in: Panizza, M. (Ed.), Environmental Geomorphology. Developments in Earth Surface Processes, 4. Elsevier, pp. 197–214. https://doi.org/10.1016/S0928-2025(96)80021-6

Pidek, I.A., Poska, A., Hrynowiecka, A., Brzozowicz, D., Żarski, M., 2021. Two pollen-based methods of Eemian climate reconstruction employed in the study of the Żabieniec-Jagodne palaeolakes in central Poland. Quat. Int. in press. https://doi.org/10.1016/j.quaint.2021.09.014

Pop, E., 2014. Analysis of the neumark-nord 2/2 lithic assemblage: results and interpretations, in: Gaudzinski-Windheuser, S., Roebroeks, W. (Eds.), Multidisciplinary Studies of the Middle Palaeolithic Record from Neumark-Nord (Germany), Verö!Entlichungen Des Landesamtes Für Denkmalpflege Und Archäologie Sachsen-Anhalt – Landesmuseum Für Vorgeschichte Band 69. Landesamt für Denkmalpflege und Archäologie Sachsen-Anhalt, Landesmuseum für Vorgeschichte, Halle(Saale), pp. 143–195.

Pop, E., Bakels, C., 2015. Semi-open environmental conditions during phases of hominin occupation at the Eemian Interglacial basin site Neumark-Nord 2 and its wider environment. Quat. Sci. Rev. 117, 72–81. https://doi.org/10.1016/j.quascirev.2015.03.020

Pop, E., Kuijper, W., van Hees, E., Smith, G., García-Moreno, A., Kindler, L., Gaudzinski-Windheuser, S., Roebroeks, W., 2016. Fires at Neumark-Nord 2, Germany: An analysis of fire proxies from a Last Interglacial Middle Palaeolithic basin site. J. F. Archaeol. 41, 603–617. https://doi.org/10.1080/00934690.2016.1208518

Presnyakova, D., Archer, W., Braun, D.R., Flear, W., 2015. Documenting differences between early stone age flake production systems: An experimental model and archaeological verification. PLoS One 10, 1–26. https://doi.org/10.1371/journal.pone.0130732

Preusser, F., Degering, D., Fuchs, M., Hilgers, A., Kadereit, A., Klasen, N., Krbetschek, M., Richter, D., Spencer, J.Q.G., 2008. Luminescence dating: basics, methods and applications. E&G Quat. Sci. J. 57, 95–149. https://doi.org/10.3285/eg.57.1-2.5

Pross, J., Klotz, S., Mosbrugger, V., 2000. Reconstructing palaeotemperatures for the Early and Middle Pleistocene using the mutual climatic range method based on plant fossils. Quat. Sci. Rev. 19, 1785–1799. https://doi.org/10.1016/S0277-3791(00)00089-5

Rapoport, A., 2008. Archaeology and Environment-Behavior Studies. Archeol. Pap. Am. Anthropol. Assoc. 16, 59–70. https://doi.org/10.1525/ap3a.2006.16.1.59

Rasmussen, S.O., Bigler, M., Blockley, S.P., Blunier, T., Buchardt, S.L., Clausen, H.B., Cvijanovic, I., Dahl-Jensen, D., Johnsen, S.J., Fischer, H., Gkinis, V., Guillevic, M., Hoek, W.Z., Lowe, J.J., Pedro, J.B., Popp, T., Seierstad, I.K., Steffensen, J.P., Svensson, A.M., Vallelonga, P., Vinther, B.M., Walker, M.J.C., Wheatley, J.J., Winstrup, M., 2014. A stratigraphic framework for abrupt climatic changes during the Last Glacial period based on three synchronized Greenland ice-core records: refining and extending the INTIMATE event stratigraphy. Quat. Sci. Rev. 106, 14–28. https://doi.org/10.1016/j.quascirev.2014.09.007

Reid, J.J., Rathje, W.L., Schiffer, M.B., 1974. Expanding Archaeology. Am. Antiq. 39, 125–126. https://doi.org/10.2307/279227

Richter, D., Grün, R., Joannes-Boyau, R., Steele, T.E., Amani, F., Rué, M., Fernandes, P., Raynal, J.-P., Geraads, D., Ben-Ncer, A., Hublin, J.-J., McPherron, S.P., 2017. The age of the hominin fossils from Jebel Irhoud, Morocco, and the origins of the Middle Stone Age. Nature 546, 293–296. https://doi.org/10.1038/nature22335

Richter, D., Krbetschek, M., 2014. Preliminary luminescence dating results for two Middle Palaeolithic occupations at Neumark-Nord 2, in: Gaudzinski-Windheuser, S., Roebroeks, W. (Eds.), Multidisziplinary Studies of the Middle Palaeolithic Record from Neumark-Nord (Germany). Volume 1. Veröffentlichungen des Landesamtes für Archäologie Sachsen-Anhalt - Landesmuseum für Vorgeschichte 69, Halle(Saale), pp. 131–136.

Richter, D., Wagner, G.A., 2015. Chronometric Methods in Paleoanthropology, in: Henke, W., Tattersall, I. (Eds.), Handbook of Paleoanthropology. Springer, Berlin, Heidelberg, pp. 317–350. https://doi.org/10.1007/978-3-642-39979-4_10

Richter, J., 2016. Leave at the height of the party: A critical review of the Middle Paleolithic in Western Central Europe from its beginnings to its rapid decline. Quat. Int. 411, 107–128. https://doi.org/10.1016/j.quaint.2016.01.018

Richter, J., 2006. Neanderthals in their landscape., in: Neanderthals in Europe. pp. 51–66.

Richter, J., 1997. Sesselfelsgrotte III. Der G-Schichten-Komplex der Sesselfelsgrotte. Zum Verständnis des Micoquien. Quartär Bibliothek 7, Saarbrücker Druckerei und Verlag, Saarbrücken.

Roebroeks, W., 2014. Terra incognita : The Palaeolithic record of northwest Europe and the information potential of the southern North Sea. Netherlands J. Geosci. - Geol. en Mijnb. 93, 43–53. https://doi.org/10.1017/njg.2014.1

Roebroeks, W., Bakels, C.C., Coward, F., Hosfield, R., Pope, M., Wenban-Smith, F., 2015. 'Forest Furniture' or 'Forest Managers'? On Neanderthal presence in Last Interglacial environments, in: Settlement, Society and Cognition in Human Evolution. Cambridge University Press, New York, pp. 174–188. https://doi.org/10.1017/CBO9781139208697.011

Roebroeks, W., Conard, N.J., van Kolfschoten, T., Dennell, R.W., Dunnell, R.C., Gamble, C., Graves, P., Jacobs, K., Otte, M., Roe, D., Svoboda, J., Tuffreau, A., Voytek, B.A., Wenban-Smith, F., Wymer, J.J., 1992. Dense Forests, Cold Steppes, and the Palaeolithic Settlement of Northern Europe [and Comments and Replies]. Curr. Anthropol. 33, 551–586. https://doi.org/10.1086/204113

Roebroeks, W., Soressi, M., 2016. Neandertals revised. Proc. Natl. Acad. Sci. 113, 6372–6379. https://doi.org/10.1073/pnas.1521269113

Rolland, N., Dibble, H.L., 1990. A New Synthesis of Middle Paleolithic Variability. Am. Antiq. 55, 480–499.

Roos, C.I., Bowman, D.M.J.S., Balch, J.K., Artaxo, P., Bond, W.J., Cochrane, M., D'Antonio, C.M., DeFries, R., Mack, M., Johnston, F.H., Krawchuk, M.A., Kull, C.A., Moritz, M.A., Pyne, S., Scott, A.C., Swetnam, T.W., 2014. Pyrogeography, historical ecology, and the human dimensions of fire regimes. J. Biogeogr. 41, 833–836. https://doi.org/10.1111/jbi.12285

Russell Coope, G., 2000. The climatic significance of coleopteran assemblages from the Eemian deposits in southern England. Netherlands J. Geosci. 79, 257–267. https://doi.org/10.1017/S0016774600021740

Salonen, J.S., Hemens, K.F., Seppä, H., Birks, H.J.B., 2013. Pollen-based palaeoclimate reconstructions over long glacial-interglacial timescales: methodological tests based on the Holocene and MIS 5d-c deposits at Sokli, northern Finland. J. Quat. Sci. 28, 271–282. https://doi.org/10.1002/jqs.2611

Sánchez Goñi, M.F., 2020. Regional impacts of climate change and its relevance to human evolution. Evol. Hum. Sci. 2, 1–27. https://doi.org/10.1017/ehs.2020.56

Sandgathe, D.M., Dibble, H.L., Goldberg, P., McPherron, S.P., Turq, A., Niven, L., Hodgkins, J., 2011. Timing of the appearance of habitual fire use. Proc. Natl. Acad. Sci. 108, E298–E298. https://doi.org/10.1073/pnas.1106759108

Scherjon, F., Bakels, C., MacDonald, K., Roebroeks, W., 2015. Burning the Land. Curr. Anthropol. 56, 299–326. https://doi.org/10.1086/681561

Schmitz, R.W., Thissen, J., 1998. Vorbericht über die Grabungen 1995-1997 in der mittelpaläolithischen B1-Schicht der Ziegeleigrube Dreesen in Rheindahlen. Archäologisches Korrespondenzblatt 28, 483–498.

Schokker, J., Cleveringa, P., Murray, A.S., 2004. Palaeoenvironmental reconstruction and OSL dating of terrestrial Eemian deposits in the southeastern Netherlands. J. Quat. Sci. 19, 193–202. https://doi.org/10.1002/jqs.808

Seierstad, I.K., Abbott, P.M., Bigler, M., Blunier, T., Bourne, A.J., Brook, E., Buchardt, S.L., Buizert, C., Clausen, H.B., Cook, E., Dahl-Jensen, D., Davies, S.M., Guillevic, M., Johnsen, S.J., Pedersen, D.S., Popp, T.J., Rasmussen, S.O., Severinghaus, J.P., Svensson, A., Vinther, B.M., 2014. Consistently dated records from the Greenland GRIP, GISP2 and NGRIP ice cores for the past 104 ka reveal regional millennial-scale δ18O gradients with possible Heinrich event imprint. Quat. Sci. Rev. 106, 29–46. https://doi.org/10.1016/j.quascirev.2014.10.032

Shackleton, N.J., 1969. The last interglacial in the marine and terrestrial records. Proc. R. Soc. London. Ser. B. Biol. Sci. 174, 135–154. https://doi.org/10.1098/rspb.1969.0085

Shackleton, N.J., 1967. Oxygen Isotope Analyses and Pleistocene Temperatures Re-assessed. Nature 215, 15–17. https://doi.org/10.1038/215015a0

Shackleton, N.J., Chapman, M., Sánchez-Goñi, M.F., Pailler, D., Lancelot, Y., 2002. The Classic Marine Isotope Substage 5e. Quat. Res. 58, 14–16. https://doi.org/10.1006/qres.2001.2312

Shackleton, N.J., Sánchez-Goñi, M.F., Pailler, D., Lancelot, Y., 2003. Marine Isotope Substage 5e and the Eemian Interglacial. Glob. Planet. Change 36, 151–155. https://doi.org/10.1016/S0921-8181(02)00181-9

Sier, M.J., Peeters, J., Dekkers, M.J., Parés, J.M., Chang, L., Busschers, F.S., Cohen, K.M., Wallinga, J., Bunnik, F.P.M., Roebroeks, W., 2015. The Blake Event recorded near the Eemian type locality - A diachronic onset of the Eemian in Europe. Quat. Geochronol. https://doi.org/10.1016/j.quageo.2015.03.003

Sier, M.J., Roebroeks, W., Bakels, C.C., Dekkers, M.J., Brühl, E., De Loecker, D., Gaudzinski-Windheuser, S., Hesse, N., Jagich, A., Kindler, L., Kuijper, W.J., Laurat, T., Mücher, H.J., Penkman, K.E.H., Richter, D., van Hinsbergen, D.J.J., 2011. Direct terrestrial–marine correlation demonstrates surprisingly late onset of the last interglacial in central Europe. Quat. Res. 75, 213–218. https://doi.org/10.1016/j.yqres.2010.11.003

Simensen, T., Halvorsen, R., Erikstad, L., 2018. Methods for landscape characterisation and mapping: A systematic review. Land use policy 75, 557–569. https://doi.org/10.1016/j.landusepol.2018.04.022

Soressi, M., 2005. Late Mousterian Lithic Technology. Its Implications for the Pace of the Emergence of Behavioural Modernity and the Relationship between Behavioural Modernity and Biological Modernity., in: Blackwell, L., d'Errico, F. (Eds.), From Tools to Symbols. University of Witswatersand Press, Johannesburg, pp. 389–417.

Speleers, B., 2000. The relevance of the Eemian for the study of the Palaeolithic occupation of Europe. Netherlands J. Geosci. 79, 283–291. https://doi.org/10.1017/S0016774600021764

Stewart, J.R., 2005. The ecology and adaptation of Neanderthals during the non-analogue environment of Oxygen Isotope Stage 3. Quat. Int. 137, 35–46. https://doi.org/10.1016/j.quaint.2004.11.018

Strahl, J., Krbetschek, M.R., Luckert, J., Machalett, B., Meng, S., Oches, E.A., Rappsilber, I., Wansa, S., Zöller, L., 2010. Geologie, Paläontologie und Geochronologie des Eem-Beckens Neumark-Nord 2 und Vergleich mit dem Becken Neumark-Nord 1 (Geiseltal, Sachsen-Anhalt). Eiszeitalter und Gegenwart (Quaternary Sci. Journal) 59, 120–167. https://doi.org/10.3285/eg.59.1-2.09

Stremme, H., Felix-Henningsen, P., Weinhold, H., Christensen, S., 1982. Paläoböden in Schleswig-Holstein. Geol. Jb. F 14, 311–361.

Thiel, C., Buylaert, J.P., Murray, A., Terhorst, B., Hofer, I., Tsukamoto, S., Frechen, M., 2011.

Luminescence dating of the Stratzing loess profile (Austria) - Testing the potential of an elevated temperature post-IR IRSL protocol. Quat. Int. 234, 23–31. https://doi.org/10.1016/j.quaint.2010.05.018

Thieme, H., 2007. Die Schoeninger Speere: Mensch und Jagd vor 400 000 Jahren. Theiss, Stuttgart.

Thieme, H., Veil, S., 1985. Neue Untersuchungen zum eemzeitlichen Elefanten-Jagdplatz Lehringen, Ldkr. Verden. Die Kd. N.F. 36, 11–58.

Thrasher, I.M., Mauz, B., Chiverrell, R.C., Lang, A., 2009. Luminescence dating of glaciofluvial deposits: A review. Earth-Science Rev. 97, 133–146. https://doi.org/10.1016/j.earscirev.2009.09.001

Tode, A., 1982. Der altsteinzeitliche Fundplatz Salzgitter-Lebenstedt. Teil I, archäologischer Teil. Böhlau, Köln, Wien.

Turner, C., 2002. Formal Status and Vegetational Development of the Eemian Interglacial in Northwestern and Southern Europe. Quat. Res. 58, 41–44. https://doi.org/10.1006/qres.2002.2365

Turner, C., 2000. The Eemian interglacial in the North European plain and adjacent areas. Netherlands J. Geosci. 79, 217–231. https://doi.org/10.1017/S0016774600023660

Tzedakis, C., 2003. Timing and duration of Last Interglacial conditions in Europe: a chronicle of a changing chronology. Quat. Sci. Rev. 22, 763–768. https://doi.org/10.1016/S0277-3791(03)00004-0

Uthmeier, T., Kels, H., Schirmer, W., Böhner, U., 2011. Neanderthals in the cold: Middle Paleolithic sites from the open-cast mine of Garzweiler, Nordrhein-Westfalen (Germany), in: Conard, N.J., Richter, J. (Eds.), Neanderthal Lifeways, Subsistence and Technology: One Hundred Fifty Years of Neanderthal Study. Springer, pp. 25–41. https://doi.org/10.1007/978-94-007-0415-2_4

Valde-Nowak, P., Łanczont, M., 2021. State-of-the-art overview of the Loess Palaeolithic of Poland. J. Quat. Sci. jqs.3356. https://doi.org/10.1002/jqs.3356

Van Kolfschoten, T., Parfitt, S.A., Serangeli, J., Bello, S.M., 2015. Lower Paleolithic bone tools from the 'Spear Horizon' at Schöningen (Germany). J. Hum. Evol. 89, 226–263. https://doi.org/10.1016/j.jhevol.2015.09.012

Vandenberghe, J., 2015. River terraces as a response to climatic forcing: Formation processes, sedimentary characteristics and sites for human occupation. Quat. Int. https://doi.org/10.1016/j.quaint.2014.05.046

Vandenberghe, J., 2013a. Cryoturbation Structures, in: S.A, E. (Ed.), The Encyclopedia of Quaternary Science,. pp. 430–435.

Vandenberghe, J., 2013b. Grain size of fine-grained windblown sediment: A powerful proxy for process identification. Earth-Science Rev. 121, 18–30. https://doi.org/10.1016/j.earscirev.2013.03.001

Vandenberghe, J., Sun, Y., Wang, X., Abels, H.A., Liu, X., 2018. Grain-size characterization of reworked fine-grained aeolian deposits. Earth-Science Rev. 177, 43–52. https://doi.org/10.1016/j.earscirev.2017.11.005

Veil, S., Breest, K., Höfle, H.-C., Meyer, H.-H., Plisson, H., Urban-Küttel, B., Wagner, G.A., Zöller, L., 1994. Ein mittelpaläolithischer Fundplatz aus der Weichsel-Kaltzeit bei

Lichtenberg, Lkr. Lüchow-Dannenberg. Germania 72, 1–66.

Velichko, A., Novenko, E., Pisareva, V., Zelikson, E., Boettger, T., Junge, F., 2005. Vegetation and climate changes during the Eemian interglacial in Central and Eastern Europe: comparative analysis of pollen data. Boreas 34, 207–219. https://doi.org/10.1080/03009480510012890

Velichko, A.A., 1988. Geoecology of the Mousterian in East Europeand the adjacent areas, in: L'Homme de Neandertal. Liège, pp. 181–206.

Velichko, A.A., Morozova, T.D., 2010. Basic features of late pleistocene soil formation in the east european plain and their paleogeographic interpretation. Eurasian Soil Sci. 43, 1535–1546. https://doi.org/10.1134/S1064229310130120

Vernot, B., Zavala, E.I., Gómez-Olivencia, A., Jacobs, Z., Slon, V., Mafessoni, F., Romagné, F., Pearson, A., Petr, M., Sala, N., Pablos, A., Aranburu, A., de Castro, J.M.B., Carbonell, E., Li, B., Krajcarz, M.T., Krivoshapkin, A.I., Kolobova, K.A., Kozlikin, M.B., Shunkov, M. V., Derevianko, A.P., Viola, B., Grote, S., Essel, E., Herráez, D.L., Nagel, S., Nickel, B., Richter, J., Schmidt, A., Peter, B., Kelso, J., Roberts, R.G., Arsuaga, J.-L., Meyer, M., 2021. Unearthing Neanderthal population history using nuclear and mitochondrial DNA from cave sediments. Science (80-.). 372. https://doi.org/10.1126/science.abf1667

Walkling, A., 1997. Käferkundliche Untersuchungen an weichselzeitlichen Ablagerungen der Bohrung Groß Todtshorn (Kr. Harburg; Niedersachsen). Schriftenr. der Dtsch. Geol. Gesellschaft 4, 87–102.

Wallinga, J., 2002. Optically stimulated luminescence dating of fluvial deposits: A review. Boreas 31, 303–322. https://doi.org/10.1080/030094802320942536

Wallinga, J., Cunningham, A.C., 2014. Luminescence Dating, Uncertainties, and Age Range, in: Encyclopedia of Scientific Dating Methods. Springer Netherlands, Dordrecht, pp. 1–9. https://doi.org/10.1007/978-94-007-6326-5_197-1

Weber, T., 1990. Paläolithische Funde aus den Eemvorkommen von Rabutz, Grabschütz und Gröbern, in: Eißmann, L. (Ed.), Die Eemwarmzeit Und Die Frühe Weichsel- Eiszeit Im Saale-Elbe-Gebiet. Geologie, Paläontologie, Palökologie, Altenburger Naturwissenschaftliche Forschungen 5. Naturkundliches Museum Mauritianum, Altenburg.

Weber, T., Beye, U., 2015. Paläolithische „Flussfunde" aus Mitteldeutschland. Die Kd. N.F. 63, 183–196.

Weiss, M., 2020. The Lichtenberg Keilmesser - it's all about the angle. PLoS One 15, e0239718. https://doi.org/10.1371/journal.pone.0239718

Weiss, M., 2019. Beyond the caves: stone artifact analysis of late Middle Paleolithic open-air assemblages from the European Plain. Universiteit Leiden.

Weiss, M., 2015. Stone tool analysis and context of a new late Middle Paleolithic site in western central Europe - Pouch-Terrassenpfeiler, Ldkr. Anhalt-Bitterfeld, Germany. Quartär 62, 23–62. https://doi.org/10.7485/QU62_2

Weiss, M., Lauer, T., Wimmer, R., Pop, C.M., 2018. The Variability of the Keilmesser-Concept: a Case Study from Central Germany. J. Paleolit. Archaeol. 1, 202–246. https://doi.org/10.1007/s41982-018-0013-y

Wenzel, S., 2007. 12. Neanderthal presence and behaviour in central and Northwestern Europe during MIS 5e, in: Sirocko, F., Claussen, M., Sánchez-Goñi, M.F., Litt, T. (Eds.), The Climate of Past Interglacials. Elsevier, pp. 173–193. https://doi.org/10.1016/S1571-0866(07)80037-6

Weyrich, L.S., Duchene, S., Soubrier, J., Arriola, L., Llamas, B., Breen, J., Morris, A.G., Alt, K.W., Caramelli, D., Dresely, V., Farrell, M., Farrer, A.G., Francken, M., Gully, N., Haak, W., Hardy, K., Harvati, K., Held, P., Holmes, E.C., Kaidonis, J., Lalueza-Fox, C., de la Rasilla, M., Rosas, A., Semal, P., Soltysiak, A., Townsend, G., Usai, D., Wahl, J., Huson, D.H., Dobney, K., Cooper, A., 2017. Neanderthal behaviour, diet, and disease inferred from ancient DNA in dental calculus. Nature 544, 357–361. https://doi.org/10.1038/nature21674

Winsemann, J., Lang, J., Roskosch, J., Polom, U., Böhner, U., Brandes, C., Glotzbach, C., Frechen, M., 2015. Terrace styles and timing of terrace formation in the Weser and Leine valleys, northern Germany: Response of a fluvial system to climate change and glaciation. Quat. Sci. Rev. 123, 31–57. https://doi.org/10.1016/j.quascirev.2015.06.005

Wintle, A.G., 1997. Luminescence dating: laboratory procedures and protocols. Radiat. Meas. 27, 769–817. https://doi.org/10.1016/S1350-4487(97)00220-5

Wiśniewski, A., Adamiec, G., Badura, J., Bluszcz, A., Kowalska, A., Kufel-Diakowska, B., Mikolajczyk, A., Murczkiewicz, M., Musil, R., Przybylski, B., Skrzypek, G., Stefaniak, K., Zych, J., 2013. Occupation dynamics north of the Carpathians and Sudetes during the Weichselian (MIS5d-3): The Lower Silesia (SW Poland) case study. Quat. Int. 294, 20–40. https://doi.org/10.1016/j.quaint.2011.09.016

Wiśniewski, A., Lauer, T., Chłoń, M., Pyżewicz, K., Weiss, M., Badura, J., Kalicki, T., Zarzecka-Szubińska, K., 2019. Looking for provisioning places of shaped tools of the late Neanderthals: A study of a Micoquian open-air site, Pietraszyn 49a (southwestern Poland). Comptes Rendus Palevol 18, 367–389. https://doi.org/10.1016/j.crpv.2019.01.003

Wood, R., 2015. From revolution to convention: the past, present and future of radiocarbon dating. J. Archaeol. Sci. 56, 61–72. https://doi.org/10.1016/j.jas.2015.02.019

Yelovicheva, Y., Sanko, A., 1999. Palynostratigraphy of the Poozerie Glaciation (Vistulian) in Belarus. Geolocial Q. 43, 203–212.

Zagwijn, W., 1996. An analysis of Eemian climate in Western and Central Europe. Quat. Sci. Rev. 15, 451–469. https://doi.org/10.1016/0277-3791(96)00011-X

Zagwijn, W., 1989. Vegetation and climate during warmer intervals in the Late Pleistocene of western and central Europe. Quat. Int. 3–4, 57–67. https://doi.org/10.1016/1040-6182(89)90074-8

Zagwijn, W., 1983. Sea-level changes in The Netherlands during the Eemian. Geol. en Mijnb. 62, 437–450.

Zagwijn, W., 1961. Vegetation, climate and radiocarbon datings in the Late Pleistocene of the Netherlands. Part I: Eemian and Early Weichselian. Meded. Geol. Sticht. NS 14, 15–45.

Zagwijn, W., Paepe, R., 1968. Die Stratigraphie der weichselzeitlichen Ablagerungen der Niederlande und Belgiens. E&G – Quat. Sci. J. 19, 10–31.

Zimov, S.A., Zimov, N.S., Tikhonov, A.N., Chapin, F.S., 2012. Mammoth steppe: a high-productivity phenomenon. Quat. Sci. Rev. 57, 26–45. https://doi.org/10.1016/j.quascirev.2012.10.005