Neandertal adaptations to Interglacial conditions – a case study from the Eemian site Neumark-Nord 2 (Germany)

Pop, E.A.L.

Author: Pop, E.A.L.
Title: Neandertal adaptations to Interglacial conditions : a case study from the Eemian site Neumark-Nord 2 (Germany)
Issue Date: 2015-09-22

4. Fires at Neumark-Nord 2 (Germany)

An analysis of fire proxies from a Last Interglacial Middle Palaeolithic basin site.

Pop, E., Kuijper W., van Hees, E., Smith, G., Garcia-Moreno, A., Kindler, L., Gaudzinski-Windheuser, S., Roebroeks, W.

Submitted to Journal of Field Archaeology

4. Fires at Neumark-Nord 2 (Germany)

An analysis of fire proxies from a Last Interglacial Middle Palaeolithic basin site

Abstract

Few sites with evidence for fire use are known from the Last Interglacial. Hearth features are rarely preserved, probably as a result of post-depositional processes. The small postglacial basins that dominate the sedimentary context of the Eemian record are however high-resolution environmental archives often containing charcoal particles. This case study presents the macroscopic charcoal record of the Neumark-Nord 2 basin (Germany) and its correlation with the distinct find levels of the basin margin which also contain thermally altered archaeological material, showing increased charcoal quantities corresponding to phases of hominin presence. As both the identified charcoal and the thermally altered material require the burning of heavy fuels not naturally occurring within the local environment, the patterns fit best with recurrent anthropogenic fires within the watershed. This research shows the potential of small basin localities in the reconstruction of local fire histories, where clear archaeological features like hearths are missing.

Keywords

Fire use; Eemian; Last Interglacial; charcoal; heated flint; burned bone; sedimentary basins

4.1 Introduction

Recent years have seen a heated debate over the question when in the deep history of the human lineage hominins started to use fire on a regular basis for purposes such as cooking and thermoregulation. Some workers have suggested that already Homo erectus was a proficient fire user at 1,8 Ma (Carmody and Wrangham 2009; Wrangham 2009; Gowlett and Wrangham 2013), while reviews of the European evidence (Roebroeks and Villa 2011) and from the Levant (Shimelmitz et al. 2014) suggest that there was no habitual fire use there until much later, from approximately 350,000 years ago onward. Using and producing fire is not necessarily the same (Sorensen, Roebroeks, and van Gijn 2014), and Sandgathe and colleagues (2011) hypothesize that only modern humans at the very end of the Late Pleistocene were able to produce fire at will, rather than being dependent on natural fires. While much of this debate is about the chronology of fire use, there is also little information about the specific types of use of fire, both on- as well as off-site, i.e. within domestic "camp site" settings as well as in the surrounding landscape (Scherjon et al. 2015). Minimally from the late Middle Pleistocene onward some Neandertals used fire to synthesize birch bark pitch (Koller, Baumer, and Mania 2001; Mazza et al. 2006) while studies of microfossils from dental calculus have shown that some late Neandertals were cooking plant food (Henry, Brooks, and Piperno 2011). The database on European Middle and Late Pleistocene fire use compiled by Roebroeks and Villa (2011) is heavily dominated by rock shelter sites from cold- to cool stage settings, while the long sequences in the Levant discussed by Shimelmitz and colleagues (2014) are all from karstic settings. With the exception of a few early sites like Beeches Pit (Gowlett et al. 2005; Preece et al. 2006), precious little is known of warm-temperate interglacial fire use in open air sites, simply because such sites are rare.

The record of European Last Interglacial (Eemian) localities is strongly biased towards open-air sites, and more specifically freshwater localities, whether it concern rivers, lakes or small pools (Speleers 2000; Roebroeks and Speleers 2002; Gaudzinski 2004; Gaudzinski-Windheuser and Roebroeks 2011). In open-air contexts, evidence for fire use is often swiftly removed by natural processes (Sergant, Crombé, and

Perdaen 2006), in particular near freshwater localities. Especially lighter elements, such as ash and charcoal are easily subjected to transport. Heated (and as a result often fragmented) lithics and burned faunal remains can also be susceptible to natural transport in freshwater contexts when we consider the potential of fragmentation by large herbivore bioturbation in combination with the often sloping margins of these environments. While evidence for anthropogenic fire use may still be present at a site, its lack of spatial coherence makes it more difficult to distinguish from natural fires, as caused by lightning, volcanic eruptions or spontaneous combustion (Roebroeks and Villa 2011). While the margins of basin localities may not provide the ideal context for preserving in situ hearths or fire places because of relatively low sedimentation rates and erosion, as well as increased disturbance by water and animals, the deeper parts of these basins are usually characterized by relatively continuous sedimentation, which can result in thick deposits with comparatively less post-depositional disturbance (Pop et al. in press). These basin deposits provide rich environmental records instrumental for providing a biostratigraphic (pollen) record as well as environmental reconstructions of the local vegetation (e.g. Bakels 2012; Bakels 2014; Kuijper 2014; Pop and Bakels 2015). They also trap charcoal particles produced in the immediate vicinity of the basin and, depending on the size of the particles, the wider landscape (e.g. Scott 2010 and references therein). The time-depth of these basin records varies with basin size and shape, as well as with subsidence and compaction, but often covers large parts of the Eemian Interglacial (e.g. Neumark-Nord 1 and Gröbern: Litt 1990a; Litt 1990b; Seifert 1990, see figure 1). So instead of documenting (series of) individual fires or hearth features, the thick undisturbed deposits in these basins have the potential to document fire events in their catchment area over several thousands of years.

Unlike many Mesolithic basin localities (Bos, Bohncke, and Janssen 2006; Mighall et al. 2008; Innes, Blackford, and Simmons 2010), known Eemian freshwater localities have not been systematically sampled for charcoal. Evidence for fire, whether anthropogenic or natural, is often limited to diffuse scatters of charcoal at for example Neumark-Nord 1 (Mania et al. 1990; Brühl and Mania 2003), Grabschütz (Mania et al. 1990), Lehringen (Deibel-Rosenbrock 1960; Thieme, Veil, and Meyer 1985), and Burgtonna (Schüler 1999), and charred hazelnut fragments and charcoal patches at Rabutz (Toepfer 1958) (see figure 1). Also not systematically sampled, but nevertheless tantalizing, is the evidence for anthropogenic use of fire provided by the site of Taubach. Here, several layers yielding large amounts of charred material (or Brandschichten) were identified, containing fire-reddened pieces of travertine, charcoal and charred bones, which at the time of discovery were interpreted as hearths (Klopfleisch 1883; Götze 1892). The fact that this fieldwork took place in the early days of the discipline needs to be considered, but analysis of the faunal material has shown that part of the humanly modified bone assemblage indeed shows evidence of burning (Bratlund 1999). Similar layers of charred material have been found at the interglacial site Ehringsdorf (Behm-Blancke 1960), but the excavated lower travertines have been shown to date to the penultimate interglacial complex (OIS 7), rather than to the Eemian (Blackwell and Schwarcz 1986). In short, well-documented evidence for anthropogenic fire-use during the Eemian is very limited.

The Eemian Interglacial basin site Neumark-Nord 2 offers the opportunity to not only study the archaeological fire evidence from the excavated

Figure 1: Geographical position of Neumark-Nord 2 and other Eemian sites mentioned in the text (circles: sedimentary basin sites, stars: travertine sites) relative to the maximum ice extents of the Saalian and Weichselian glaciers. Modified after Speleers (2000).

margin of the basin, but also a more than 7000 years long environmental record from the basin itself, which contains, among others, macroscopic charcoal and charred seeds. However, "…to evaluate the fire history of ancient occupations we are limited by the amount and quality of the available data" (Alperson-Afil 2012: 111). This certainly applies to this case study, as reconstructing fire histories was never the primary objective of the Neumark-Nord 2 rescue excavations, which focused on the archaeology present at the margins of the small basin and its chronological and environmental setting. Hearth features, often focal point of fire studies, were not observed at the site. Thermally altered flint artefacts and faunal remains were mostly found in the sieving residue and therefore identified as such after the rescue excavation, during subsequent laboratory analysis. Furthermore, the sediment samples taken from the basin area were primarily aimed at palynological and malacological analysis, but ancillary counts of other macro-remains, including macroscopic charcoal and charred seeds, were eventually carried out as well (Kuijper 2014).

Despite the limitations set by excavation and sampling strategies and the complicated sedimentary history of the basin (Hesse and Kindler 2014; Pop et al. in press), the Neumark-Nord 2 record allows an in-depth assessment of the fire evidence from an Eemian Interglacial locality. This study addresses a very straightforward question: are the fire proxies the product of Neandertal use of fire or the result of natural (forest) fire(s) and/or of a combination of both processes? By looking at the quantity, vertical distribution, size and species representation of the charcoal and charred seeds from the basin area, as well as at the thermally altered lithics and faunal remains found during excavation of the basin margin, it may be possible to establish proximity, frequency and scale/type of the fires at stake. As the environmental data from the basin area can be unambiguously linked to the archaeological find levels at the basin margin, it is possible to also study the correlation between these datasets: are charcoal concentrations correlated to phases of hominin presence and absence as reflected in the archaeological record, including thermally altered lithics and faunal remains? Both the individual datasets (from the basin- and excavation area) and their relationship may provide evidence for either a natural or an anthropogenic origin of the fire proxies.

4.2 Neumark-Nord 2

Neumark-Nord 2 (NN2) is located ca. 170 km southwest of Berlin (Germany, figure 1). The site is situated in a former lignite quarry that was exploited until the early 1990's. This exploitation led to the discovery of two basin structures that formed due to the activity of a brown coal diapir. Neumark-Nord 1 (NN1) was investigated from the 1980's onwards (Mania et al. 1990). The NN2 site (figure 2), on which this study focuses, has been excavated between 2004 and 2008. The fine-grained silt loams of the NN2 basin infill contain several find levels (NN2/3, NN2/2, NN2/1) yielding ca. 23.000 lithics and 125.000 faunal remains. Within the basin area, Hauptprofil 7 (figures 2, 3) exposes the complete basin sequence, from which samples were taken for environmental reconstructions and dating purposes (Sier et al. 2011; Strahl et al. 2011; Bakels 2014).

Absolute dating methods show that the NN2 find levels date to the Last Interglacial, which matches stratigraphic and palaeomagnetic observations (Sier et al. 2011; Strahl et al. 2011). Pollen analysis shows that the basin infill documents the complete vegetational succession of the Eemian Interglacial (Sier et al. 2011; Strahl et al. 2011; Bakels 2014). The environment surrounding the basin was semi-open with the margins of the basin covered with species characteristic of grasslands and disturbed/trampled soils (Pop and Bakels 2015). Analysis of the lithic assemblage shows that on-site knapping was carried out (Pop 2014) on raw materials and with hammerstones both derived from local till deposits (Pop 2014; Langejans et al. forthcoming). The faunal assemblage, in which horse, aurochs and red- and fallow deer dominate, is heavily cut marked and fragmented, providing evidence for butchering taking place at the locale, while bone breakage patterns indicate marrow extraction (Kindler, Smith, and Wagner 2014).

4.3 Materials & methods

The fire proxies from the basin area consist of macroscopic charcoal and charred seeds obtained from Hauptprofil 7 (abbr.: HP7): a 11 m high profile within the basin area between the excavation and basin center (figures 2, 3). From unit 5 upwards, five liter samples were taken at a 5 cm interval (n=120) along the profile and subsequently sieved using increasingly fine mesh sizes of 5, 2, 1 and 0.5 mm. The macroscopic charcoal particles and charred seeds were separated from other residues and counted using a Wild M7a microscope with magnifications of 6-30x. Taxonomic determination of the charcoal fragments larger than 1 mm was done using a Leitz Ortholux II microscope using magnifications of 100-200x and a Wild M7a microscope. The species determination of the charred seeds was done using a Wild M7a microscope. One location within the excavation area near the basin margin (excavation square 216/298; figure 2) was also sampled (in 2 liter samples) and analyzed for macroscopic charcoal and charred seeds following the methods outlined above.

The fire proxies from the excavation area at the margin of the NN2 basin (figures 2, 3) consist of thermally altered lithics and mammalian faunal remains. Heated flint artefacts were retrieved from find levels NN2/2 and NN2/1 (figure 4). The heated flint artefacts were identified during lithic analysis following the excavation using (a combination of) several criteria: discoloration, the presence of cracking (craquelé), being a 'pot lid' or showing negatives of them (Sergant, Crombé, and Perdaen 2006). As for the faunal material, only the finds from find level NN2/3 and NN2/2 have been systematically analyzed for thermal modification thus far. They were identified on the basis of color and fracturing characteristics (e.g. Shipman, Foster, and Schoeninger 1984; Stiner et al. 1995).

The lithostratigraphic units at HP7, from which the charcoal samples were taken, could be followed

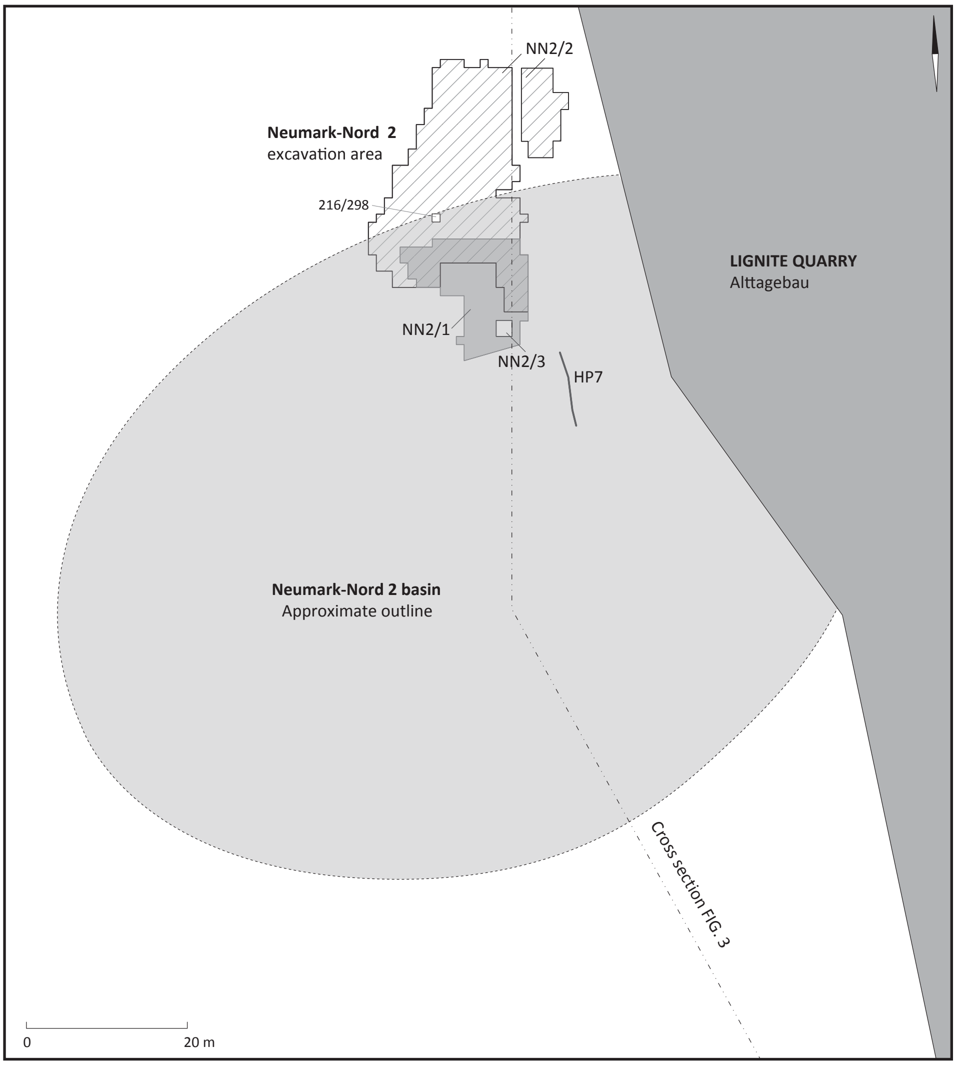

Figure 2: Position of the Neumark-Nord 2 excavation area and Hauptprofil 7 (HP7) in relation to the approximate outline of the former basin. The eastern part of the basin was missing before excavation due to mining activity (dark gray). The former Neumark-Nord 1 basin is situated ca. 200 m SE, further into the main lignite quarry area. The cross-section line refers to figure 3.

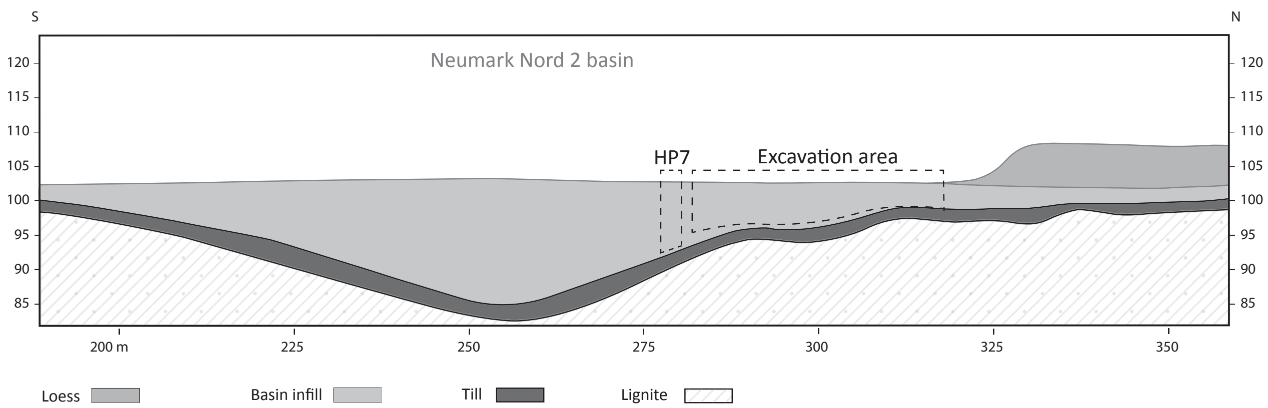

Figure 3: Schematic North-South cross-section of the NN2 basin and the position of Hauptprofil 7 (HP7) and the Neumark-Nord 2 excavation area (Modified from Sier et al., 2011).

upslope and correlated with the find levels and main find concentrations (Hesse and Kindler 2014; Pop et al. in press), which yielded the thermally altered archaeological material.

4.4 Results

4.4.1 Fire proxies from the excavation area

4.4.1.1 Lithics

The lowermost find level, NN2/3 (figure 4), has been excavated over 4 m² surface area only (figure 2) and yielded a small lithic assemblage of 63 pieces, none of which show signs of having been heated. Find levels NN2/2 and NN2/1, excavated over significantly larger areas (figure 2), yielded more substantial lithic assemblages and will be discussed in more detail.

The NN2/2 flint assemblage (n=14.539) contains 344 heated flints artefacts (2.3%). The characteristics of the heated flint elements range from "weakly-" (reddish shine, isolated cracks) to "moderately-" (pot-lid fractures, cracks and color changes) and "heavily" heated (white to grey discoloration) (Sergant, Crombé, and Perdaen 2006). Thermal modification is more frequently occurring among chunks (8%; see Supplementary Material 1) which are per definition difficult to orientate, angular (fragmented) pieces. This pattern is most likely caused by fragmentation as a result of heating. Of the flakes and chips, resp. 1.6 and 2.5% were affected. Cores and tools show characteristics indicative of heating as well, but in lower percentages (<1%).

The horizontal distribution of the heated flint artefacts from NN2/2 shows a strong concentration in the center of the excavation area (figure 5B), following

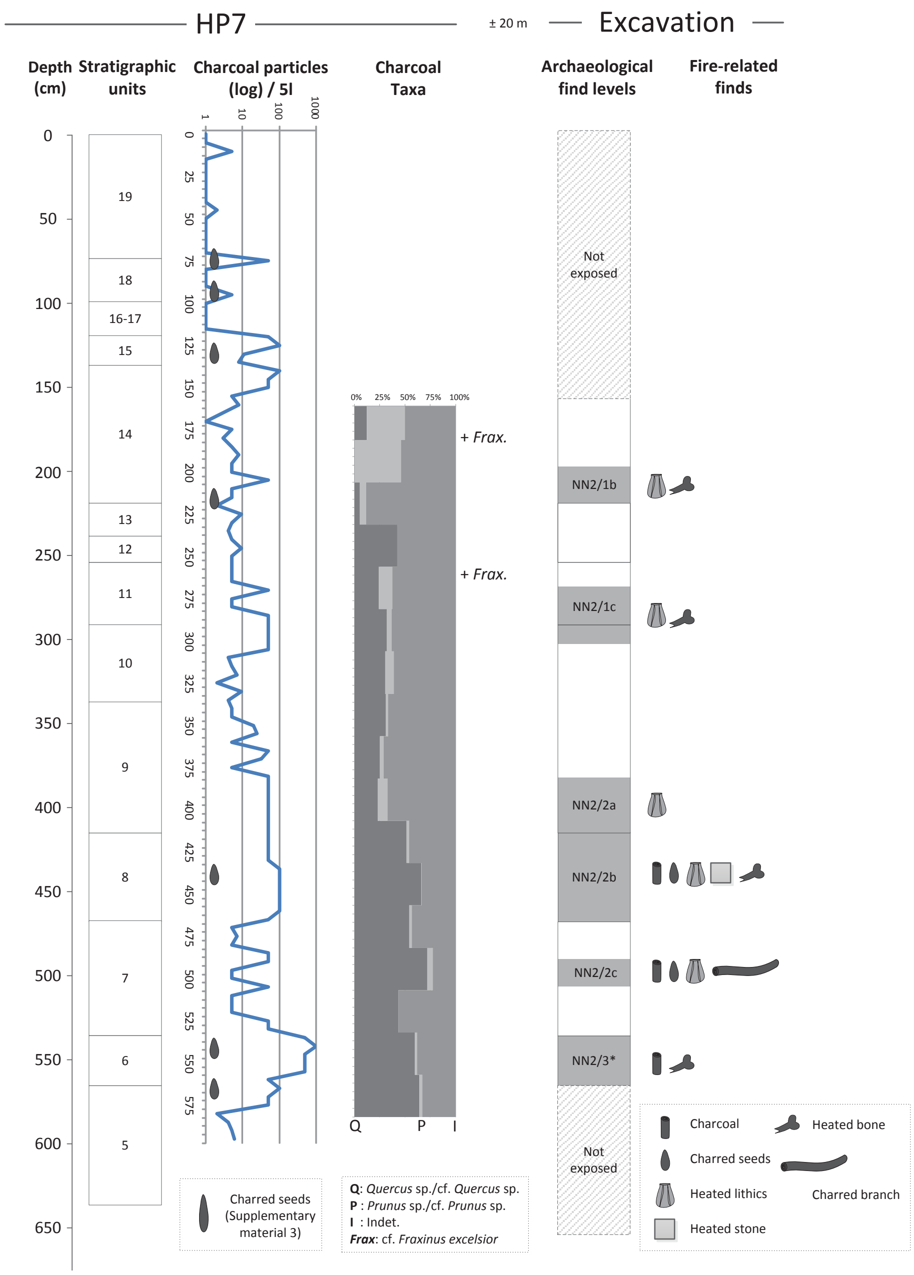

Figure 4: Hauptprofil 7 with the concentration of charcoal (particles/5l) log scale; the position of charred seeds (see table 6); the identified charcoal taxa and the position of the find levels with main find concentrations (gray) at the basin margin relative to HP7, including heated lithics, burned faunal remains and other fire-related finds.

the overall distribution of flint artefacts across the site (figure 5A). The vertical distribution of the heated flint artefacts within the NN2/2b subunits is presented in table 1. Due to decreasing sedimentation, the stratigraphy of these subunits shows a decreasing complexity from south to north, resulting in different subunit-sets depending on the location within the site (Hesse and Kindler 2014; Pop et al. in press). The northern area contains 2.6% heated artefacts, but subunits could not be distinguished. The northeastern area shows percentages of 2.2% (“BO”), 3.6% (“BU”) and 1.9% (“B”; a conflation of layers “BO” and “BU”). On average the percentage of heated flints from this sector (2.7%) is comparable to the north sector. In the middle sector, percentages fluctuate between 1% (“B1”) to 3.4% (B2). Taken together the percentage of heated artefacts is comparable to the north and northeast sector with 2.5%. There seems to be a decline in heated artefacts when moving to the southern sector with an average of 1.6% heated artefacts. In this sector the percentage of heated flints from the individual subunits ranges from 2.9% (layer B1/B2) to no heated flint artefacts (“B1”; “B3u”).

Find level NN2/1 yielded 8 heated lithics from a total assemblage of 2404 pieces (0.3%). The lithics can be subdivided in assemblages from layer NN2/1c (n=1931) and NN2/1b (n=473) of which resp. 7 (0.4%) and 1 (0.2%) are heated. The characteristics of the identified heated pieces fall in the “weakly” to “moderately heated” categories (cf. Sergant, Crombé, and Perdaen 2006). The typology of the pieces is limited to debitage elements (flakes and chunks). The distribution of the heated flint artefacts overlaps with the general higher concentration of artefacts of NN2/1, situated in the southern part of the excavated area.

4.4.1.2 Faunal remains

Both NN2/3 and NN2/2 have been investigated for the thermal alteration of faunal remains. The faunal remains of NN2/1 have not been analyzed systematically, but did yield thermally altered elements (Kindler pers. comm.).

NN2/3 contains 6 thermally altered faunal elements, which is 3.1% of the total faunal assemblage (n=191).

Of a sample of 16351 faunal remains from the NN2/2 assemblage 298 are thermally altered (1.8%). The black or clear white discolorations are indicative of burning. Due to heat-induced changes it was not possible to determine the taxa of most burned faunal remains.

The distribution of the burned faunal remains (figure 5D) differs from the distribution of the heated lithics and unburnt faunal remains (figures 5B, 5C). This may be explained by the higher overall frequency of small faunal remains/fragments in this area, which may be the product of in situ fragmentation. Like the heated lithics, burned faunal remains can be found in all subunits of the NN2/2 find level (table 2). Percentages range from 0.1% in “B3u/B3b” to 1.8% in “B2” in the mid and northeast sectors of the excavation area. Following the horizontal distribution presented

Sector	Layer	N	Heated	%
North	B	1591	41	2.58
Mid	B1	597	6	1.01
	B1/B2	691	10	1.45
	B2	2253	77	3.42
	B3	2891	69	2.39
	B3B	330	7	2.12
	B3U	247	7	2.83
	Total	7009	176	2.51
South	B1	123	0	0.00
	B1/B2	241	7	2.90
	B2a	350	5	1.43
	B2a/B3o	147	3	2.04
	B3o	1734	25	1.44
	B3m	633	11	1.74
	B3u	31	0	0.00
	Total	3259	51	1.56

Layer	N	Heated	%	Sector
B	478	9	1.88	Northeast
BO	1113	24	2.16	
BU	1089	39	3.58	
Total	2680	72	2.69	

Table 1: Absolute and relative quantities of heated flint artefacts per layer of the NN2/2b find level.

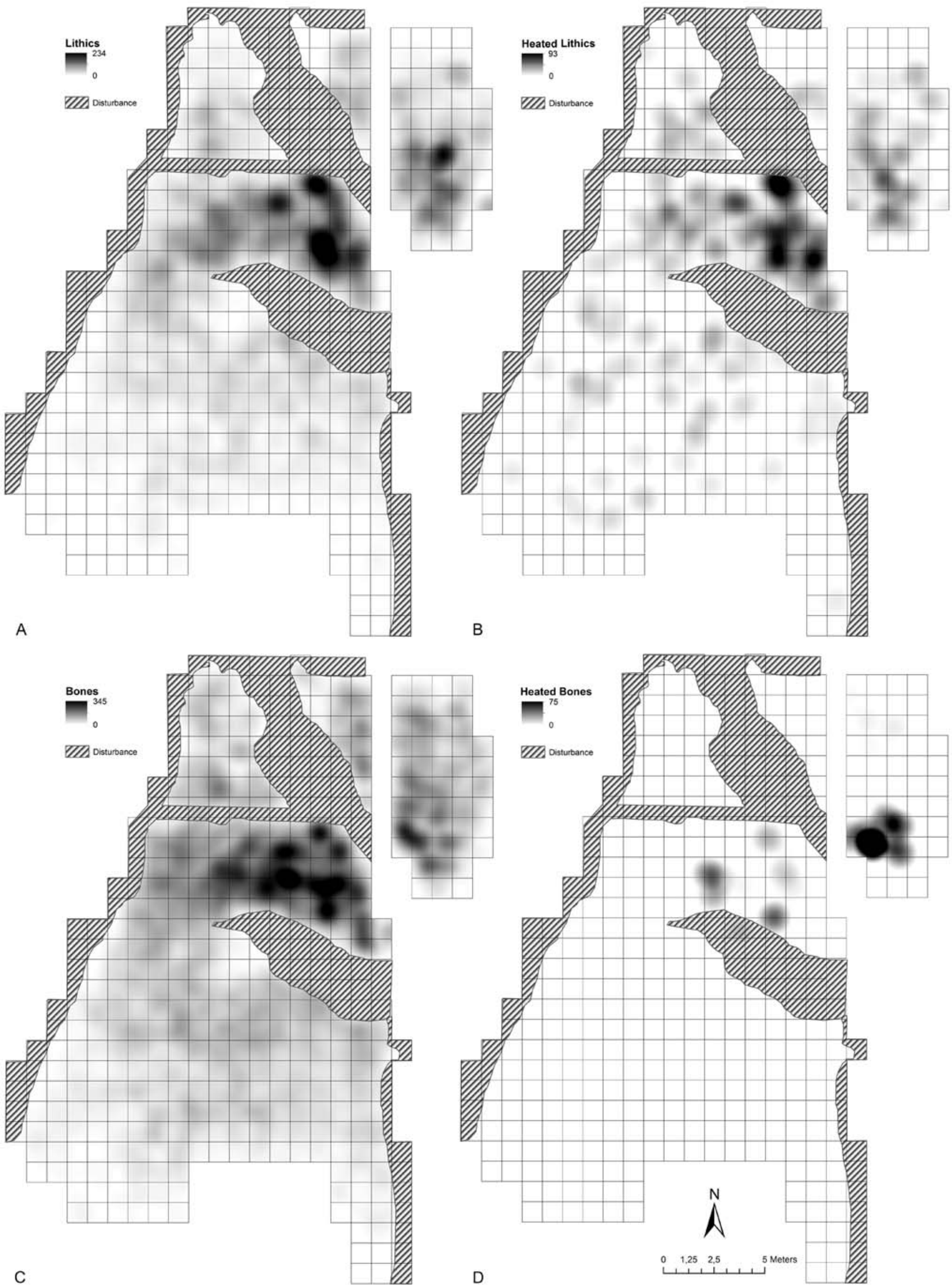

Figure 5: Kernel density maps of NN2/2b showing: A) all the lithics; B) the heated lithics; C) all faunal remains; D) the heated faunal remains.

Table 2: Absolute and relative quantities of burned faunal remains per subunit of the NN2/2b find level. *: including layer B3b

	Layer	N	Heated	%
Mid	B1	590	5	0.85
	B2	3371	62	1.84
	B3	5337	50	0.94
	B3U*	1820	1	0.05
	Total	11118	118	1.06

Layer	N	Heated	%	
B	1281	7	0.55	Northeast
BO	509	21	4.13	
BU	3443	152	4.41	
Total	5233	180	3.44	

earlier, the percentages per sub unit in the NE sector are significantly higher with 4.4% ("Bu") and 4.1% ("Bo").

4.4.1.3 Macroscopic charcoal

Macroscopic charcoal was encountered in the excavation area within find levels NN2/3, NN2/2, and NN2/1 (Laurat and Brühl 2009, Kindler pers. comm.) but only systematically recorded and collected at square 216/298 of find level NN2/2 (figure 2). The sampled subunits of unit 7 and 8 show fairly constant charcoal concentrations, with the exception of subunit "C" (table 3). Four dispersed, larger charcoal and charred wood elements were recorded at NN2/2 (Supplementary Material 2), the largest one around 140 cm in length (figure 6). The outside of this branch of oak (Quercus sp.) is charred, while this is not the case for the inner part of the piece. The fact that such a large piece of wood has been preserved, may have been facilitated by the charring on the outside, protecting the inner, uncharred, part (Braadbaart and Poole 2008). The other (non-systematically) recorded occurrences of charcoal concern several 1 to 5 mm large fragments (n=11) retrieved from the 4 m^2 excavation of find level NN2/3, which can all be identified as Quercus sp.

4.4.1.4 Charred seeds

Six charred seeds have been found at sampling location 216/298 (Supplementary Material 3) only two could be identified: Vicia sp. (subunit 'C') and Corylus avellana (subunit 'B1').

4.4.2 Fire proxies from the basin area

4.4.2.1 Macroscopic charcoal

The lower size limit of the macroscopic charcoal retrieved from HP7 is determined by the smallest mesh size used during sieving: 0.5 mm (500 µm), while the maximum size of recovered particles lies around 5 mm. Most particles lie within the 1-2 mm size range. The charcoal fragments do not show edge rounding.

The vertical distribution of the macroscopic charcoal of HP7 is shown in figure 4. After a start with low charcoal concentrations (<10/5l), lithostratigraphic unit 6 shows the largest peak of the sequence, with densities of 1000 particles/5l. In unit 7 the number of charcoal particles is significantly lower, but fluctuating between samples with less than 10 and peaks of ca. 50 particles per 5 liter. Unit 8 starts with increased and stable counts of around 100/5l and a slight decrease in its upper third. This continues in the lower part of unit 9, while in the upper part concentrations decrease to less than 10/5l. In unit 10 values increase to 50/5l in the upper part, which is maintained in lower unit 11 after which values decrease to less than 10/5l. Concentrations are the same in unit 12 and 13 and most of unit 14, with the exception of one peak in the lower part of unit 14 and higher concentrations in the upmost part of the same unit. After this concentrations are (close to) zero, with the exception of one peak at the top of unit 18.

Charcoal particles larger than 1 mm were submitted

Layer	Unit	Sample size (l)	Charcoal particles	Charcoal particles / liter	Charred seeds
NN2/2 - B1	8	2	100	50	3
NN2/2 - B3 upper	8	2	100	50	0
NN2/2 - B3 middle	8	2	100	50	0
NN2/2 - B3 lower	8	2	100	50	0
NN2/2 - C	7	5	100	20	3

Table 3: Charcoal & charred seeds concentration per layer of the NN2/2 find level at square 216/298.

Figure 6: 140 cm long charred oak branch (Quercus sp.) found in find level NN2/2c.

to taxonomic analysis. All of the analyzed charcoal particles originate from deciduous trees. About half (51.9%) of the charcoal particles could not be identified further. The other half of the charcoal particles is dominated by *Quercus* sp. and cf. *Quercus* sp. (42.4%; figure 7). *Prunus* sp. and cf. *Prunus* sp. represent 5.6%. The remaining 0.2% is cf. *Fraxinus excelsior*. The large "indet." category of deciduous charcoal may contain a significant, but unquantifiable, amount of *Corylus*, as it is the dominant taxon in the pollen record and very difficult to identify microscopically as characteristic features (scalariform openings) are often lost when charred (van Rijn 1999). The representation of *Quercus* sp., *Prunus* sp., and indet. along the sequence is shown in figure 4. Overall a decrease of *Quercus* sp. charcoal is visible along the studied part of the profile, and an concomitant increase of charcoal of *Prunus* sp. and other deciduous (indet.) trees.

4.4.2.2 Charred seeds

Charred seeds of various species were found at HP7. Like the charcoal, the highest concentration of charred seeds can be found in unit 6, representing 80% of the total assemblage (figure 4, details in Supplementary Material 3). The rest of the charred seeds are incidental occurrences with only slightly increased counts in units 5 and 15. The charred seeds of unit 6 and the assemblage in general are dominated by charred seeds of Poaceae (true grasses). Other frequently occurring species in the lower part of the profile are *Carex* sp., Fabaceae sp. and *Medicago* sp (see Supplementary Material 3). Also notable is the presence of a charred acorn fragment of *Quercus* sp. and a charred pit of *Prunus spinosa* (Kuijper 2014). The seeds from the upper part of the profile are mostly from *Asperula* sp./ *Galium* sp.

4.5. Discussion

4.5.1 Thermally altered flint artefacts and faunal remains

Within the sequence thermally altered flint and faunal remains occur in low quantities (resp. 2.3 and 1.8% of the totals), but show a recurring presence: they occur in find levels NN2/3 (thermally altered faunal remains only), NN2/2 and NN2/1 (figure 4) and within the subunits of find levels NN2/2 and NN2/1 (tables 1, 2). The absence of heated flint artefacts in NN2/3 is probably the result of the small assemblage size, given the low percentages observed in other find levels. The spatial distribution of the often small-sized, thermally altered flint and faunal remains in find level NN2/2b

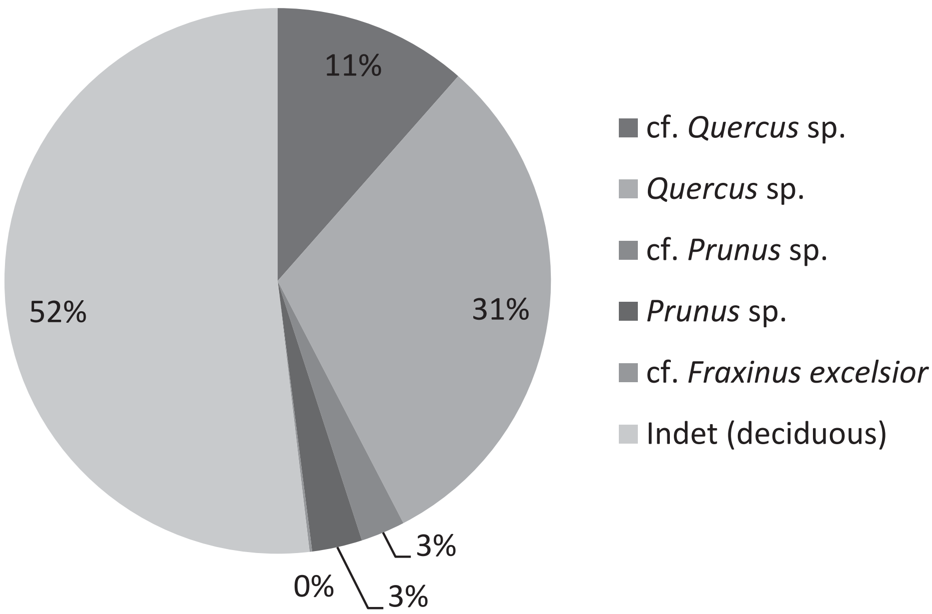

Figure 7: Identified charcoal taxa (n=1984) recovered from Hauptprofil 7 (HP7)

largely follows the distribution of the unheated and unburned material (figure 5), which includes larger faunal remains, flint artefacts and manuports up to 1 kg in weight, therefore showing no evidence for any form of downslope size sorting (see Pop et al. 2015). Furthermore, in this and other find levels, sedimentary features indicative of high energy transport are lacking (Hesse and Kindler 2014; Mücher 2014; Pop et al. in press). This indicates that the thermally altered lithics and faunal remains found at the basin margin are, like the rest of the archaeological assemblage, of local origin, i.e. they have not been subjected to significant reworking.

Macroscopically observable alterations on lithic artefacts, as documented for the Neumark-Nord 2 assemblage, are indicative of heating temperatures of at least 300-350°C (Sergant, Crombé, and Perdaen 2006; Richter 2007; Richter, Alperson-Afil, and Goren-Inbar 2011), which is confirmed for a selection of pieces by passing the TL heating plateau test (Richter and Krbetschek 2014). Thermal fracture, as observed on many of the studied pieces, has been shown to take place when the material is exposed to temperatures in excess of 400 °C (Purdy and Brooks 1971; Domanski, Webb, and Boland 1994; Domanski and Webb 1992; Buenger 2003). Although clear-cut correlations between specific characteristics of heating and precise temperatures do not exist (Richter, Alperson-Afil, and Goren-Inbar 2011), the observed heavily altered flint artefacts (being calcined and strongly fragmented) must have been exposed to significantly higher temperatures than the minimum temperatures indicated above (i.e. > 300-400°C). The heat induced alterations observed on the faunal remains of Neumark-Nord 2 include black and white discoloration with minor greyish or bluish parts (stages 4/5), which are roughly indicative of temperatures above 600°C (cf. Shipman, Foster, and Schoeninger 1984). Further evidence for relatively high heating temperatures affecting the archaeological material is provided by several large-sized rocks showing discoloration and surfaces covered with cracks (Langejans et al. forthcoming). A pilot study on one large specimen using a TL heating plateau test confirms that it has been thermally altered (Reidsma, Pop, and Reimann 2014).

When considering the potential effects of wildfires on archaeological material, the local availability of vegetation/fuel is an important factor. Pollen analysis shows that the margins of the Neumark-Nord 2 basin were at the time vegetated with species characteristic of grasslands and disturbed/trampled soils (e.g. *Polygonum aviculare*), the latter most likely caused by large herbivores (Bakels 2014; Pop and Bakels 2015). This reconstruction is supported by the molluscan data reflecting strictly local conditions: a dominance of mollusks characteristic of open environments and an almost complete absence (<0.5%) of forest species (Kuijper 2014; Pop and Bakels 2015). Furthermore, there is no soil evidence for tree stands on the basin margin. The absence of trees excludes the possibility for crown fires and limits the local availability of heavy fuels (Deal et al. 2012). Grasslands fires and fires in riparian zones that could potentially affect the basin margin are characterized by light fuels and therefore low surface temperatures and rapid burning/low residence times (Stinson and Wright 1969; Bailey and Anderson 1980; Trollope 1984; Bellomo 1990; Bellomo 1993; Whelan 1995; Clements 2010; Deal et al. 2012). As a result, these types of fires do not produce the thermal alterations as observed on the lithic artefacts and faunal remains (Shipman, Foster, and Schoeninger 1984; Seabloom, Sayler, and Ahler 1991; Buenger 2003; Preece et al. 2006; Deal et al. 2012).

Another factor to consider is burial depth of the material during heating (Bellomo 1993; Bellomo 1994; Campbell et al. 1995; Ryan 2002; Deal et al. 2012). In the case of the lithic artefacts, affected material must have been lying on or just below the surface, as a sediment cover of 2-3 cm can already shield flint material from reaching critical temperatures, under fires for at least 90 minutes (Campbell et al. 1995). In the case of grassland fires, even surface temperatures are usually insufficient to thermally alter archaeological material, while 0.5 cm burial depth further reduces temperatures from 200-300 degrees to less than 100 degrees (Ryan 2002). The likelihood of Neumark-Nord 2 artefacts being buried under shallow deposits is high under conditions of low-energy overland flow and bioturbation (e.g. trampling) (Pop and Bakels 2015; Pop et al. in press). Furthermore, during high water levels and –tables these deposits would have been characterized by a relatively high moisture content, further inhibiting penetration of heat (Campbell et al. 1995; Buenger 2003).

The recurring presence of locally affected archaeological material can be interpreted as multiple, temporally distinct, fire events taking place within the watershed. The observed thermal alterations do not normally occur with fires in environments only providing light fuels (e.g. a grassland fire), especially considering the expected soil moisture content and likelihood of artefacts being (shallowly) buried. While it cannot be excluded that such fuels were coincidentally occurring at the margins of the basin and were lit by natural grassland fires, it seems more likely that the heavy fuels were brought to the site and were subsequently burned in controlled fires, thereby affecting the archaeological material already present at or just below the surface.

4.5.2 Macroscopic charcoal and charred seeds

The charcoal from the basin area documented at NN2 concerns macroscopic charcoal particles between 0.5 mm and 5 mm in size. As the calcareous silt loams of the NN2 basin infill were deposited by overland flow and animal activity took place at the margin of the basin (Sier et al. 2011; Pop and Bakels 2015; Pop et al. in press), we can expect that both caused fragmentation of the charcoal through mechanical- (transport, bioturbation, sediment pressure; Scott and Damblon 2010) and chemical weathering (soil alkalinity; (Braadbaart, Poole, and van Brussel 2009). Rounding has not been observed on the charcoal particles, which can be a consequence of limited transport and/ or in-situ fragmentation, especially when charcoal has been produced by high temperatures (Scott 2010 and references therein).

Many studies have demonstrated that microscopic charcoal (< ca. 200 µm) is easily transported by air and may therefore represent regional fire events, while large (macroscopic) charcoal (> ca. 200 µm) is mostly of local origin (i.e. originating from within a watershed) (Clark 1988; Clark 1990; MacDonald et al. 1991; Clark and Royall 1995; Whitlock and Millspaugh 1996; Clark and Patterson 1997; Tinner et al. 1999; Carcaillet et al. 2001; Gardner and Whitlock 2001; Higuera, Sprugel, and Brubaker 2005), in particular larger sized (>500-1000 µm) particles (Ohlson and Tryterud 2000; Lynch, Clark, and Stocks 2004), as predominantly recovered from Neumark-Nord 2. However, more recent work studying charcoal transport over larger distances, shows that macroscopic charcoal may be transported over several km's (Tinner et al. 2006; Peters and Higuera 2007). We can therefore not a priori exclude the possibility that part of the macroscopic charcoal, in particular from the smaller size classes, was transported from beyond the watershed into the basin by thermal updrafts associated with large-scale forest fires (Clark 1988; Clark 1990). However, where they occur within the sequence, charred seeds and larger charcoal fragments (figure 4) provide evidence for the local nature of fire events, increasing the likelihood of the macroscopic charcoal originating from a fire within the watershed as well.

Macroscopic charcoal concentrations within the HP7 stratigraphy (figure 4) vary strongly between very low- (<10 part./5l), low- to moderate- (50-100 part./5l) and high concentrations (1000 part./5l). Especially the difference between the concentrations in unit 6 and the rest of the sequence are noteworthy. Although sedimentation rates varied during the deposition of the basin infill (Sier et al. 2011; Pop et al. in press), they cannot fully explain the large differences in charcoal concentrations. Nor is there evidence or variability in the preservation of charcoal within the sequence. The variability in charcoal concentrations could therefore indicate differences in the scale or frequencies of local fires or contribution of resp. local and extra-local sources.

Analysis of the macroscopic charcoal larger than 1 mm in size shows that all of the recovered charcoal originates from deciduous trees and therefore represents heavy fuels. These species are all represented in published pollen spectra of the site (Sier et al. 2011; Strahl et al. 2011; Bakels 2014). The marked decrease of *Quercus* sp. at the cost of other deciduous species is reflected in the pollen record of NN2 (Sier et al. 2011; Bakels 2014) and the Eemian vegetation development at other sites (e.g. Turner 2002). Notable is however the high percentage (> 50%) of *Quercus* sp. charcoal in units 7 and 8 (PAZ IVa), when compared to its representation in the pollen spectra (10-20%). This apparent overrepresentation in the charcoal record in comparison with the pollen record may be a consequence of differential pollen production between taxa, differential preservation of either pollen or charcoal between taxa, preferential use of *Quercus* sp. by hominins as a fuel, or a combination of these factors.

To recapitulate: the macroscopic charcoal recovered from the Neumark-Nord 2 basin originates from heavy fuels, in this case deciduous tree species, of which oak is the best represented. The macroscopic charcoal has most likely been produced within the watershed, as the fragmented particles co-occur with charred seeds and a charred branch, although (limited) input from extralocal sources cannot be excluded.

4.5.3 Correlation between thermally altered archaeological finds and charcoal

Using documented exposures in between, the lithostratigraphic units at HP7 could be directly followed upslope to the find levels exposed at the excavation area (Hesse and Kindler 2014; Pop et al. in press). This made it possible to correlate the charcoal record with distinct phases of hominin presence and absence at the basin margin, as well as the associated thermally altered lithic artefacts and faunal remains (figure 4). Striking is the fact that where the two datasets can be compared (therefore excluding unit 15-19), find levels correlate with increased charcoal deposition in the basin. Inversely, phases of inferred hominin absence correspond to low charcoal concentrations in the basin.

Phases of increased presence of (heavy-fuel derived) charcoal particles in HP7 also correlate with the thermally altered lithics and faunal remains within the find levels, which provides unambiguous evidence for the local, recurrent presence of fire at Neumark-Nord 2. These patterns are strongly suggestive of a direct correlation between hominin activity and fire activity within the basin environment, a pattern best explained as resulting from recurrent use of fire by Neandertals, whose presence in these find levels is further attested by large assemblages of lithic artefacts and cut-marked and heavily fragmented remains of dozens of large mammals. The moderate charcoal peaks, most likely produced by anthropogenic fires, are present against a low, but continuous background signal which may represent charcoal input from extra-local sources or, more probable, slightly reworked charcoal from previous fire events or the input from other phases of occupation at the basin other than the ones documented in the excavated area.

Although the charcoal peak of unit 6 correlates with archaeological find level NN2/3, the character of this peak, indicative of substantially larger charcoal concentrations compared to the rest of the sequence, suggests an increase in frequency or scale of fire activity within the basin environment. This may indicate (a) natural fire(s) burning heavy fuels within the watershed, a high frequency or large-scale anthropogenic fires or a combination of both natural and anthropogenic fires. Roebroeks and Bakels (2015) speculated that the patterns may reflect intentional burning of the landscape, as it co-occurs with a strong increase in non-arboreal pollen, i.e. an opening-up of the landscape, providing space for oak and hazel and their edible hazelnuts and acorns. Unfortunately, little evidence is available from the basin margin, as the small-sized excavations of the find level correlating to unit 6, NN2/3, yielded a small lithic and faunal assemblage of which only a few faunal remains show signs of thermal alteration. The fact that none of the lithic artefacts have been visibly affected by the fire, may be due to the fact that the find sample was too small or that most of the fire activity predated the deposition of the archaeological finds

4.5.4 The absence of hearth features

If the fire evidence from NN2 has an anthropogenic origin, why were fire-place related features not observed during the excavations of the basin margin? Hominin occupation of the basin margin seems to have coincided with phases of increased water presence within the basin (Pop and Bakels 2015; Pop et al. in press). This correlation may have introduced several disturbing factors which possibly influenced the preservation of hearth features. During these phases water input took place by overland flow, most likely facilitated by a saturated subsoil (Mücher 2014; Pop et al. in press). Overland flow is able to transport especially lighter elements like charcoal, ash and heated sediments (e.g. Scott 2010), i.e. the remains of most hearth features. Furthermore, large ungulates visited the basin margin, as indicated by animal footprints and indirectly by the presence of Polygonum aviculare (Laurat, Jurkenas, and Brühl 2007; Bakels 2014), especially when the basin provided a sufficient water supply (Pop and Bakels 2015). The activities of these mammals caused a decreased vegetation cover, increasing the effect of overland flow, while their treading also reworked sediments and promoted downslope dispersal. Trampling also fragmented heated lithics, burned bone and charcoal, making them more vulnerable to transport. In the case of charcoal, fragmentation through soil alkalinity may have played a similar role (Braadbaart, Poole, and van Brussel 2009). The combined effect of trampling and overland flow might have been instrumental in obscuring or obliterating evidence for fire use, especially when it consisted of unstructured, single-phase fire places.

4.6. Conclusion

The Neumark-Nord 2 (NN2) record allowed a detailed study of the fire evidence from a basin locality dating to the warm-temperate Eemian Interglacial; a period with very different environmental conditions than the preceding glacial periods, but with very limited evidence for hominin fire use thus far. The recurring presence of thermally altered archaeological material indicates that multiple, temporally distinct, fire events took place within the watershed. The heavy fuels required to obtain the observed thermal alterations were not naturally occurring in the immediate environment and may therefore indicate anthropogenic involvement. The macroscopic charcoal recovered from the basin area does originate from heavy fuels and most likely from fires taking place within the watershed. The common origin of thermally altered material from the margin and macroscopic charcoal from the basin area is supported by the correlations between these two datasets. The interrelationship between fire proxies on the one hand and phases of hominin presence in the other is best explained by recurrent use of fire by hominins active at the basin margin, in addition to flint knapping and the extensive processing of dozens of large herbivores. The reasons for a lack of discernable hearth features in a basin context like Neumark-Nord 2, which may have been relatively ephemeral to begin with, includes overland flow, which readily transports fine grained sediments and lighter fire residues alike, while animal trampling may disturb features and cause further fragmentation of fire proxies.

Although hearth features were absent in the open-air setting of Neumark-Nord 2, the relatively straightforward datasets used in this research provide patterns that are highly suggestive of recurrent hominin use of fire at the margins of the Neumark-Nord 2 basin. Nevertheless, the presented arguments could be strengthened with a better control of heating temperature estimates, for example by employing micromorphological and XRD analysis of the faunal remains with macroscopic signs of thermal alteration. More detailed information on the source area of the charcoal from the basin area can be acquired by comparing the macroscopic charcoal record and the microscopic charcoal record as obtainable from the existing pollen slides. Lastly, TL analysis of the fire cracked rocks from Neumark-Nord 2 as well as experimental research on similar rock types may provide further indications of heating temperatures and, equally important, elucidate on the potential use of fire at the locality. Both the data presented here, as well as the possibilities for further research illustrate the potential for reconstructing hominin fire use in an open-air, water-laid setting like Neumark-Nord 2.

Acknowledgements

We would like to thank Alexander Verpoorte for reading and commenting on the manuscript. Further thanks go out to our other colleagues within the Neumark-Nord 2 project, as well as to two anonymous JFA reviewers for providing constructive feedback.

References

Alperson-Afil, Nira. 2012. "Archaeology of Fire: Methodological Aspects of Reconstructing Fire History of Prehistoric Archaeological Sites." Earth-Science Reviews 113 (3-4): 111–19. doi:10.1016/j.earscirev.2012.03.012.

Bailey, Arthur W., and Murray L. Anderson. 1980. "Fire Temperatures in Grass, Shrub and Aspen Forest Communities of Central Alberta." Journal of Range Management Archives 33 (1): 37–40.

Bakels, C. 2012. "Non-Pollen Palynomorphs from the Eemian Pool Neumark-Nord 2: Determining Water Quality and the Source of High Pollen-Percentages of Herbaceous Taxa." Review of Palaeobotany and Palynology 186: 58–61.

Bakels, C. 2014. "A Reconstruction of the Vegetation in and around the Neumark-Nord 2 Basin, Based on a Pollen Diagram from the Key Section HP7 Supplemented by Section HP10." In Multidisciplinary Studies of the Middle Palaeolithic Record from Neumark-Nord (Germany). Volume I, edited by S. Gaudzinski-Windheuser, W. Roebroeks, and H. Meller, 97–108. Veröffentlichungen Des Landesamtes Für Denkmalpflege Und Archäologie Sachsen-Anhalt 69. Halle: Landesmuseum für Vorgeschichte.

Behm-Blancke, G. 1960. Altsteinzeitliche Rastplätze Im Traver Tingebiet von Taubach, Weimar, Ehringsdorf. Hermann Böhlaus Nachfoger.

Bellomo, R.V. 1990. Methods for Documenting Unequivocal Evidence of Humanly Controlled Fire at Early Pleistocene Archaelogical Sites in East Africa: The Role of Actualistic Studies.

———. 1993. "A Methodological Approach for Identifying Archaeological Evidence of Fire Resulting from Human Activities." Journal of Archaeological Science 20 (5): 525–53.

———. 1994. "Methods of Determining Early Hominid Behavioral Activities Associated with the Controlled Use of Fire at FxJj 20 Main, Koobi Fora, Kenva." Journal of Human Evolution 27 (1–3): 173–95. doi:10.1006/jhev.1994.1041.

Blackwell, B., and H. P. Schwarcz. 1986. "U-Series Analyses of the Lower Travertine at Ehringsdorf, DDR." Quaternary Research 25 (2): 215–22. doi:10.1016/0033-5894(86)90058-X.

Bos, J.A.A., S.J.P. Bohncke, and C.R. Janssen. 2006. "Lake-Level Fluctuations and Small-Scale Vegetation Patterns During the Late Glacial in The Netherlands." Journal of Paleolimnology 35 (2): 211–38. doi:10.1007/s10933-005-8517-0.

Braadbaart, F., and I. Poole. 2008. "Morphological, Chemical and Physical Changes during Charcoalification of Wood and Its Relevance to Archaeological Contexts." Journal of Archaeological Science 35 (9): 2434–45. doi:10.1016/j.jas.2008.03.016.

Braadbaart, F., I. Poole, and A.A. van Brussel. 2009. "Preservation Potential of Charcoal in Alkaline Environments: An Experimental Approach and Implications for the Archaeological Record."

Journal of Archaeological Science 36 (8): 1672–79. doi:10.1016/j.jas.2009.03.006.

Bratlund, B. 1999. "Taubach Revisited." Jahrbuch Des Römisch-Germanischen Zentralmuseums Mainz 46 (2000): 61–174.

Brühl, E., and D. Mania. 2003. "Neumark-Nord: A Late Middle Pleistocene Lake Shore with Synchronous Sites of Different Functional Character." Abstract Données Récentes Sur Les Modalités de Peuplement En Europe Au Paléolithique Inférieur et Moyen Rennes, Université de Rennes 1: 22–25.

Buenger, Brent A. 2003. "The Impact of Wildland and Prescribed Fire on Archaeological Resources." University of Kansas. http://firearchaeology.com/firearchaeology/Direct_Effects_files/Dissertation%20Buenger.pdf.

Campbell, G. S., J. D. Jungbauer Jr, K.L. Bristow, and R. D. Hungerford. 1995. "Soil Temperature and Water Content beneath a Surface Fire." Soil Science 159 (6): 363–74.

Carcaillet, C., M. Bouvier, B. Fréchette, A.C. Larouche, and P.J.H. Richard. 2001. "Comparison of Pollen-Slide and Sieving Methods in Lacustrine Charcoal Analyses for Local and Regional Fire History." The Holocene 11 (4): 467–76. doi:10.1191/095968301678302904.

Carmody, R.N., and R.W. Wrangham. 2009. "The Energetic Significance of Cooking." Journal of Human Evolution 57 (4): 379–91. doi:10.1016/j.jhevol.2009.02.011.

Clark, J.S. 1988. "Particle Motion and the Theory of Charcoal Analysis: Source Area, Transport, Deposition, and Sampling." Quaternary Research 30 (1): 67–80. doi:10.1016/0033-5894(88)90088-9.

———. 1990. "Fire and Climate Change during the Last 750 Yr in Northwestern Minnesota." Ecological Monographs 60 (2): 135–59.

Clark, J.S., and W. A. Patterson. 1997. "Background and Local Charcoal in Sediments: Scales of Fire Evidence in the Paleorecord." In Sediment Records of Biomass Burning and Global Change, edited by James S. Clark, Hélène Cachier, Johann G. Goldammer, and Brian Stocks, 23–48. NATO ASI Series 51. Springer Berlin Heidelberg. http://link.springer.com/chapter/10.1007/978-3-642-59171-6_3.

Clark, J.S., and P.D. Royall. 1995. "Particle-Size Evidence for Source Areas of Charcoal Accumulation in Late Holocene Sediments of Eastern North American Lakes." Quaternary Research 43 (1): 80–89. doi:10.1006/qres.1995.1008.

Clements, Craig B. 2010. "Thermodynamic Structure of a Grass Fire Plume." International Journal of Wildland Fire 19 (7): 895–902.

Deal, Krista, Leaonard DeBano, Michael Elliot, Charles Haecker, Ann Trinkle Jones, Roger Kelly, Kristine Lee, et al. 2012. "Wildland Fire in Ecosystems Effects of Fire on Cultural Resources and Archaeology." JFSP Synthesis Reports, January. http://digitalcommons.unl.edu/jfspsynthesis/3.

Deibel-Rosenbrock, W. 1960. Die Funde von Lehringen. Stader Jahrbuche 65. Stade.

Domanski, M., and J.A. Webb. 1992. "Effect of Heat Treatment on Siliceous Rocks Used in Prehistoric Lithic Technology." Journal of Archaeological Science 19 (6): 601–14. doi:10.1016/0305-4403(92)90031-W.

Domanski, M., J. A. Webb, and J. Boland. 1994. "Mechanical Properties of Stone Artefact Materials and the Effect of Heat Treatment*." Archaeometry 36 (2): 177–208. doi:10.1111/j.1475-4754.1994.tb00963.x.

Gardner, J.J, and C. Whitlock. 2001. "Charcoal Accumulation Following a Recent Fire in the Cascade Range, Northwestern USA, and Its Relevance for Fire-History Studies." The Holocene 11 (5): 541–49.

Gaudzinski, S. 2004. "A Matter of High Resolution? The Eemian Interglacial (OIS 5e) in North-Central Europe and Middle Palaeolithic Subsistence." International Journal of Osteoarchaeology 14 (34): 201–11.

Gaudzinski-Windheuser, S., and W. Roebroeks. 2011. "On Neanderthal Subsistence in Last Interglacial Forested Environments in Northern Europe." In Neanderthal Lifeways, Subsistence and Technology, edited by N. Conard and J. Richter, 61–71. Vertebrate Paleobiology and Paleoanthropology 19. Springer Netherlands.

Götze, A. 1892. "Die Paläolithische Fundstelle Taubach Bei Weimar." Zeitschrift Für Ethnologie 24: 366–77.

Gowlett, J. A. J., J. Hallos, S. Hounsell, V. Brant, and N. C. Debenham. 2005. "Beeches Pit: Archaeology, Assemblage Dynamics and Early Fire History of a Middle Pleistocene Site in East Anglia, UK." Eurasian Prehistory 3 (2): 3–38.

Gowlett, J.A.J., and R.W. Wrangham. 2013. "Earliest Fire in Africa: Towards the Convergence of Archaeological Evidence and the Cooking Hypothesis." Azania: Archaeological Research in Africa 48 (1): 5–30. doi:10.1080/0067270X.2012.756754.

Henry, A.G., A.S. Brooks, and D.R. Piperno. 2011. "Microfossils in Calculus Demonstrate Consumption of Plants and Cooked Foods in Neanderthal Diets (Shanidar III, Iraq; Spy I and II, Belgium)." Proceedings of the National Academy of Sciences 108 (2): 486–91.

Hesse, N., and L. Kindler. 2014. "Geologie Und Genese Der Quartären Beckenfüllung Neumark-Nord 2 Und Deren Ausgrabung." In Multidisciplinary Studies of the Middle Palaeolithic Record from Neumark-Nord (Germany). Volume I, edited by S. Gaudzinski-Windheuser, W. Roebroeks, and H. Meller, 13–38. Veröffentlichungen Des Landesamtes Für Denkmalpflege Und Archäologie Sachsen-Anhalt. Halle: Landesmuseum für Vorgeschichte.

Higuera, Philip E., Douglas G. Sprugel, and Linda B. Brubaker. 2005. "Reconstructing Fire Regimes with Charcoal from Small-Hollow Sediments: A Calibration with Tree-Ring Records of Fire." The Holocene 15 (2): 238–51. doi:10.1191/0959683605hl789rp.

Innes, J., J. Blackford, and I. Simmons. 2010. "Woodland Disturbance and Possible Land-Use Regimes during the Late Mesolithic in the English Uplands: Pollen, Charcoal and Non-Pollen Palynomorph Evidence from Bluewath Beck, North York Moors, UK." Vegetation History and Archaeobotany 19 (5-6): 439–52. doi:10.1007/s00334-010-0266-y.

Kindler, L., G. Smith, and M. Wagner. 2014. "Introduction to the Faunal Analysis at Neumark-Nord 2." In Multidisciplinary Studies of the Middle Palaeolithic Record from Neumark-Nord (Germany). Volume I, edited by S. Gaudzinski-Windheuser, W. Roebroeks, and H. Meller, 197–210. Veröffentlichungen Des Landesamtes Für Denkmalpflege Und Archäologie Sachsen-Anhalt 69. Halle: Landesmuseum für Vorgeschichte.

Klopfleisch, F. 1883. Die Grabhügel von Leubingen, Sömmerda Und Nienstedt: Voraufgehend: Allgemeine Einleitung. Charakteristik Und Zeitfolge Der Keramik Mitteldeutschlands. Bearbeitet von Friedrich Klopfleisch. Mit in Den Text Gedruckten Abbildungen Und 2 Tafeln in Farbendruck. Otto Hendel.

Koller, J., U. Baumer, and D. Mania. 2001. "High-Tech in the Middle Palaeolithic: Neandertal-Manufactured Pitch Identified." European Journal of Archaeology 4 (3): 385–97. doi:10.1177/146195710100400315.

Kuijper, W. 2014. "Investigation of Inorganic, Botanical and Zoological Remains of an Exposure of Last Interglacial (Eemian) Sediments at Neumark - Nord 2 (Germany)." In Multidisciplinary Studies of the Middle Palaeolithic Record from Neumark-Nord (Germany). Volume I, edited by S. Gaudzinski-Windheuser, W Roebroeks, and H. Meller, 79–96. Veröffentlichungen Des Landesamtes Für Denkmalpflege Und Archäologie Sachsen-Anhalt 69. Halle: Landesmuseum für Vorgeschichte.

Langejans, G, D Charalampopoulos, E Pop, C Arps, and A Verbaas. forthcoming. "Middle Paleolithic Macro-Lithic Artifacts from Neumark Nord 2 (Germany): Unraveling the Neandertal Toolkit"

Laurat, T., and E. Brühl. 2009. "Grabungsbericht Band I: Bericht Zu Den Archäologischen Ausgrabungen Im Tagebau Neumark-Nord (Geiseltal), Ldkr. Saalekreis." Landesamt für Denkmalpflege und Archäologie.

Laurat, T., D. Jurkenas, and E. Brühl. 2007. "Spuren Im Ton - Pleistozäne Tierspuren Vom Mittelpaläolithischen Fundhorizont Neumark Nord 2/2 (Geiseltal, Sachsen-Anhalt)." Hallesches Jahrbericht Geowissenschaft 23: 195–98.

Litt, T. 1990a. "Pollenanalytische Untersuchungen Zur Vegetations-Und Klimaentwicklung Während Des Jungpleistozäns in Den Becken von Gröbern Und Grabschütz." Altenburger Naturwissenschaftliche Forschungen 5: 92–103.

———. 1990b. "Stratigraphie Und Ökologie Des Eeminterglazialen Waldelefanten-Schlachtplatzes von Gröbern, Kreis Gräfenhainichen." In Neumark-Gröbern: Beiträge Zur Jagd Des Mittelpaläolithischen Menschen, edited by D. Mania, M. Thomae, T. Litt, and T. Weber. Veröffentlichungen Des Landesmuseums Für Vorgeschichte Halle 43.

Lynch, J.A., J.S. Clark, and B.J. Stocks. 2004. "Charcoal Production, Dispersal, and Deposition from the Fort Providence Experimental Fire: Interpreting Fire Regimes from Charcoal Records in Boreal Forests." Canadian Journal of Forest Research 34 (8): 1642–56. doi:10.1139/x04-071.

MacDonald, G. M., C. P. S. Larsen, J. M. Szeicz, and K. A. Moser. 1991. "The Reconstruction of Boreal Forest Fire History from Lake Sediments: A Comparison of Charcoal, Pollen, Sedimentological, and Geochemical Indices." Quaternary Science Reviews 10 (1): 53–71. doi:10.1016/0277-3791(91)90030-X.

Mania, D., M. Thomae, T. Litt, and T. Weber. 1990. "Neumark-Gröbern: Beiträge Zur Jagd Des Mittelpaläolithischen Menschen." Veröffentlichungen Des Landesmuseums Für Vorgeschichte in Halle 43.

Mazza, P.P.A, F. Martini, B. Sala, M. Magi, M.P. Colombini, G. Giachi, F. Landucci, C. Lemorini, F. Modugno, and E. Ribechini. 2006. "A New Palaeolithic Discovery: Tar-Hafted Stone Tools in a European Mid-Pleistocene Bone-Bearing Bed." Journal of Archaeological Science 33 (9): 1310–18.

Mighall, T.N., S. Timpany, J.J Blackford, J.B. Innes, C.E. O'Brien, W. O'Brien, and S. Harrison. 2008. "Vegetation Change during the Mesolithic and Neolithic on the Mizen Peninsula, Co. Cork, South-West Ireland." Vegetation History and Archaeobotany 17 (6): 617–28. doi:10.1007/s00334-007-0136-4.

Mücher, H. J. 2014. "Neumark-Nord 2, a Shallow Eemian Pool in Northern Central Germany. A Micromorphological Study of Its Infill." In Multidisciplinary Studies of the Middle Palaeolithic Record from Neumark-Nord (Germany). Volume I, edited by S Gaudzinski, W Roebroeks, and H. Meller, 39–46. Veröffentlichungen Des Landesamtes Für Denkmalpflege Und Archäologie Sachsen-Anhalt 69. Halle: Landesmuseum für Vorgeschichte.

Ohlson, M., and E. Tryterud. 2000. "Interpretation of the Charcoal Record in Forest Soils: Forest Fires and Their Production and Deposition of Macroscopic Charcoal." The Holocene 10 (4): 519–25. doi:10.1191/095968300667442551.

Peters, Matthew Edward, and Philip Edward Higuera. 2007. "Quantifying the Source Area of Macroscopic Charcoal with a Particle Dispersal Model." Quaternary Research 67 (2): 304–10. doi:10.1016/j.yqres.2006.10.004.

Pop, E. 2014. "Analysis of the Neumark-Nord 2/2 Lithic Assemblage: Results and Interpretations." In Multidisciplinary Studies of the Middle Palaeolithic Record from Neumark-Nord (Germany). Volume I, edited by S. Gaudzinski-Windheuser, W. Roebroeks, and H. Meller, 143–96. Veröffentlichungen Des Landesamtes Für Denkmalpflege Und Archäologie Sachsen-Anhalt 69. Halle: Landesmuseum für Vorgeschichte.

Pop, E., and C. Bakels. 2015. "Semi-Open Environmental Conditions during Phases of Hominin Occupation at the Eemian Interglacial (OIS5e) Basin Site Neumark-Nord 2." Quaternary Science Reviews 117: 72–81.

Pop, E., C. Bakels, W. Kuijper, H. J. Mücher, and M. van Dijk. 2015. "The Dynamics of Small Postglacial Lake Basins and the Structure of Their Archaeological Record: A Case Study of the Middle Palaeolithic Site Neumark-Nord 2, Germany." Geoarchaeology 30 (5).

Preece, R. C., J. A. J. Gowlett, S. A. Parfitt, D. R. Bridgland, and S. G. Lewis. 2006. "Humans in the Hoxnian: Habitat, Context and Fire Use at Beeches Pit, West Stow, Suffolk, UK." Journal of Quaternary Science 21 (5): 485–96.

Purdy, Barbara A., and H. K. Brooks. 1971. "Thermal Alteration of Silica Minerals: An Archeological Approach." Science 173 (3994): 322–25. doi:10.1126/science.173.3994.322.

Reidsma, F., E. Pop, and T. Reimann. 2014. Fire (?) Cracked Rock and Palaeolithic Cooking (academic Poster). Archaeology in Transition Symposium. Leiden University.

Richter, D. 2007. "Advantages and Limitations of Thermoluminescence Dating of Heated Flint from Paleolithic Sites." Geoarchaeology 22 (6): 671–83. doi:10.1002/gea.20180.

Richter, D., N. Alperson-Afil, and N. Goren-Inbar. 2011. "Employing TL Methods for the Verification of Macroscopically Determined Heat Alteration of Flint Artefacts from Palaeolithic Contexts." Archaeometry 53 (4): 842–57. doi:10.1111/j.1475-4754.2010.00581.x.

Richter, D., and M Krbetschek. 2014. "Preliminary Luminescence Dating Results for Two Middle Palaeolithic Occupations at Neumark-Nord 2." In Multidisciplinary Studies of the Middle Palaeolithic Record from Neumark-Nord (Germany). Volume I, edited by S Gaudzinski-Windheuser, W Roebroeks, and H. Meller, 131–36. Veröffentlichungen Des Landesamtes Für Denkmalpflege Und Archäologie Sachsen-Anhalt 69. Halle: Landesmuseum für Vorgeschichte.

Roebroeks, W., and C. Bakels. 2015. "'Forest Furniture' or 'Forest Managers'? Neandertal Presence in Last

Interglacial Environments.” In Settlement, Society and Cognition in Human Evolution. Landscapes in Mind, edited by F. Coward, R. Hosfield, M. Pope, and Francis F. Wenban-Smith, 174–88. Cambridge: Cambridge University Press.

Roebroeks, W., and B. Speleers. 2002. “Last Interglacial (Eemian) Occupation of the North European Plain and Adjacent Areas.” In Le Dernier Interglaciaire et Les Occupations Humaines Du Paléolithique Moyen, edited by A. Tuffreau and W. Roebroeks, 31–39. Lille: CERP.

Roebroeks, W., and P. Villa. 2011. “On the Earliest Evidence for Habitual Use of Fire in Europe.” Proceedings of the National Academy of Sciences 108 (13): 5209–14. doi:10.1073/pnas.1018116108.

Ryan, Kevin C. 2002. “Dynamic Interactions between Forest Structure and Fire Behavior in Boreal Ecosystems.” Silva Fennica 36 (1): 13–39.

Sandgathe, D.M., H.L. Dibble, P. Goldberg, S. McPherron, A. Turq, L. Niven, and J. Hodgkins. 2011. “Timing of the Appearance of Habitual Fire Use.” Proceedings of the National Academy of Sciences 108 (29): E298–E298. doi:10.1073/pnas.1106759108.

Scherjon, Fulco, Corrie Bakels, Katharine MacDonald, and Wil Roebroeks. 2015. “Burning the Land - An Ethnographic Study of Off-Site Fire Use by Current and Historically Documented Foragers and Implications for the Interpretation of Past Fire Practices in the Landscape.” Current Anthropology. doi:10.1086/681561.

Schüler, T. 1999. “Mittelpalaolithische Artefakte Aus Dem Travertinsteinbruch von Burgtonna, Lkr. Gotha.” Ausgr U. Funde Im Freist. Thüringen 4, 1–6.

Scott, A.C. 2010. “Charcoal Recognition, Taphonomy and Uses in Palaeoenvironmental Analysis.” Palaeogeography, Palaeoclimatology, Palaeoecology 291 (1–2): 11–39. doi:10.1016/j.palaeo.2009.12.012.

Scott, A.C., and F. Damblon. 2010. “Charcoal: Taphonomy and Significance in Geology, Botany and Archaeology.” Palaeogeography, Palaeoclimatology, Palaeoecology 291 (1-2): 1–10. doi:10.1016/j.palaeo.2010.03.044.

Seabloom, Robert W., Rodney D. Sayler, and S. A. Ahler. 1991. “Effects of Prairie Fire on Archeological Artifacts.” Park Science 11 (1).

Seifert, M. 1990. “Ein Interglazial von Neumark-Nord (Geiseltal) Im Vergleich Mit Anderen Interglazialvorkommen in Der DDR.” In Neumark-Gröbern. Veröffentlichungen Des Landesmuseums Für Vorgeschichte Halle., edited by D. Mania, M. Thomae, T. Litt, and T. Weber, 149–58. Veröffentlichungen Des Landesmuseums Für Vorgeschichte Halle 43.

Sergant, J., P. Crombé, and Y. Perdaen. 2006. “The ‘invisible’ Hearths: A Contribution to the Discernment of Mesolithic Non-Structured Surface Hearths.” Journal of Archaeological Science 33 (7): 999–1007. doi:10.1016/j.jas.2005.11.011.

Shimelmitz, R., S.L. Kuhn, A.J. Jelinek, A. Ronen, A.E. Clark, and M. Weinstein-Evron. 2014. “‘Fire at Will’: The Emergence of Habitual Fire Use 350,000 Years Ago.” Journal of Human Evolution, The Role of Freshwater and Marine Resources in the Evolution of the Human Diet, Brain and Behavior, 77 (December): 196–203. doi:10.1016/j.jhevol.2014.07.005.

Shipman, P., G. Foster, and M. Schoeninger. 1984. “Burnt Bones and Teeth: An Experimental Study of Color, Morphology, Crystal Structure and Shrinkage.” Journal of Archaeological Science 11 (4): 307–25. doi:10.1016/0305-4403(84)90013-X.

Sier, M.J., W. Roebroeks, C.C. Bakels, M.J. Dekkers, E.B. Brühl, D. De Loecker, S. Gaudzinski-Windheuser, et al. 2011. “Direct Terrestrial–marine Correlation Demonstrates Surprisingly Late Onset of the Last Interglacial in Central Europe.” Quaternary Research 75 (1): 213–18.

Sorensen, A., W. Roebroeks, and A. van Gijn. 2014. “Fire Production in the Deep Past? The Expedient Strike-a-Light Model.” Journal of Archaeological Science 42 (February): 476–86. doi:10.1016/j.jas.2013.11.032.

Speleers, B. 2000. “The Relevance of the Eemian for the Study of the Palaeolithic Occupation of Europe.” In The Eemian—local Sequences, Global Perspectives, edited by T. van Kolfschoten and P. Gibbard, 79:283–92. Geologie En Mijnbouw.

Stiner, M.C., S.L. Kuhn, S. Weiner, and O. Bar-Yosef. 1995. “Differential Burning, Recrystallization, and Fragmentation of Archaeological Bone.” Journal of Archaeological Science 22 (2): 223–37. doi:10.1006/jasc.1995.0024.

Stinson, Kenneth J., and Henry A. Wright. 1969. “Temperatures of Headfires in the Southern Mixed Prairie of Texas.” Journal of Range Management 22

(3): 169. doi:10.2307/3896335.

Strahl, J., M. R Krbetschek, J. Luckert, B. Machalett, S. Meng, E. A Oches, I. Rappsilber, S. Wansa, and L. Zöller. 2011. "Geologie, Paläontologie Und Geochronologie Des Eem-Beckens Neumark-Nord 2 Und Vergleich Mit Dem Becken Neumark-Nord 1 (Geiseltal, Sachsen-Anhalt)." Quaternary Science Journal 59: 120–67.

Thieme, H., S. Veil, and W. Meyer. 1985. "Neue Untersuchungen Zum Eemzeitlichen Elefanten-Jagdplatz Lehringen, Ldkr. Verden." Die Kunde 36: 11–85.

Tinner, Willy, Simone Hofstetter, Fabienne Zeugin, Marco Conedera, Thomas Wohlgemuth, Lukas Zimmermann, and Roman Zweifel. 2006. "Long-Distance Transport of Macroscopic Charcoal by an Intensive Crown Fire in the Swiss Alps - Implications for Fire History Reconstruction." The Holocene 16 (2): 287–92. doi:10.1191/0959683606hl925rr.

Tinner, Willy, Priska Hubschmid, Michael Wehrli, Brigitta Ammann, and Marco Conedera. 1999. "Long-Term Forest Fire Ecology and Dynamics in Southern Switzerland." Journal of Ecology 87 (2): 273–89. doi:10.1046/j.1365-2745.1999.00346.x.

Toepfer, V. 1958. "Steingeräte Und Palökologie Der Mittelpaläolithischen Fundstelle Rabutz." Jahresschrift Für Mitteldeutsche Vorgeschichte 41/42: 140–77.

Trollope, W. S. W. 1984. "Fire in Savanna." In Ecological Effects of Fire in South African Ecosystems, 149–75. Springer. http://link.springer.com/chapter/10.1007/978-3-642-69805-7_7.

Turner, C. 2002. "Formal Status and Vegetational Development of the Eemian Interglacial in Northwestern and Southern Europe." Quaternary Research 58 (1): 41–44. doi:10.1006/qres.2002.2365.

Van Rijn, P. 1999. "Houtskool van de Romeinse 'rookkuil', Dr. Poelsstraat, Heerlen." BIAXiaal 72. http://www.biax.nl/resources/content/report_file_663_72.pdf.

Whelan, R.J. 1995. The Ecology of Fire. Cambridge University Press.

Whitlock, Cathy, and Sarah H. Millspaugh. 1996. "Testing the Assumptions of Fire-History Studies: An Examination of Modern Charcoal Accumulation in Yellowstone National Park, USA." The Holocene 6 (1): 7–15. doi:10.1177/095968369600600102.

Wrangham, R.W. 2009. Catching Fire: How Cooking Made Us Human. Profile Books.

Supplementary information

Supplementary table 1: Distribution of heated flint artefacts among various artefact classes.

	Non-heated	%	Heated	%	Total	%	% heated of type
Flake	11520	77.1	189	54.9	11709	76.6	1.61
Chip	1642	11.0	42	12.2	1684	11.0	2.49
Chunk	1168	7.8	107	31.1	1275	8.3	8.39
Core	605	4.1	6	1.7	611	4.0	0.98
Total	*14935*	*100.0*	*344*	*100.0*	*15279*	*100.0*	*2.25*

	Non-heated	%	Heated	%	Total	%	% heated of type
Non-mod.	14210	95.1	338	98.3	14548	95.2	2.3
Modified	725	4.9	6	1.7	731	4.8	0.8
Total	*14935*	*100.0*	*344*	*100.0*	*15279*	*100.0*	*2.3*

Supplementary table 2: Large charcoal and charred wood from the NN2/2 excavation.

Findnr.	Square	Layer	Photo	Remarks	X	Y	Z
26582	213/300	B1/B2	No		213,38	300,39	
23016	222/300	B3o	No		222,78	300,83	
19904	219/298	C	Yes	ca. 60 cm, branch, not charred?	219,73	298,76	
29187	224/286	C	Yes	140 cm in length, branch, charred	224,4	286,95	96,513

Supplementary table 3: Species table charred seeds from Hauptprofil 7 (HP7).

cm	unit	Eleocharis palustris	Asperula sp. / Galium sp.	Stipa cf pennata	Carex sp.	Chenopodium album	Chenopodium hybridum	Poaceae	Quercus sp.	Prunus spinosa	cf Medicago sp.	Fabaceae div.sp.	Veronica sp.	cf Setaria viridis	*Total*
75-80	18	1	-	-	-	-	-	-	-	-	-	-	-	-	*1*
95-100	18	1	-	-	-	-	-	-	-	-	-	-	-	-	*1*
125-130	15	-	4	-	-	-	-	-	-	-	-	-	-	-	*4*
130-135	15	-	1	-	-	-	-	-	-	-	-	-	-	-	*1*
215-220	14	-	1	-	-	-	-	-	-	-	-	-	-	-	*1*
440-445	8	-	-	1 awn	-	-	-	-	-	-	-	-	-	-	*1*
535-540	6	-	-	-	1	1	1	25	1 fr. fruit base	-	-	1	-	-	*30*
540-545	6	-	-	-	1	-	-	-	-	1	1	1, 1 fr.	-	-	*5*
545-550	6	-	-	-	1 fr.	-	1	-	-	-	1	3	1	-	*7*
550-555	6	-	-	-	2	1	-	-	-	-	-	1	-	-	*4*
555-560	6	-	-	-	-	-	-	-	-	-	1	-	-	-	*1*
560-565	6	-	-	-	-	-	-	-	-	-	1	-	-	-	*1*
565-570	5	-	cf, 1 fr.	-	1	-	-	-	-	-	-	-	-	1	*3*
Total		*2*	*6*	*0*	*5*	*2*	*2*	*25*	*0*	*1*	*4*	*5*	*1*	*1*	*60*